STYLOSANTHES AS A FORAGE AND FALLOW CROP

Proceedings of the Regional Workshop on the Use of *Stylosanthes* in West Africa held in Kaduna, Nigeria, 26–31 October 1992

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Preface

Over the past four decades the genus *Stylosanthes* has received major focus across the tropics as a means of improving ruminant production. This was favoured by the discovery of many "new" species which offered the required flexibility for growth in diverse agro-climatic situations. In constraint-free conditions, *Stylosanthes* could potentially produce up to 15 tons of dry matter with a crude-protein content ranging from 12 to 18 %. However, such ideal conditions are rare in the tropics. Variations in rainfall, humidity, length of growing periods and soil fertility can affect the level of productivity and the usefulness of *Stylosanthes* to the production systems.

In sub-Saharan Africa, natural resource-dependent ruminant livestock suffer from seasonal fluctuations of feed quality and quantity. Low nutritive quality-related growth disorders predominate the problems encountered in raising livestock across all the ecological zones. As an attempt to improve livestock nutrition, the genus *Stylosanthes* was introduced into many countries in West Africa, starting in the late 1950s.

Research in integrating *Stylosanthes* into production systems intensified in West Africa with the opening of ILCA's subhumid zone research site in Kaduna, Nigeria in 1978. The genus *Stylosanthes* was used as a source of good quality livestock feed and for its ability to biologically fix Nitrogen to support intensification of cropping without prolonged fallows and to regenerate soil fertility. Development of techniques to maximise the benefits of integrating of *Stylosanthes* into crop–livestock systems took a number of years of on-station and on-farm research. Meanwhile, several national efforts involving *Stylosanthes* were also undertaken in the region.

Sub-Saharan African countries together carry approximately 150 million tropical livestock units. However, little effort is made to grow forages for the primary purpose of feeding livestock. Low-input agriculture and associated land degradation have become major problems, threatening the future security of food and feed supplies in many of the countries.

To deal with these problems, the following questions have to be addressed:

Is there sufficient knowledge on *Stylosanthes* to help alleviate these problems? What more is needed for farmers in the region to benefit from *Stylosanthes*?

This workshop brought together scientists, particularly from the West African countries, to share their experiences in the use of *Stylosanthes* in the farming systems of those countries. Scientists from other regions, within and outside Africa, made valuable contributions and their participation turned the workshop away from being strictly West African, was originally intended.

Several people contributed individually and collectively to organise this workshop. The ILCA Team in Kaduna, Nigeria, worked many months under the able coordination of Dr G. Tarawali. The workshop could not have been possible without the generous financial support of ILCA, and the workshop participants requested special acknowledgement to ILCA for this support. A special word of thanks to Mr S. Adoutan, Publications Section, for editing the French papers and translating the abstracts and to Miss Etalem Engeda, Highlands Programme, for secretarial support. As there were many francophone participants, simultaneous English/French interpretation became necessary and we wish to thank Mr. E. Achakobe and W.K. Akpawu for a good job done in this respect.

There are many who strive to bring about agricultural change in Africa particularly in the crop–livestock production sector, which we believe is the key to sustainable production from the land resources at the disposal of the African farmer. Their task is not easy and it is to them these proceedings are dedicated.

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Keynote address

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His Excellency the Governor of Kaduna State

The Honourable Minister for Agriculture

Honourable Commissioners

Invited guests, Distinguished Ladies and Gentlemen

It gives me great pleasure to be invited to give a keynote address to a gathering of scientists assembled to discuss a forage legume that is very important for the livestock industry in this country. It is also a significant step in the right direction by the International Livestock Centre for Africa (ILCA), the organiser of this workshop, to consider that the genus of *Stylosanthes* merits attention in farming systems of the West African subregion in general and in Nigeria in particular. ILCA is well known and its activities cut across ruminant production systems in Nigeria in the two important zones where it operates. We continue to have a good working relationship both in research and extension activities in these two zones, namely the subhumid programme centred in Kaduna and the humid programme in Ibadan. The alley farming forage-development programme in the humid areas has increased the dry season feed supply for ruminants in the southern parts of the country, besides being a commendable venture towards crop–livestock integration and the enhancement of soil fertility. The extension package was developed about a decade ago and it is serving a useful purpose for smallholder farmers with sheep and goats.

The introduction of *Stylosanthes* through the concept of fodder banks — a concentrated legume-based pasture to provide supplementary feed for ruminants — is playing a vital role in increasing livestock production, especially in the subhumid zone. Since concentrate feeds like groundnut and cottonseed cake as supplements to ruminants have become scarce and expensive, farmers no longer provide these feeds to their livestock and it has become unprofitable to finish cattle with such feeds. However, animals allowed to graze stylo-based fodder banks daily for two or three hours obtained supplemental crude protein equivalent to 1 kg/day of cottonseed cake.

Stylos are not new in Nigeria; as early as the 1940s, they were used as pastures in various parts of the country. They are adapted to a wide range of tropical climates with rainfall ranging from 900 to over 2000 mm.[1] Stylos have several useful characteristics:

1) They are relatively easy to establish, even on poor savannah soils since they have relatively low requirements for soil nutrients, especially phosphorus. They are also capable of fixing atmospheric nitrogen for their own benefit and that of associated grasses.

2) Most stylos do not require a special rhizobium inoculant because the cowpea varieties used in the northern parts of the country provide a ready source of rhizobium in the soil.

1. For more historical details see reviews by Agishi, pp. 275–285, and de Leeuw and Mohamed-Saleem, pp. 129–135.

3) The introduced stylos in Nigeria survive well into the dry season. The perennial stylos extend their greenness into the late dry season and provide valuable forage for livestock during this period, containing 7–9% crude protein.

Establishment

Stylos are established in Nigeria mainly i) as forage in mixed pastures; ii) in cropping systems and iii) as the main legume component of fodder banks.

Stylos in mixed pastures and as "cut-and-carry" feed

The need to improve the nutritive value of native pastures was suggested many years ago, since their productivity had declined due to overgrazing and lack of fertiliser applications. Grazing trials on mixed stylo pasture were started in Zaria in the late 1960s.

Mixed pastures of stylos and grasses were also introduced in ranches and grazing reserves and have been used for hay production. At the end of the rains, it is customary for livestock producers to make hay for dry-season feeding; the quality of hay improves when legumes are included. In the subhumid zone hay-making starts around September–October, when dry-matter yields are high containing adequate crude protein. Care must be taken to wilt and dry the cut hay for a few hours before baling. Although leaf shattering is common in Verano stylo/grass hay, animals consume the fallen leaves with relish. At the peak of the dry season a good-quality stylo/grass hay would cost ₦ 5–10 per bundle.

Another area where stylos may have considerable importance in future is in "cut-and-carry" systems. Some farmers have adopted this system in which forage legumes are cut daily and fed to confined animals. Peri-urban dairy production systems envisage the development of efficient feeding of dairy cattle around urban centres aimed at supplying dairy products to the cities. A small area of concentrated legume fodder will be cultivated to supplement a three- or four-cow unit. A forage legume like stylo is considered a prime candidate.

Stylos in crop production

Lack of fertilisers is a major constraint to crop production; they are expensive and often unavailable, especially during the cropping season. Soils planted with stylos are enriched by the accumulation of nitrogen fixed in the root nodules, which gradually becomes available to the companion crops. Stylo can be undersown into existing grass swards or in rotation with cereal crops (like maize, sorghum or millet) to increase available forage for livestock, whilst intercropping of cereal crops with stylo is also possible.[2]

Stylo in the fodder-bank system

Although other legumes have been tried, stylos remain the major legume in fodder-bank systems. Earlier in the development of the fodder-bank package, Cook stylo was used and proved a highly productive forage yielding up to 6 t/ha of dry matter. Its ability to remain green far into the dry season has been remarkable and the concept of fodder-bank development was built around this cultivar; it matures earlier than Schofield stylo thus enabling it to drop its seeds before the annual savannah fires commence. The advantage of this is that the fallen seeds repopulate stands faster than those sown with Schofield stylo. However, in the early 1980s Cook and Schofield stylo succumbed to anthracnose, a disease caused by the fungus *Collectotrichum gloeosporoides*; the two cultivars are, therefore, no longer used in fodder banks.

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2. Stylo in crop production in Nigeria is reviewed by Tarawali and Mohamed-Saleem (see pp. 183–192).

Since its inception in 1987, the NLPD project has established over 700 fodder banks under various credit schemes.[3] The rate of adoption has declined somewhat in recent years due to greater emphasis on cash crop production and logistical and financial constraints of input delivery. However, a recent survey among agropastoralists ascertained continued interest in fodder banks and an increase in adoption is anticipated once constraints have been removed.

The fodder-bank innovation has been supported by our National Animal Research Advisory Committee and its technical committees. Therefore, the NLPD has sponsored four research projects aimed at further studying various aspects of stylo forage production:

- Multi-locational testing of fodder banks.
- Optimal utilisation of fodder banks for increasing the reproductive efficiency of Bunaji cattle.
- Evaluation of the role of forage legumes in enhancing crop production and soil fertility.
- Adoption of rotational cropping within fodder banks by agropastoralists.

The last three projects are being executed by Nigerian scientists in collaboration with Australian counterparts through support from the Australian Centre for International Agricultural Research (ACIAR), Canberra. The Federal Ministry of Agriculture, Water Resources and Rural Development is sponsoring the first national workshop on forage seed production and utilisation which will be held in November 1992, immediately after ILCA's workshop on *Stylosanthes*.

While establishing fodder banks in various parts of the country, NLPD became aware of several constraints. They range from scarcity of land to the current economic hardships faced by many agropastoralists for which solutions are being sought at the appropriate level. However, there are some which need mention at this gathering of scientists, in particular those from ILCA headquarters who beside being eminent scientists are also responsible for planning ILCA's policies on livestock research and development in Africa.

Whereas ILCA's sites in Nigeria are located in the subhumid and humid zones, two-thirds of the 13 million cattle and over half of the 50 million sheep and goats are found in the semi-arid zone. Due to scarcity of grazing during the dry season pastoralists are compelled to drive their breeding herds to more southerly areas where they become exposed to several disease risks causing reduced production. It is therefore highly desirable to conduct more research in the Sudanian and Sahel zones in Nigeria. This need has become more pressing since some stylo species, while successful in the subhumid zone, failed to produce similar results further north. Out of several cultivars screened so far, only Verano stylo has been recommended. This cultivar has a limited range of performance; in parts of the subhumid and in most of the semi-arid zone, it dries and sheds its leaves at the end of the wet season.

On a more positive note, although the low-input oversowing strategy has often been met with failure, the reality is that stylo species have been spreading from research plots and from established fodder banks into adjacent rangelands, showing their ability to colonise new habitats. I therefore believe that this workshop will focus on these problems and offer solutions. Our farmers are eagerly awaiting alternative technology that the stylos can offer in revolutionising their farming enterprise.

I wish to conclude my address by paying tribute to the late Malam Haruna, an uneducated farmer, who lived in Kurmin Biri, an ILCA case study area and who made a great personal contribution to the fodder-bank concept. Malam Haruna was one of the pastoralists whose cereal crop was undersown with stylo; because of sowing too early the results were not very encouraging as there was excessive competition between his crop and the stylo. However, the farmer, instead of getting annoyed with the ILCA team (of which

3. See a detailed review by Ajileye et al, pp. 311–316.

I was a member), he fenced his farm and allowed his animals access during the peak of the dry season, which worked very well. Although the farmer did not call it a fodder bank, the ILCA team developed the farmer's innovation into the fodder-bank concept. I recollect this story and call the attention of this gathering of scientists to the fact that illiterate farmers may lack scientific knowledge, but often possess great wisdom derived from age-old traditions and the experiences accumulated during their life time. If such wisdom is married to modern knowledge, it may contribute substantially to progress.

Honourable Minister and State Commissioners, invited guests, ladies and gentlemen, thank you for your attention and I wish all of you fruitful deliberations and a safe journey back to your respective destinations.

Section 1

The biology of *Stylosanthes* and its importance in West Africa and Latin America

Revue des travaux de recherche, de vulgarisation et d'utilisation effectués sur *Stylosanthes* en Afrique de l'Ouest

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Résumé

Depuis 35 ans, différentes espèces de *Stylosanthes* ont été introduites et testées pour améliorer la valeur bromatologique des parcours naturels et pour créer des pâturages artificiels dans les régions humides de l'Afrique de l'Ouest francophone. *Stylosanthes guianensis* cv. Schofield a été d'abord le centre d'intérêt de la plupart des essais avec des légumineuses fourragères. Ceux-ci ont porté sur le comportement et la mise au point des techniques agronomiques de semis, d'utilisation, d'entretien et de production semencière, l'évaluation des performances et la place de cette culture fourragère dans les systèmes de production animale. Des sérieuses difficultés ont limité l'utilisation de cette variété, notamment les dégâts causés par l'anthracnose (*Colletotrichum gleosporioides)* depuis 1978 et les bas prix des produits d'origine animale. Dès lors, l'intensification de l'élevage à faible coût et l'intégration des éleveurs transhumants dans les régions à vocation agricole se sont appuyées sur la création de pâturages associant la graminée pérenne *Panicum maximum* cv. C1 et la légumineuse fourragère *Stylosanthes hamata* cv. Verano. Une nouvelle série d'essais est actuellement en cours dans neuf pays d'Afrique pour étudier le comportement de nouvelles espèces de légumineuses dont plusieurs du genre *Stylosanthes* (projet RABAOC).

Enfin, des données sont présentées sur les rendements de *Stylosanthes guianensis*, sa valeur fourragère, son ingestion et l'effet résiduel de sa culture sur les rendements du maïs.

A review of research, extension and utilization studies on *Stylosanthes* in West Africa

Abstract

For 35 years, various species of Stylosanthes have been introduced and tested in the humid zones of francophone West Africa to improve the nutritional value of natural ranges and to establish artificial pastures. Most experiments with fodder legumes first focused on S. guianensis cv Schofield and covered plant behaviour, sowing techniques, management, maintenance and seed production, performance evaluation and the importance of this species in livestock production systems.

Use of S. guianensis *by farmers was restricted by major constraints, including attacks by anthracnose (*Colletotrichum gloeosporioides) *since 1978 and the low price of animal products. Consequently, development of low cost intensified animal production and integration of transhumant pastoralists in crop areas were based on establishment of pastures associating the perennial grass* Panicum maximum *cv C1 and the fodder legume* Stylosanthes

hamata *cv Verano. A series of new trials is currently underway in nine African countries on the behaviour of new legume species, including several* Stylosanthes *spp (WAFNET Project).*

Finally, this paper presents data on S. guianensis*, its nutritive value and intake as well as its residual effect on the yield of a subsequent maize crop.*

Introduction

La végétation des savanes de l'Afrique de l'Ouest est riche en espèces de légumineuses herbacées. Mais paradoxalement, la contribution des légumineuses à la biomasse herbacée de ces savanes est très faible, alors que celle des graminées est extrêmement importante. La principale raison généralement avancée pour expliquer ce phénomène est le passage fréquent des feux de brousse.

Les légumineuses fourragères remplissent deux fonctions essentielles dans les pâturages et les parcours, à savoir d'une part elles équilibrent la ration alimentaire du bétail grâce à leur richesse en matières azotées et en sels minéraux et d'autre part elles améliorent la fertilité du sol en l'enrichissant en azote.

Les recherches agronomiques et zootechniques s'intéressent depuis longtemps aux avantages des cultures de légumineuses. En Afrique de l'Ouest, il y a plus de 35 ans que des expérimentations d'envergure ont commencé sur des espèces introduites. C'est sur les graminées pérennes que les recherches sur les plantes fourragères ont été le plus avancées, mais des résultats importants ont également été obtenus sur légumineuses.

L'élevage a connu un grand essor à la suite des progrès en matière de santé animale, puis des efforts de sélection et d'amélioration génétique des animaux domestiques. Les principales contraintes techniques sur lesquelles la recherche travaille tout spécialement aujourd'hui sont d'ordre alimentaire, notamment l'insuffisance quantitative des ressources fourragères, l'irrégularité saisonnière et interannuelle des productions des pâturages ainsi que la qualité nutritive médiocre des fourrages. Plusieurs espèces du genre Stylosanthes figurent parmi les quelques espèces de légumineuses herbacées pérennes qui ont changé les pratiques de l'élevage dans les régions humides et subhumides de l'Afrique occidentale et centrale.

Schéma général des recherches sur *Stylosanthes*

L'introduction des nouvelles espèces de *Stylosanthes* pour l'élevage a suivi le schéma d'expérimentation classique, allant de la découverte de la ressource génétique à tester jusqu'à sa vulgarisation.

Les prospections et les choix de nouvelles espèces et variétés et de nouveaux écotypes ont été effectués selon des critères de qualité agronomique et fourragère dans des régions du monde aux climats comparables à ceux de l'Afrique. Le mérite en revient à des organisations spécialisées de portée internationale, en particulier la Commonwealth Scientific and Industrial Research Organization (CSIRO) en Australie et le Centro Internacional de Agricultura Tropical (CIAT) en Colombie. La diffusion de ces ressources génétiques fut assurée non seulement par ces centres mais aussi par d'autres organismes ou centres internationaux tels que l'Organisation des Nations Unies pour l'alimentation et l'agriculture (FAO), le Conseil international des ressources phytogénétiques (IBPGR) et le Centre international pour l'élevage en Afrique (CIPEA). C'est du principal berceau des *Stylosanthes*, c'est-à-dire l'Amérique tropicale, que proviennent la plupart des lignées étudiées, mais les espèces africaines n'ont pas pour autant été totalement négligées dans les essais.

L'introduction des lignées et les essais de comportement et de multiplication ont été conduits dans plusieurs centres d'expérimentation africains. Les principaux points d'introduction et d'essais en Afrique francophone ont été le Centre ORSTOM d'Adiopodoumé en Basse-Côte d'Ivoire, le centre de recherches zootechniques (CRZ) de Minankro près de Bouaké en Côte d'Ivoire centrale et l'Institut de recherches zootechniques (IRZ) de Wakwa dans l'Adamaoua camerounais. Des échanges d'informations et de matériels ont eu lieu avec d'autres centres nationaux de recherche similaires situés dans d'autres régions tropicales. Par la suite, les sites d'expérimentation se sont multipliés dans de nombreuses régions, apportant des précisions sur l'adaptation des plantes testées aux spécificités locales.

Les protocoles d'essai ont compris et comprennent encore une série d'étapes qui, de l'introduction à la vulgarisation, s'étalent sur une dizaine d'années (Roberge, 1976).

En ce qui concerne les actions de développement, la disponibilité des ressources génétiques que constituent les variétés sélectionnées de *Stylosanthes* a entraîné une adaptation et une évolution des pratiques d'élevage et des systèmes de production. Les recherches sur les *Stylosanthes* n'ont jamais été séparées des possibilités d'utilisation et de valorisation. En station, des essais réalisés avec des troupeaux ont permis de définir les pratiques susceptibles d'être recommandées aux éleveurs et aux agriculteurs. Les chercheurs ont suivi de près leurs applications en milieu réel afin de pouvoir évaluer l'intérêt technico-économique de ces innovations et d'orienter en conséquence les actions de développement.

Espèces et variétés vulgarisables

Stylosanthes guianensis

Alors appelé *S. gracilis, S. guianensis* fut introduit à Adiopodoumé (Côte d'Ivoire) en 1956 (Botton, 1957, 1958) à l'occasion d'un programme de recherche sur les légumineuses destinées à protéger les sols et à améliorer leur fertilité dans les plantations et les cultures.

En 1958, l'IEMVT (Institut d'élevage et de médecine vétérinaire des pays tropicaux) introduisait cette espèce à Bouaké dans des essais de comportement de légumineuses fourragères (Cadot, 1971). L'intérêt de cette plante fut vite découvert et de nombreuses expérimentations lui furent consacrées. Dès 1966, la récolte des semences à la moissonneuse-batteuse était mise au point. La scarification des graines dans un cône polisseur à riz améliorait leur pouvoir germinatif. Dès 1968, la vulgarisation fut entreprise tandis que se poursuivaient des essais visant à perfectionner les itinéraires techniques.

La production de semences s'est développée au CRZ, dans certains programmes de développement et un projet de ferme semencière a même été lancé.

Au Cameroun, *S. guianensis* est connu et utilisé depuis les années 50 et est même devenu spontané le long des routes. Malgré ses défauts, cette espèce a la réputation d'être bien adaptée aux conditions climatiques et édaphiques de l'Adamaoua (Rippstein, 1985). Elle fut particulièrement étudiée au CRZ de Wakwa et a donné lieu en particulier à de nombreux essais d'alimentation des bovins. Les objectifs assignés à son emploi étaient la complémentation de l'alimentation des bovins en saison sèche et l'amélioration de la fertilité des sols et de la flore naturelle des parcours.

Au Sénégal, *S. guianensis* fut dès 1966 l'une des premières légumineuses fourragères introduites à la ferme expérimentale de Sangalkham près de Dakar. Sous ce climat, avec seulement 500 mm de pluies par an, la culture n'a pu se maintenir qu'avec l'irrigation et s'est révélée mal adaptée à cette région. En Casamance où le climat est plus humide, les essais ont donné de bons résultats mais l'espèce fut rapidement anéantie par l'anthracnose.

Au Burkina Faso, *S. guianensis* fut essayé dans la région de Bobo Dioulasso à la suite de ses succès en Côte d'Ivoire. Il fut surtout utilisé en casiers irrigués pour régénérer la fertilité des sols de rizières. Un programme de production de semences a même été exécuté quelque temps par la FAO.

Au Niger, la culture de cette légumineuse dans des périmètres irrigués le long du fleuve a été préconisée dans les années 70 en association avec des essais de fertilisation phosphorique. La maîtrise de l'irrigation faisait partie des objectifs techniques car cette espèce s'avère sensible aux immersions.

A partir de 1978, l'extension rapide de l'anthracnose (*Colletotrichum gleosporioides*) a touché les différentes espèces de *Stylosanthes* et en particulier a beaucoup affecté *S. guianensis* dont le cultivar le plus répandu (cv. Schofield) s'est révélé particulièrement sensible à cette maladie. Les facultés d'adaptation des *Stylosanthes* ont alors été remises en question et l'on a aussitôt cherché des légumineuses de substitution.

Stylosanthes hamata

Les premiers essais effectués sur cette espèce remontent aux années 70. Facile à cultiver, elle a rapidement attiré l'attention. On lui a reproché cependant de se comporter en plante annuelle, ce qui a conduit à lui préférer *S. guianensis*, plus productive et plus persistante. Les dégâts causés par l'anthracnose sur cette dernière ont contribué à réhabiliter *S. hamata*. Sa tolérance à cette maladie, son aptitude à s'associer aux graminées et sa résistance aux feux de brousse lui ont conféré une importance toute nouvelle.

Actuellement en Côte d'Ivoire, sa capacité à persister en association avec des graminées pérennes comme *Panicum maximum* cv. C1 en fait une espèce de choix pour la création de prairies permanentes.

Au Sénégal, *S. hamata* fut introduit au Sine-Saloum et en Haute-Casamance où il s'est révélé très adapté. Il n'a cependant pas été vulgarisé, car il doit concurrencer le niébé (*Vigna unguiculata*) qui lui est traditionnellement préféré et qui, comme plante à usages multiples, est mieux intégré dans les systèmes culturaux. C'est donc sur cette dernière espèce que les efforts de recherche se poursuivent depuis 1982.

Au Burkina Faso, des essais d'introduction de légumineuses fourragères et en particulier de diverses espèces et variétés de *Stylosanthes* ont montré que *S. guianensis, S. hamata* et *S. scabra* poussaient bien en région soudano-sahélienne mais n'étaient pas suffisamment pérennes pour être vulgarisées (Klein, 1977). Des expérimentations fourragères de la FAO au Mali, au Burkina Faso et au Niger (sous climat sahélo-soudanien) ont montré que *Stylosanthes* pouvait être utilisé pour l'amélioration des parcours moyennant des mesures strictes de gestion et des programmes de mise en défense difficiles à vulgariser (Dalebroux, 1986).

Stylosanthes humilis

Encore appelée luzerne de Townsville, *S. humilis* est une espèce annuelle qui a connu un vif succès dans certaines régions semi-arides d'Australie mais n'a malheureusement pas montré en Afrique la même capacité de dissémination que dans le Queensland. Une tentative d'amélioration des parcours dans la région de Ouagadougou (Burkina Faso) par semis aérien fut conduite par des Australiens, mais n'eut aucun effet notable.

Stylosanthes fruticosa

Etudiée en raison de sa résistance à la sécheresse, cette espèce autochtone commune en Afrique n'a jusqu'à présent pas donné de résultats agronomiques suffisants pour justifier une vulgarisation.

Stylosanthes scabra

En dépit de sa résistance à la sécheresse et au broutage, cette espèce, dont certaines variétés sont résistantes à l'anthracnose, est encore peu utilisée principalement en raison de sa trop grande sensibilité aux feux de brousse.

Nouvelles introductions

Un nouveau programme d'introduction de plantes fourragères tropicales est actuellement en cours. Le programme RABAOC (Réseau d'aliments du bétail d'Afrique de l'Ouest et centrale) teste dans neuf pays d'Afrique occidentale et centrale du matériel végétal proposé par le CIAT et par le CIPEA. Il a pour but d'identifier les possibilités de valorisation de ces plantes pour l'alimentation du bétail en zones humide et subhumide, c'est-à-dire dans les régions d'Afrique recevant plus de 1 000 mm de pluies par an et/ou situées au sud du 12^{e} parallèle nord. Dans ce cadre, plusieurs espèces de *Stylosanthes* sont étudiées, les principaux critères d'évaluation étant la facilité d'établissement (comportement et acclimatation), la production de biomasse en saison humide, l'adaptabilité à la saison sèche (production de matière sèche et rythme de repousse après coupe) et la capacité de production de semences.

Par ailleurs, la rapidité de couverture et les phases phénologiques sont observées. Au nombre des introductions actuellement à l'étude dans le cadre du programme RABAOC, citons *S. capitata* cv. Capica (CIAT 10280), *S. guianensis* cv. Pucallpa (CIAT 184), *S. guianensis* var. *pauciflora* (CIAT 10136), *S. macrocephala* cv. Pioneiro (CIAT 1281), *S. hamata* (CIAT 147), *S. hamata* cv. Verano (provenance CIPEA) et *S. sympodialis* (CIAT 1044).

Il ressort des résultats préliminaires de deux années d'observation que dans l'ensemble des sites, les deux introductions les plus prometteuses étaient *S. guianensis* cv. Pucallpa et *S. hamata* cv. Verano. La première s'est bien comportée en ce qui concerne la facilité d'établissement, la production de biomasse, la résistance à la saison sèche et la production de semences. Elle est suivie de très près par la variété *pauciflora*, qui ne produit malheureusement guère de semences. Ces deux introductions se sont révélées jusqu'ici relativement peu sensibles à l'anthracnose.

Quant à *S. hamata*, il a été très bien noté pour la facilité d'établissement, la production de biomasse en saison des pluies et la production de semences, mais il se comporte comme une plante annuelle.

Les espèces *S. macrocephala* et *S. sympodialis* semblent les moins prometteuses faute d'une bonne adaptation à la saison sèche.

D'autres écotypes, y compris d'origine africaine, seront prochainement introduits dans les essais.

Résultats agronomiques

Mise au point des techniques culturales

La revue des publications et des rapports publiés au cours des années 60 et 70 montre l'importance accordée aux études agronomiques de *S. guianensis* par rapport à celles des autres légumineuses fourragères. Des expérimentations très diverses ont été effectuées avec pour objectif de mettre au point les techniques de semis, de fumure, de désherbage, de hauteur de coupe et de durée d'exploitation de cette espèce. Elles ont été conduites pour beaucoup en Côte d'Ivoire (Roberge *et al.*, 1978; Messager, 1984) et ont bénéficié des résultats acquis en République centrafricaine, à Madagascar, au Cameroun (Piot, 1971; Yonkeu *et al.*, 1985) et au Sénégal. Des fiches techniques ont été produites dans de nombreux pays, ainsi que des monographies synthétisant les connaissances (Audru, 1971).

Les techniques de culture proposées diffèrent selon les objectifs d'installation et d'exploitation de la légumineuse.

La production de semences a été bien maîtrisée. En particulier, le désherbage chimique a été mis au point, proposant plusieurs formules. Le désherbage a également été proposé pour la mise en place de prairies et s'est avéré compétitif avec de simples gyrobroyages.

Rendements

Les chiffres de rendement sont nombreux et diffèrent selon les conditions de culture, de climat et d'exploitation. Roberge *et al.* (1976) rapportent à Tombokro, dans le centre de la Côte d'Ivoire (1 300 mm de pluies/an), des chiffres de 4,5 à 12,0 t de matière sèche par hectare (tableaux 1 et 2) pour une culture pure en sec en fauche intégrale.

Tableau 1. *Rendements de* Stylosanthes guianensis *(t MS/ha) à Tombokro (Côte d'Ivoire) sur sol gravillonnaire induré en profondeur*

	1re année	2^{e} année	3^{e} année	Moyenne
Sans fertilisation	7,4	6,5	4,5	6,1
Avec fertilisation (P, K, CaO, MgO)	10,5	11,2	7,2	9,6

Tableau 2. *Rendements de* Stylosanthes guianensis *(t MS/ha) à Tombokro (Côte d'Ivoire) sur sol profond*

	1re année	2^{e} année	3^{e} année	Moyenne
Sans fertilisation	10,9	7,6	5,6	8,0
Avec fertilisation	12,0	10,7	7,7	10,1

La capacité de charge est en moyenne de 1,6 et 2,5 UBT/ha sur sol gravillonnaire respectivement sans et avec fertilisation contre 2,1 et 2,7 UBT/ha sur sol profond. Ces chiffres sont en harmonie avec les résultats d'essais de charge réalisés à Bouaké (1 200 mm de pluies/an) en Côte d'Ivoire, où une charge de 1,8 tête/ha a été observée pour des zébus au pâturage sur *Stylosanthes* non fertilisé, chiffre qui passait à 2,3 têtes avec un complément de graines de coton et de farine de riz. Par ailleurs, une charge de 2,9 têtes/ha a été enregistrée pour des taurins N'Dama et Baoulé en embouche de longue durée sur *Stylosanthes*. Enfin, la charge était de 2,3 têtes/ha pour la finition de boeufs N'Dama de 4 ans sur pâturage de *Stylosanthes* de 2 ans.

Avec irrigation, les rendements ont atteint à Tombokro 20 t de MS par hectare en première année, mais la culture pure ne peut être maintenue plus de trois ans. La production de semences au cours d'un cycle annuel est en moyenne de 100 à 150 kg/ha. Le rendement optimum semble cependant avoir été obtenu à Wakwa (Cameroun) avec 400 kg/ha (Rippstein, 1985).

Valeur fourragère

Les espèces de *Stylosanthes* ont fait l'objet de nombreuses analyses fourragères (Rivière, 1978). Les résultats de l'analyse chimique de *S. guianensis* sont présentés au tableau 3. Indépendante de la longueur du temps de repousse, la valeur fourragère demeure élevée pendant la saison sèche.

Tableau 3. *Résultats de l'analyse chimique du fourrage de* Stylosanthes guianensis *en Côte d'Ivoire*

Temps de repousse (jours)	Matière sèche (%)	Protéines brutes (%)	Cellulose brute (%)	Ca	P	Mg	K	MAD (%)	UF/kg MS	MAD/ UF
				(% de MS)						
28	20,40	18,97	24,08	1,50	0,45	0,34	2,42	14,9	0,73	204
42	18,87	19,23	25,19	1,37	0,44	0,33	2,64	15,1	0,73	207
56	19,16	16,60	27,18	1,45	0,36	0,26	2,62	12,5	0,70	179
70	19,96	16,15	27,22	1,42	0,32	0,29	2,61	12,1	0,69	175

Des mesures d'ingestibilité ont été effectuées sur des bovins en Côte d'Ivoire (Glattleider, 1976) et au Cameroun (Rippstein, 1985) (tableau 4) et des travaux se poursuivent actuellement à Bouaké sur la digestibilité *in vivo*.

Tableau 4. *Consommation moyenne d'ensilage et de foin de* Stylosanthes *par de jeunes femelles zébus*

Age (jours)	Ensilage		Foin	
	kg MS/ tête/j	kg MS/100kg PV/j	kg MS/ tête/j	kg MS/100kg PV /j
0 – 20	2,8	1,1	4,7	1,6
20 – 40	3,1	1,2	5,1	1,8
40 – 57	2,5	1,0	4,3	1,5
Moyenne	2,8	1,1	4,7	1,7

Etant donné que sa composition chimique est proche de celle de la luzerne (*Medicago sativa*), il a été envisagé de cultiver *S. guianensis* pour la production de farine destinée à l'alimentation des monogastriques. Les recherches ont montré que la plante entière était trop riche en lignine. La farine de feuilles est plus riche que celle de la luzerne en certains acides aminés, principalement la lysine, en oligo-éléments et en pigments caroténoïdes, mais plus pauvre en tryptophane et en phosphore. Il n'est guère recommandé de l'utiliser pour l'alimentation des volailles alors qu'elle est tout à fait acceptable pour les porcs. Ce projet de production de farine de *S. guianensis* fut abandonné en raison du prix élevé de cette farine, une situation imputable à la faible durée d'exploitation de la prairie en fauche et au faible rendement en feuilles par rapport à la production d'une luzernière (Dalibard, 1981).

Effets sur la fertilité du sol

Un essai comparatif de plantes fourragères a été conduit à Tombokro (Côte d'Ivoire) pendant trois ans sur quatre graminées et *S. guianensis*. La production était intégralement fauchée et sortie du champ. Deux régimes de fertilisation étaient appliqués: soit une fertilisation destinée à compenser approximativement les exportations minérales (F), soit pas de fertilisation (O). Après ces trois ans, du maïs a été semé avec (F) ou sans (O) fertilisation. Les résultats sont résumés au tableau 5 (moyenne de quatre essais).

Ces résultats montrent que les rendements en maïs étaient plus élevés lorsque les engrais étaient appliqués sur les cultures fourragères précédentes plutôt que sur le maïs lui-même. Par ailleurs, les graminées sont un moins bon précédent culturel que la légumineuse. Celle-ci a apporté au sol une quantité d'azote estimée entre 100 et 150 kg/ha.

Tableau 5. *Rendements en maïs (t/ha à 15% d'humidité) après trois ans de cultures fourragères (à Tombokro*

Fertilisation des plantes fourragères Fertilisation du maïs	oui oui	oui oui	oui oui	non non	Moyenne
Précédent:					
Panicum maximum	4,09	2,43	2,62	1,12	2,57
Pennisetum purpureum	4,96	3,75	3,45	1,42	3,40
Brachiaria mutica	4,78	3,68	2,87	1,06	3,10
Melinis minutiflora	5,11	4,45	2,19	0,71	3,11
Moyenne graminées	4,74	3,58	2,79	1,08	3,08
Stylosanthes guianensis	6,22	5,30	3,57	1,84	4,23
Différence en valeur	1,48	1,72	0,78	0,76	1,15
Différence en %	(+ 31)	(+ 48)	(+ 28)	(+ 70)	(+ 37)

Par contre les teneurs du maïs en phosphore et en potasse étaient faibles après toutes les plantes (Roberge, 1976).

Stylosanthes et intensification fourragère

Les premiers objectifs furent d'enrichir la flore des pâturages naturels et d'améliorer la jachère traditionnelle en la raccourcissant. Par la suite, la mise en place de cultures pures entrait dans des systèmes plus intensifs d'affouragement. L'évolution des pratiques d'élevage s'est appuyée en partie sur l'emploi de cette légumineuse.

Les essais d'amélioration de la flore des pâturages ont souvent été décevants car peu persistants.

Les dispositifs de recherche en station se sont orientés rapidement vers des systèmes d'élevage intensifiés avec recours à des prairies permanentes ou temporaires à base d'espèces fourragères sélectionnées. D'abord ce furent des associations graminées–légumineuses, puis *Stylosanthes* en culture pure.

Des essais de complémentation de saison sèche pour des bovins ont donné des résultats intéressants (Rippstein, 1985).

Néanmoins, on a identifié plusieurs difficultés d'utilisation. D'abord, l'établissement par semis est difficile en raison des exigences de la préparation du sol. Les premières étapes de la végétation sont lentes et les graminées comme les adventices peuvent étouffer la légumineuse. Il faut alors l'aider par un passage rapide du troupeau ou par un gyrobroyage. Par ailleurs, l'association avec une graminée est très difficile à maintenir et la gestion doit être rigoureuse car la plante résiste mal au surpâturage. L'exploitation doit intervenir tous les 45 à 60 jours en saison des pluies. Un temps de repos de plus de 100 jours est néfaste. Exploitée en fauche, la légumineuse doit être coupée chaque fois un peu plus haut car la base des tiges se lignifie. La pérennité ne dépasse guère trois ans. Il convient également de noter que *Stylosanthes guianensis* ne résiste pas au feu alors que *S. hamata* régénère à partir de ses semences après le passage du feu. Enfin, étant donné que le foin de *Stylosanthes* est de qualité médiocre car les feuilles se séparent des tiges, ces légumineuses conviennent mieux à des réserves sur pied.

L'amélioration des savanes et la constitution de prairies artificielles avec *S. guianensis* ont perdu beaucoup de leur intérêt depuis les dégâts dus à l'anthracnose. Tant que de nouvelles variétés résistantes à cette maladie n'auront pas été trouvées, les *Stylosanthes* auront peu d'avenir dans les zones humides.

Jusqu'ici, les techniques ont rarement dépassé les limites des stations de recherche. Aux difficultés techniques d'établissement, de gestion et de pérennité déjà citées s'ajoute la concurrence des sous-produits agricoles, notamment ceux de la culture du coton, plus faciles à utiliser, plus efficaces et moins chers.

Les modèles d'intensification fourragère actuellement vulgarisés en milieu paysan sont basés sur des systèmes choisis en raison de leur capacité de tolérance des erreurs de gestion, comme le surpâturage et les feux. Dans le nord de la Côte d'Ivoire, ils visent à mieux promouvoir l'intégration des éleveurs transhumants dans les terroirs agricoles, en vue de lutter contre les problèmes sociaux liés aux dégâts des troupeaux sur les cultures. Ces systèmes comprennent des pâturages associant *Panicum maximum* cv. C1 et *S. hamata* cv. Verano. Ces surfaces représentent un niveau d'intensification intermédiaire à coût limité et sont destinées à maintenir les animaux parqués pendant toute la saison des cultures, c'est-à-dire jusqu'en décembre (Dulieu et César, 1989).

Conclusion

Malgré les qualités des *Stylosanthes* par rapport à la plupart des autres légumineuses, les éleveurs des régions d'Afrique de l'Ouest ne disposent pas de variétés suffisamment faciles à semer, persistantes, résistantes au feu, économiques et de bonne qualité pour généraliser l'utilisation de cette culture fourragère. La recherche d'espèces plus adaptées paraît plus que jamais nécessaire.

D'autre part, le recours aux cultures fourragères dépend beaucoup des prix des produits d'origine animale et de leur capacité de promouvoir l'intensification de la production.

Enfin, des progrès doivent être réalisés dans l'organisation des productions agricoles et animales au niveau des terroirs en vue de tirer le meilleur parti possible des avantages des légumineuses fourragères.

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Stylosanthes for pasture development: An overview of ILCA's experience in Nigeria

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Abstract

To improve livestock productivity in sub-Saharan Africa sustainable solutions to seasonal deficiencies in feed availability and quality are required. Traditionally, livestock rearing has been the specialised vocation of nomadic and transhumant pastoralists and therefore, for a long time, technological changes in livestock and feed production management strategies have been targeted at this group. During the last two decades nomadic pastoralists have been settling in large numbers for several reasons and for a long time settled pastoralists were not considered a potential target group for improving livestock productivity in sub-Saharan Africa. When ILCA started work in the subhumid zone of Nigeria in 1987, it saw an opportunity to complement national research by introducing improvement interventions among sedentarised agropastoralists.

Settled pastoralists take up cropping on a regular basis and part of their available resources are diverted from livestock to cropping activities. During the last two decades the number of arable farmers investing in livestock has also increased. These trends signal an emergence of more strongly integrated crop–livestock systems across sub-Saharan Africa which may eventually help cope with the need for greater agricultural output.

To overcome feed deficiencies, various forages, including *Stylosanthes,* were found promising. However, until recently none of the species were adopted by the farmers because there is no tradition of growing forages in West Africa. Hence, there had to be closer interaction with the producers to biotechnically and socioculturally tailor forages to the prevailing farming systems. This required a multidisciplinary team to address the complex issues of species compatibility, competition, rotational sequences and management for developing forage–crop associations. These were the main focus of ILCA feed development research and the genus *Stylosanthes* provided the principal germplasm for on-station and on-farm research. Major findings by ILCA from this work during the past decade are summarised in the papers presented at this workshop.

Utilisation du *Stylosanthes* dans la mise en valeur des parcours: synthèse des travaux du CIPEA au Nigéria

Résumé

L'amélioration de la productivité du bétail en Afrique subsaharienne passe par la mise au point de solutions viables aux problèmes des pénuries alimentaires saisonnières et de la qualité médiocre des aliments du bétail. Etant donné que l'élevage a traditionnellement été la vocation exclusive des éleveurs nomades et transhumants, ces derniers furent pendant longtemps les seuls groupes cibles des innovations technologiques en matière de gestion du cheptel et de production alimentaire. Au cours des vingt dernières années, de nombreux éleveurs nomades se sont sédentarisés et ce, pour plusieurs raisons; cependant, pendant *longtemps, ils n'ont jamais été associés aux actions visant à promouvoir le développement de l'élevage en Afrique subsaharienne. Lorsqu'en 1987 le CIPEA commença ses travaux dans la zone subhumide du Nigéria, le Centre inclut ces agropasteurs sédentarisés dans ses travaux, élargissant ainsi le champ de la recherche sur l'élevage au Nigéria.*

Les éleveurs sédentarisés pratiquent régulièrement l'agriculture et détournent une partie de leurs ressources de l'élevage pour les consacrer aux activités agricoles. De même, le nombre de paysans qui investissent dans l'élevage a également augmenté au cours des vingt dernières années. Ces tendances sont les signes précurseurs de l'émergence, partout en Afrique subsaharienne, de systèmes mixtes plus profondément intégrés, lesquels pourraient permettre enfin d'augmenter la production agricole dans la région.

Certaines espèces fourragères prometteuses, dont certaines appartiennent au genre Stylosanthes*, pourraient aider à résoudre le problème des pénuries d'aliments du bétail. Jusqu'à une date récente cependant, elles n'étaient toujours pas adoptées par les paysans dans la mesure où, par tradition, les plantes fourragères ne sont pas cultivées en Afrique de l'Ouest. Par conséquent, il faudra créer en étroite collaboration avec les producteurs les conditions biotechniques et socio-culturelles nécessaires pour les introduire dans les systèmes agraires de la région. Cela suppose la mise en place d'une équipe de recherche pluridisciplinaire pour étudier des problèmes complexes, y compris en ce qui concerne la compatibilité et la concurrence entre espèces, la séquence des rotations et la gestion des diverses espèces en vue de déterminer des associations appropriées entre les plantes fourragères et les cultures. C'est ainsi d'ailleurs que l'on peut résumer les objectifs des recherches effectuées par le CIPEA en station et en milieu paysan sur les aliments du bétail, recherches basées sur du matériel génétque de* Stylosanthes*. Les principaux résultats enregistrés dans ce domaine au cours des dix dernières années sont résumés dans diverses communications présentées au présent séminaire.*

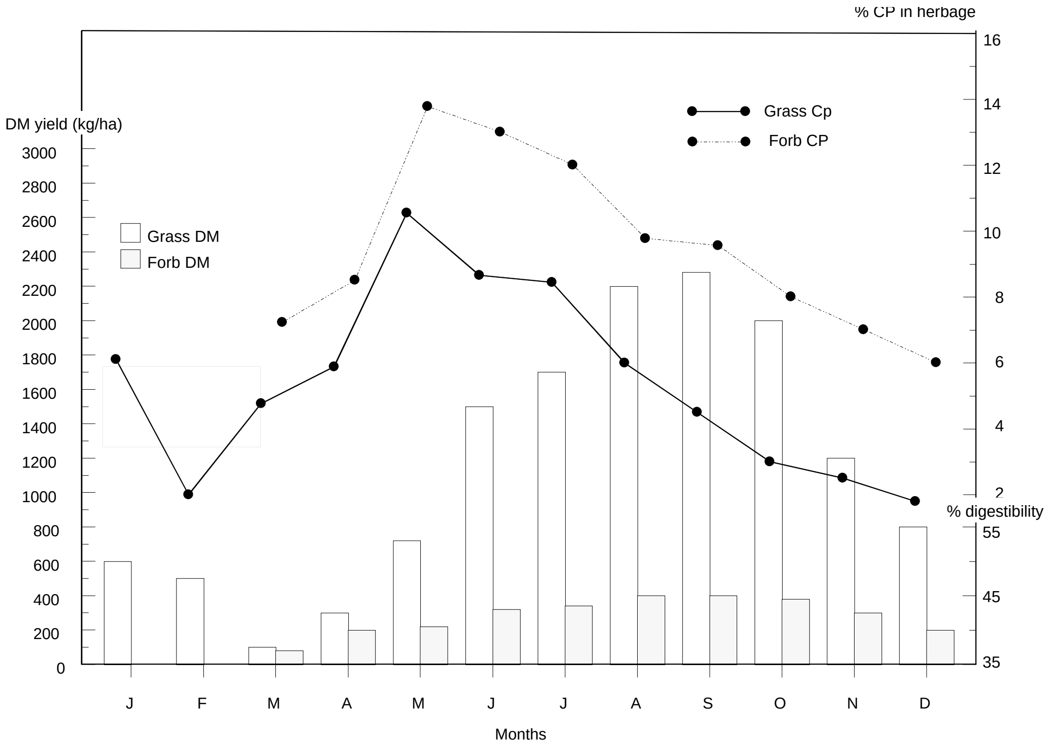
Introduction

It is estimated that there are 14 million cattle and 56 million small ruminants in Nigeria (RIM, 1992). Despite this, the cost of imports of milk and meat products into the country has reached such high levels that a ban on their importation was recently imposed. Ruminant livestock are mainly kept by a single tribe, the FulBe, whose way of life ranges from nomadism to permanent settlement. The majority are semi-settled and concentrated in the drier north where the length of growing period is less than 180 days. In this zone, dry seasons are harsh and long and, as the tsetse fly recedes, herds are taken south for water and fodder. However, the last decades have witnessed an increasing trend in the settlement of pastoralists in the subhumid zone (defined by a growing period of 180–270 days and rainfall of 900–1500 mm). Several factors such as the recent droughts, effective tsetse control and increased cultivation have favoured this process of pastoral sedentarisation.

Natural pastures provide the cheapest source of nutrients for ruminants, but fail to meet the nutritional needs of livestock throughout the year. Herbage growth follows the rainfall pattern and it is predominantly made up of low-quality grasses (Figure 1). Likewise, crude-protein content in the herbage is sufficient for maintenance and production during only three to four months in a year. By the end of the dry season, body-weight losses of up to 10–20% are common. This nutritional stress is associated with reproductive wastage, deaths and prolonged calving intervals in traditionally managed herds.

Large responses to feed supplementation have been reported in researcher-managed trials of various national institutions and were confirmed by ILCA. In some cases, supplementation with concentrates increased the calving rate to 77% compared with 40% in unsupplemented herds (Synge, 1980). Although a few resourceful pastoralists were supplementing their stock with concentrates (like groundnut and cottonseed cake) at the time that ILCA started in Nigeria, feed supplementation with agro-industrial by-products

Figure 1. *Generalised productivity and utilisation pattern of natural herbage at Kachia Grazing Reserve.*



is no longer practised due to a 600% price increase and shortages. Thus, the competition for crop residues, which are of better quality than the natural herbage, has intensified and crop residue grazing explains why pastoralists prefer to settle in close proximity to cropping communities. Settled pastoralists and agropastoralists, therefore, became the target group of ILCA.

Research approach and programme

Previous attempts to increase rangeland productivity using conventional techniques (bush control, prescribed burning, rotational grazing) were unsuccessful because the rangelands are communally grazed and indiscriminately burnt. On-station trials have provided a considerable amount of information on the use of forages, particularly of legumes and on crop–forage intercropping. ILCA's first attempt at increasing rangeland productivity started in 1980 and involved undersowing the sorghum crops of selected farmers with stylos (*S. guianensis* cv Schofield and Cook and *S. hamata* cv Verano). From these on-farm trials it was observed that:

- there was no additional cost to undersowing forages as all costs (land preparation etc) were borne by the crop
- forage intercropping conflicted with the weeding practices required for the crop
- fencing was essential to protect the sown legume pastures from itinerant herds.

From these observations ILCA concluded that the techniques used to integrate forage production with food crops were inadequate, even though the intercropping of cereals and grain legumes was common practice in the area. There was ample evidence that agropastoralists were prepared to invest in growing forage crops and manage these pastures provided they were adequately protected to ensure exclusive use by the owner's herd.

ILCA's first-year experience identified the need to increase feed resources in arable farming systems and fallow lands. Different levels of researcher-managed/executed and farmer-managed/executed trials were pursued, providing feedback for further on-station trials (see also Tarawali and Mohamed-Saleem, pp. 183–192).

Improvement of fodder in the arable crop farming systems

The main hypotheses were that forage legumes could be grown in association with food crops without lowering grain yields and without the need for additional inputs. Various techniques for incorporating forage legumes (mainly Verano and Cook stylo) into compatible cereal–forage crop mixtures were assessed.

Undersowing of cereal crops

The optimal sowing time of forage legumes in cereal crops was found to be critical and differed for each cultivar. Sowing Verano stylo three weeks or Cook stylo six weeks after crop planting caused minimal grain-yield loss and increased the quality of the overall fodder (Tarawali and Mohamed-Saleem, Table 3, p. 189). When both were planted on the same day, a loss of 0.23 and 0.40 kg of grain for the local and improved sorghum, respectively, was observed for every kilogram of dry matter (DM) produced from stylo. While undersowing is a simple method, the cropped area of individual households is small and therefore the technique is suitable only for farmers who keep a few animals.

Simultaneous sowing of cereal and legumes

Lower-yielding or slower-growing forage species can be sown with crops without lowering grain yields and thus avoid the extra labour required when sowing is done later. Suitable legumes are *Centrosema pascuorum* (centro), *Alysicarpus vaginalis* and *Macroptilium lathyroides* (phasey bean). Unfortunately, seed supply of these species has been inadequate for large-scale on-farm testing.

Alternative crop geometry

The main intercropped mixtures in ILCA's study zone consist of sorghum and soybean. Thus, techniques to incorporate stylo into a sorghum/soybean crop mixture were developed; stylo was planted in several geometric arrangements with sorghum and soybean. Traditionally, sorghum and soybean are planted in single rows on ridges. Inter-row sowing of stylo with two rows of sorghum and one of soybean on alternate ridges produced the highest yields of grain and fodder per land unit, while sorghum stand density remained the same as in the traditional system.

Fodder improvement in the fallow lands

To supplement the communal grazing, agropastoralists were encouraged to fence an area and sow stylo. Land preparation was done by kraaling the herd, and scarified seeds were broadcast thereafter. When necessary, the herd was also used for weed control by grazing before and after stylo sowing. The area was protected from burning by peripheral fire traces. To allow legume yield to accumulate, grazing was deferred until the beginning of the dry season. This unit of fenced pasture was called a *fodder bank*.

Initially, there was a spontaneous response from agropastoralists to establish fodder banks. Although designed for cattle, many small farmers established mini- fodder banks for small ruminants (Ikwuegbu et al, pp. 167–174). Subsequently, researchers and farmers assessed different techniques for management fodder banks to suit the resources and requirements of individual farmers. Because of the promising adoption of fodder banks, the concept has been extended widely by the National Livestock Project Unit (NLPU), with credit facilities supported by the World Bank (Ajileye et al, pp. 311–316).

Legume-based cropping

To retain pure stands of legumes in fodder banks is difficult, as nitrophilous grasses invade, due to accumulation of biologically fixed nitrogen in the soil. To maintain legume dominance, the surplus nitrogen has to be taken up by periodic cereal cropping. Because of land tenure traditions, pastoralists are dependent on the farmers for access to crop land. Thus the direct benefits accruing to cropping from the planted forages could encourage farmers to release their fallow land to pastoralists for short-term fodder banks. As a result, the crop–livestock enterprises of individual households of the arable farmers and pastoralists could become more spatially integrated.

Research was therefore directed at comparing the input of sown legumes with that of natural pastures and fallows on subsequent grain production. Trials, with maize as the test crop, were conducted after growing stylo for different periods of time. Yields of maize grown on previous stylo plots were comparable to yields of maize fertilised with 100–120 kg N/ha (Tarawali and Mohamed-Saleem, Figure 1, pp. 186–188). These benefits to crops were confirmed at various sites across different agro-ecological zones and found to vary with management practices. They lasted up to two years and were due to improved soil physical properties, especially lower bulk density and higher water-holding capacity (Tening et al, pp. 113–122).

Subsequently, the search for low-input techniques to grow food crops within established forage pastures, became an important research priority. As labour in agropastoral households allows cultivation of only 1.0–1.5 ha per season, a two to three year rotation within a four-ha fodder bank was envisaged. Farmers found that stylo pastures were difficult to cultivate and required more labour. This prompted studies on tillage methods. To plant cereal crops into existing sown legume pastures three techniques were tried:

Sequential cropping

This technique requires complete control of growth of legumes during the crop phase, either by application of herbicide, hand-weeding or by cutting and carrying the weeded herbage to feed livestock. The pasture is allowed to regrow towards the end of the season. This technique requires sufficient seed reserves in the soil for the rapid regeneration of the stylo.

Relay cropping

This involves the suppression of herbage growth up to a specific point after which the stylo is allowed to grow with the crop.

Intersod transplanting

The cereal crop is raised in nurseries and transplanted later in the pasture. This allows selection of vigorous crop stands and growing cereal and fodder crops simultaneously. This technique may be desirable in dry years or when the growing season is short due to erratic rainfall.

Technology refinement

Problems arose when feed improvement technologies were transferred to farmers. The following examples illustrate how perception of technologies by farmers influenced ILCA's research.

Fodder-bank establishment

The recommendation for seed-bed preparation by intensive overnight kraaling of animals for a number of nights was not generally accepted. Although adopters complied they objected to grazing early in the rainy season for fear of worm infections being passed on to the cattle through the accumulated dung. Early grazing is necessary to prevent fast-growing grasses and herbs smothering the slow-growing legumes; therefore, alternative methods for fodder-bank establishment were required.

Nutrient and water-management trials

Responses to P-fertiliser differed and some farmers were disappointed with their fodder yields. This prompted a detailed study of soil nutrients and moisture use by legumes in different soil types. For example, a preliminary study using a nutrient-omission technique identified serious Cu-deficiencies in ferric Luvisols, the correction of which was necessary for higher productivity, particularly where only marginal soils are left for fodder production (Tening et al, pp. 113–122).

Legume screening

As the fodder-bank concept spread to different ecozones, the attributes of stylo were questioned. At the same time, Cook and Schofield stylo became susceptible to anthracnose, while the risk of relying only on Verano stylo became apparent. Therefore in 1982, a screening programme was started and up to 400 new lines were recorded by 1985. A serious search to identify more disease-tolerant and adaptable species was undertaken in collaboration with Centro Internacional de Agricultura Tropical (CIAT), Commonwealth Scientific and Industrial Research Organization (CSIRO) and national institutions. Among the stylo lines CIAT 136 and 184 were identified as very tolerant to anthracnose while being highly productive. *Cassia rotundifolia, Centrosema pascuorum* and *Lablab purpureus* for drier zones and *Centrosema acutifolium* for wetter zones were found promising (Tarawali et al, pp. 81–95). Therefore, with the assistance of a commercial grower, seed production of these cultivars was encouraged.

Nodulation

While *Stylosanthes capitata* proved very promising in terms of growth, quality and persistence, it did not nodulate with the indigenous cowpea type rhizobia. Therefore, the Ahmadu Bello University was brought in to address this problem (Tening et al, pp. 113–122).

Wet-season grazing of fodder banks

In areas where the cropping intensity is high, livestock suffered from feed constraints in both the wet and the dry season, making the year-round use of fodder banks an important issue (Mani et al, pp. 155–165; de Leeuw, pp. 325–334; Agishi, pp. 275–285; Ikwuegbu et al, pp. 167–174).

Conclusion

Large and small ruminant livestock are important in most smallholder production systems of sub-Saharan Africa. However, wherever they are and whatever role they play seasonal inadequacy of feed, in terms of both quantity and quality, remains a common constraint for improved livestock productivity.

When livestock producers settle, the opportunity of moving livestock to unoccupied savannah rangelands decreases and more cropping becomes an important part of their life. ILCA's feed-improvement techniques have been targeted at settled agropastoral smallholder systems. Improvement of feed quality and quantity has been the major thrust and the genus *Stylosanthes* has been used for this purpose. This paper summarises the research philosophy and programme, from 1978, when ILCA started work in the subhumid zone of Nigeria, up to 1985–86. Details of various research activities were presented in a report by von Kaufmann et al (1986). Research advances made after 1986 to improve livestock feed using *Stylosanthes* are reported in these proceedings.

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Evaluation of *Stylosanthes* for selected farming systems of tropical America

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Abstract

The performance of *Stylosanthes* spp as an animal feed or as a ley crop is described with results from both experiment station and on-farm research. Use of *Stylosanthes* spp in the American tropics is essentially confined to extensive grazing systems, including oversowing into native range, in improved grass/legume associations, or as legume banks to supplement either native range or improved, pure grass pastures. *Stylosanthes* is also being successfully integrated in crop/pasture production systems. The most important attributes of successful *Stylosanthes* cultivars, used as pasture or ley in tropical America are resistance to disease, high seed yield and adaptation to infertile soils.

Evaluation du *Stylosanthes* dans quelques systèmes agraires en Amérique tropicale

Résumé

Les résultats de l'évaluation, en station et en milieu réel, de diverses espèces de Stylosanthes *utilisées comme source d'aliment du bétail ou dans les jachères sont présentés. En Amérique tropicale,* Stylosanthes *est essentiellement utilisé dans les systèmes de parcours extensifs. Il est semé sur parcours naturel, associé avec des graminées ou utilisé dans des banques de légumineuse pour complémenter le fourrage des parcours naturels ou des pâturages améliorés de graminées pures.* Stylosanthes *est en outre intégré avec succès dans des systèmes de production agricole et fourragère. Les principales qualités de ses cultivars les plus utilisés en Amérique tropicale dans les pâturages ou les jachères sont la résistance aux maladies, une excellente production de semences et une bonne adaptation aux sols pauvres.*

Introduction

Successful use of *Stylosanthes* spp as a supplement to native range or as a component of sown grass/legume pastures is relatively recent in tropical America. Before 1970, attempts to use commercial *Stylosanthes* spp cultivars selected in Australia generally resulted in failure due to the severe susceptibility of these genotypes to anthracnose disease (caused by *Colletotrichum gloeosporioides*). In the early 1970s CIAT (Centro Internacional de Agricultura Tropical) began to acquire and screen large collections of *Stylosanthes*

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germplasm. This has resulted in the identification of genotypes with sufficient anthracnose resistance to persist where the disease is prevalent.

Use of *Stylosanthes* spp in tropical America is essentially limited to extensive grazing systems. *Stylosanthes* lines have been tested in diverse grazing systems including oversowing into native savannah, supplementation of native savannah or improved grass pasture with protein banks and in improved pastures in association with introduced grasses.

The effect of *Stylosanthes* on animal performance and soil fertility is being documented. Results are now available both from on-station and from on-farm research. Four *Stylosanthes* cultivars have been released in tropical America (CIAT, 1991) and significant adoption has been documented (Ferguson et al, 1989).

This present paper summarises results of experiment station and on-farm experience with *Stylosanthes* as animal feed and as a fallow crop in tropical America, and considers some of the attributes required of a successful *Stylosanthes* cultivar for different production systems.

Supplement to native savannah

Oversown legume

Improved forage legumes, including *Stylosanthes* spp, are not commonly utilised in tropical America to supplement native range. However, two experimental situations where *Stylosanthes* was sown in native savannah have been documented at the Carimagua Research Station in the eastern plains of Colombia. Where *Stylosanthes capitata* was oversown into native savannah in strips at a rate of 1500 or 2500 m^2 of legume per animal and grazed continuously, no effect of the legume on animal liveweight gain was detected (Hoyos, 1987). This was attributed to the extremely low proportion of legume on offer (< 1%) in the grazed savannah. The low proportion of *S. capitata* in the forage on offer was probably due to *S. capitata's* high palatability relative to the native savannah species, resulting in the *Stylosanthes* being grazed out.

In a separate trial established at Carimagua to assess the consumption and persistence of a range of legumes sown in native savannah under periodic mob grazing, *Stylosanthes guianensis* var *pauciflora* (CIAT 2031) formed as much as 37% of the forage on offer (CIAT, 1991). *S. guianensis* was among the most productive of the 10 legumes included in the trial. However, consumption of the *S. guianensis* was very low and constituted only 9% of the diet (measured in the extrusa of oesophageal-fistulated steers) even in the dry season, despite its large contribution to the forage on offer. Given the low palatability of the native range grasses, persistence of an associated legume in grazed savannah may depend on the legume also being of low palatability.

Protein banks

Supplementing native range with legume or protein banks offers the prospect of more intensive management of the legume allowing better persistence of a palatable legume such as *S. capitata*. In a study conducted at Carimagua *S. capitata* protein banks were used to supplement native savannah pastures (Schneichel et al, 1988a; 1988b). In this trial grazing animals were given free access to the banks throughout the year. Legume consumption reached 50% of the diet during the dry season. Protein intake was higher during the dry season than during the rainy season (0.44 vs 0.31 kg/animal/day). However, animal performance was poorer during the dry season than during the rainy season (0.27 vs 0.32 kg/animal/day). This suggested that digestible energy, rather than nitrogen, was limiting animal performance on native range, particularly during the dry season. This conclusion is supported by a subsequent comparison of a pure legume protein bank (*Pueraria* *phaseoloides*) with an energy bank consisting of *Andropogon gayanus* and *S. capitata* (Lascano and Plazas, 1990). Animals grazing native savannah supplemented with the energy bank performed better than those grazing unsupplemented native savannah (165 vs 117 kg/animal/year) or those grazing native savannah supplemented with a protein bank (157 vs 113 kg/animal/year). While the use of legume banks might be feasible in more intensive animal production systems, management of these banks is difficult in the more extensive systems generally encountered in the tropical American savannahs. Access to the banks must be controlled to avoid overgrazing and consequent loss of the legume. The accumulation of nitrogen in pure legume banks quickly leads to weed invasion and a resulting degradation of the protein bank (Schneichel et al, 1988a). A further disadvantage is that most of the nitrogen fixed by the legume in a protein bank is unavailable to the grass pasture.

Stylosanthes guianensis var *pauciflora* protein banks were compared with *Leucaena leucocephala* in the Brazilian Cerrados (Zoby et al, 1990). Six per cent of the area of native range was sown with legume. Legumes were oversown in a rice (*Oryza sativa* L.) crop following clearing and fertilisation on an acid (pH = 4.8) low fertility, dark red Latosol. *Stylosanthes* banks received only half the lime (1.6 vs 3.2 t/ha) and single superphosphate (0.5 vs 1.0 t/ha) as the *Leucaena* banks. The experimental area (native range plus legume bank) was subdivided and grazed rotationally.

Over a period of 532 days, daily weight gain of heifers was higher with the legume bank supplement than on pure native savannah (0.346 or 0.404 vs 0.226 kg/animal for *S. guianensis* or *L. leucocephala* banks vs native savannah, respectively). Performance in the dry season was better on the *S. guianensis*- than on the *L. leucocephala*-supplemented range (0.107 vs -0.045 kg/animal, respectively). Better performance of animals grazing *S. guianensis* banks in the dry season was attributed to its better retention of green leaf. The drought tolerance of *S. guianensis* was, in turn, attributed to its inherently better tolerance to acid soil, resulting in deeper rooting and greater access to soil moisture than *L. leucocephala*.

The authors conclude that the use of small areas of legume bank planted with rice to supplement native Cerrados range can make a net contribution to the production system of one tonne of rice and 283 kg of additional animal liveweight gain over two years, relative to the use of unsupplemented native range (Zoby et al, 1990). The authors do not mention degradation of the legume banks, probably owing to the more intensive management (including controlled access to the banks) than in the *S. capitata* banks used in the Colombian Llanos. Better performance of the *S. guianensis* banks in Brazil may also be, in part, due to the inherently lower palatability of *S. guianensis* var *pauciflora* compared with *S. capitata*.

Supplement to improved grass pasture

Improved grass–*Stylosanthes* pastures

The widest experience with *Stylosanthes* spp in tropical America is as a component of improved grass–legume pastures. Animal performance, grazing selectivity and forage quality of *A. gayanus*/*S. capitata* pastures have been well documented for the Colombian Llanos, both on-station (Bonhert et al, 1985; Bonhert et al, 1986; Lascano and Thomas, 1990) and on-farm (Vera and Sere, 1990). Weight gains exceeding 200 kg/animal/year have been recorded (Thomas et al, 1987). However, the amount of *S. capitata* in forage-on-offer tends to decrease over time. Since *S. capitata* is essentially a biennial, its presence in the pasture depends upon seedling recruitment which is not reliable in an *A. gayanus* pasture due to strong competition from the established grass (Rojas and Lascano, 1991).

Experience with *S. capitata* in improved grass/legume pastures on commercial ranches in the Colombian Llanos confirms the significant contribution of *S. capitata* to animal performance compared with pure grass pastures. On one farm where heifers grazed *A. gayanus/S. capitata* pastures, they reached their breeding weight of 300 kg in 24 months, whereas they required nearly 40 months on pure savannah pastures (Vera and Sere, 1990). The proportion of *S. capitata* in old (9–11 years) *A. gayanus*-based pastures appears to be associated with soil texture, with a higher legume content on sandy soils (CIAT, 1991). Economic analysis of these *S. capitata*-based pasture systems shows they are viable (Thomas et al, 1987).

Between 1986 and 1988 over 14 t of *S. capitata* seed was produced and about 3000 ha of *A. gayanus/S. capitata* pastures were planted in the Colombian Llanos (Ferguson et al, 1989).

S. guianensis cv Pucallpa (CIAT 184) was one component of a legume "cocktail" (including *Desmodium heterocarpon ovalifolium*, *Centrosema acutifolium*, *Centrosema pubescens* and *Centrosema macrocarpum*) tested in *Brachiaria decumbens*-based pastures in on-farm trials in the Peruvian humid tropics (Locker, 1992). While it is impossible to attribute the 5-17% increase in milk production with legumes exclusively to any one species, it is likely that *S. guianensis* was largely responsible. *S. guianensis* established more rapidly and at least initially was the dominant legume in these pastures. *S. guianensis* content in the pastures over time was influenced by management. On two farms where periodic burning of the pastures was practised *S. guianensis* content remained high (approximately 30% of forage on offer) while the contribution of *Centrosema* spp and *D. heterocarpon ovalifolium* declined (CIAT, 1991 pp. 20–58). Where burning was not practised the content of *S. guianensis* decreased to less than 20% following two years of grazing. The higher content of *S. guianensis* with burning was associated with greater recruitment of new plants from seed rather than greater survival of older plants.

In another set of on-farm trials in the Caquetá Department in Colombia, *Brachiaria*-based pastures were sown with a legume cocktail containing *S. guianensis* cv Pucallpa, *Arachis pintoi*, *D. heterocarpon ovalifolium* and several *Centrosema* spp. *S. guianensis* was a dominant component of these pastures following establishment, but the *Stylosanthes* content has decreased over time. Apparently *S. guianensis* is not persistent under grazing in this humid forest ecosystem, although it does have a role in animal performance and in the nitrogen economy of the pastures in the early stages of pasture development.

A large grazing trial was established at the CPAC experimental station near Brasilia in 1987 (G. G. Leite, 1992, unpublished). *A. gayanus* was planted with a mixture of *Stylosanthes* spp (*Stylosanthes macrocephala*; *S. capitata*; *S. guianensis* var *pauciflora*). While the content of all three *Stylosanthes* species decreased over time, *S. guianensis* was the most persistent, representing 88% of the contribution of all legumes after three years of grazing. While severe weight losses occurred during the dry season on pure *A. gayanus* pastures, animals maintained or even gained weight on the *Stylosanthes*-based pastures (G. G. Leite, 1992, unpublished).

More recent experimental work at Carimagua has documented the positive effect of *S. capitata* on the yield and nitrogen content of the associated grass, *Brachiaria dictyoneura*, during the pasture-establishment period, even before the initiation of grazing. *B. dictyoneura* in association with *S. capitata* on a sandy soil had 32% greater above-ground biomass (2.62 vs 1.99 t/ha) and 50% more nitrogen (2.12 vs 1.41 gm N/m^2) than the pure grass. This remarkably rapid nitrogen transfer from legume to grass was partially attributable to the large amounts of legume litter accumulated during the dry season (Thomas et al, 1993).

Protein banks

Owing to the difficulty commonly encountered in maintaining adequate species balance in grazed grass/legume associations, the use of legumes in pure blocks to supplement improved, pure grass pastures has been suggested (Zoby et al, unpublished). *Stylosanthes* has been tested in protein banks to supplement *A. gayanus* pastures in the Brazilian Cerrados (Zoby et al, unpublished). A significant, though small effect of the *S. guianensis* bank was detected (9% improvement in live weight during a 33-month grazing period).

Soil-fertility improvement

The development of new, acid-soil-tolerant, blast-resistant rice cultivars in tropical America (Leal et al, 1991; Sarkarung and Zeigler, 1989) has opened a range of new production system options which include pasture-rice rotations, and the establishment of pasture species simultaneously with a rice crop on newly opened land. Where *Stylosanthes* is adapted, it inevitably becomes a component of these systems. Attributes of *Stylosanthes* spp in terms of their compatibility with crop–pasture rotation systems are currently under investigation.

Pasture-crop rotation

Early experimentation has shown that rice established following a pasture yields more and responds less to fertiliser than rice sown in newly opened savannah. However, in a comparison between rice sown following a pure *A. gayanus* pasture or a *A. gayanus/S. capitata* pasture, no effect of the legume was detected either for rice yield or for response to fertiliser nitrogen applied to the rice crop due to the very low percentage (< 2%) of legume in the old *A. gayanus/S. capitata* pastures. A similar comparison of rice yields following 10 years of *B. decumbens* alone or *B. decumbens/P. phaseoloides* pastures showed a marked effect of the legume on subsequent rice yields where no fertiliser nitrogen was applied to the rice crop (2.2 vs 1.0 t/ha). For productive grass/*Stylosanthes* pastures with good legume content a similar response is expected.

Establishment with rice

A. gayanus and *S. capitata* were successfully established when sown simultaneously with rice in newly opened savannah. Sowing of *A. gayanus* and *S. capitata* with a rice crop had no detrimental effect on rice grain yield. At rice harvest, 1.8 or 0.4 t/ha of above-ground biomass was measured for *A. gayanus* or *S. capitata*, respectively, and grazing was commenced shortly following the rice harvest.

Pasture reclamation

Degraded *B. decumbens* pastures have been successfully recuperated with a rice crop undersown with a mixture of *S. capitata* and *C. acutifolium*. Ten months after rice harvest *B. decumbens* pastures without legumes had only about one-third of the total forage on offer as pastures reclaimed with rice and undersown legume (2.1 vs 7.8 t/ha total dry matter). Furthermore, nearly one-third of the total DM on offer in the pure *B. decumbens* pastures was weedy species whereas weeds constituted only 6.4% of the DM on offer in *B. decumbens* pastures recuperated with legume. The data available do not permit assessment of the relative contribution of the two legumes to the improved productivity of the reclaimed pastures.

The effect of *Stylosanthes* spp on subsequent crop performance in pasture/crop rotations will depend upon the rates of nitrogen fixation by the legume, and subsequent recycling via litter production. Nitrogen fixation rates for *Stylosanthes* spp have been measured at the Carimagua Research Station in experimental, pure-legume plots (Cadisch et al, 1989). At relatively high rates of P and K fertilisation (80 and 70 kg/ha, respectively), nitrogen fixation ranged from 69 kg/ha for *S. capitata*, to 86 kg/ha for *S. guianensis*, and to 129 kg/ha for *S. macrocephala*. Substantially lower rates of fixation were recorded where P and K fertiliser was not used (22, 49, or 25 kg/ha for *S. capitata, S. guianensis*, or *S. macrocephala*, respectively).

In grass/legume swards receiving 20 kg/ha P and K or 60 kg/ha P and K, *S. capitata* fixed between 18 and 26 kg N/t legume dry matter (DM) and derived over 85% of its nitrogen from fixation (Thomas and Asakawa, 1993).

Litter production, nitrogen content and decomposition rates have been estimated for a range of forage species, including *S. capitata* and *S. guianensis* (Thomas and Asakawa, 1993). *S. capitata* was found to have a very rapid rate of decomposition relative to the other legumes (or grasses), and so was calculated to be able to supply to the order of 40–75% of the nitrogen requirements of a pasture with 8.5 to 1.7 t DM production/year. Estimates for the other legumes, including *S. guianensis*, were much lower, mainly owing to their much slower rates of decomposition. The rapid decomposition of *S. capitata* litter is apparently associated with its low lignin content, low C:N ratio and high nitrogen concentration.

Attributes associated with successful adaptation of *Stylosanthes*

This review of experiences with *Stylosanthes* spp in tropical America permits at least a tentative assessment of the attributes determining the performance of present or future *Stylosanthes* spp cultivars in diverse grazed pasture systems in the region. Perhaps the most outstanding general attribute of the *Stylosanthes* spp commonly used in tropical America is excellent adaptation to edaphic stress. Both *S. guianensis* and *S. capitata* perform well on low pH, high aluminium soils with minimal application of fertiliser. *S. capitata* is particularly well-adapted to lighter textured soils, an attribute identified only after extensive on-farm testing. *S. guianensis* var *pauciflora* has outstanding drought tolerance and is consistently among the highest yielding forage legumes in small-plot, clipping trials harvested during the dry season.

Stylosanthes spp are easily and reliably established from seed in extensive, low-input systems where other legumes, such as *Centrosema* fail (Locker, 1992; Nada et al, 1992). This is apparently related to good seedling vigour in spite of small seed size. Small seed size assures adequate soil-seed contact even where seed is surface broadcast. As Nada (1992) points out, the commercially released or promising forage legumes developed by CIAT's Tropical Pastures Program have been selected on attributes such as high forage yield and adaptation to savannah ecosystems, rather than for ease of establishment. Perhaps more attention ought to be given to developing simple methodologies for assessing ease of establishment.

Tolerance of *S. guianensis* to periodic burning was found to be critical to the success of *S. guianensis* in on-farm trials conducted in the humid tropics of Peru (Locker, 1992). Response to burning has also been investigated in *S. capitata* (Alejo et al, 1988; Chavez, 1988). In extensive systems, pastures are often intentionally burned to remove accumulated dead vegetation, to control diseases (Lenné, 1982) or insects (Jiménez, 1978) and to control weeds; accidental fire is a permanent threat. The ability of *Stylosanthes* spp to recover following an intentional or accidental fire, either from plant survival or seedling recruitment, assures continued legume presence in the pasture.

Tolerance to grazing in *Stylosanthes* spp is intermediate among promising tropical forage legume species. *Stylosanthes* spp generally persist better under grazing than the trailing, twining legumes such as *Centrosema* spp or *P. phaseoloides*. However, when adapted strongly stoloniferous legumes, such as *D. heterocarpon ovalifolium* or *Arachis pintoi*, are even more tolerant as their growing points are better protected.

The greatest limitation to the use of *Stylosanthes* in tropical America is due to biotic stresses, particularly anthracnose disease (Irwin et al, 1984). As *Stylosanthes* spp are native to the American tropics, they are subject to attack by a diverse range of endemic pathogens and insect pests (Lenné and Calderón, 1984). Resistance to these biotic stresses does exist in natural germplasm (Miles and Lenné, 1984). Testing *Stylosanthes* germplasm accessions in their tropical American centres of origin, where pathogen diversity is supposed to be greatest, is an ideal way of identifying durable host-plant resistance (Lenné et al, 1984). Given the pathogenic diversity of the anthracnose pathogen, use of genetically heterogeneous *Stylosanthes* cultivars has been suggested (Miles and Lenné, 1984). The commercial *S. capitata* cv Capica released in Colombia, is a mixture of five germplasm accessions (Thomas et al, 1987).

High seed yield is an important attribute for any successful forage plant, both in terms of its impact on the cost of commercial seed and on soil seed reserves for new recruitment in a grazed pasture. Most *Stylosanthes* spp have a high seed yield potential, e.g. 620 to 1763 kg/ha recorded for a range of *Stylosanthes* species by Hopkinson and Walker (1984). While uneven seed maturity limits harvestable seed yield, this can be overcome by developing efficient methods of recovering seed from the soil surface (Hopkinson and Walker, 1984). Inherently low seed yield, attributable to shy flowering and low seed set, has been a limitation for some *S. guianensis* genotypes, particularly in the botanical variety *pauciflora* (Sumberg and Miles, 1982). In some instances insects can severely depress *Stylosanthes* seed yield (CIAT, 1991).

As increasing use is made of integrated pasture and crop production systems, additional attributes of a component forage legume become important. Of particular interest are properties such as the amount of nitrogen fixed and the recycling potential of the litter, which influence the availability of nutrients over time in complex production systems including crops and pastures. The relevance and importance of these attributes are being investigated and simple methods of assessing species and genotype differences are being developed.

Stylosanthes is only one of several genera under intensive investigation to develop successful forage legumes for tropical America. As genotypes tolerant or resistant to the endemic biotic stresses are found or bred, the special attributes of this genus assure its continued use in the diverse production systems of tropical America.

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Section 2

The screening and evaluation of *Stylosanthes* germplasm

Molecular analysis of genetic diversity and evolutionary relationships in *Stylosanthes* (Aubl.) Sw.

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Abstract

The taxonomy of *Stylosanthes*, a tropical legume genus, has long been disputed due to a lack of stable morphological characters. As this genus is of considerable agronomic importance, accurate species identification is essential for further improvement of domesticated cultivars.

An analysis of restriction fragment length polymorphisms in chloroplast and ribosomal DNA has been used to determine evolutionary relationships between 18 taxa from both sections in the genus.

Probes covering 85% of the chloroplast genome revealed 147 shared fragments that were used in a cladistic analysis. Twelve equally parsimonious trees were produced, using the “Branch & Bound” method of PAUP (Phylogenetic Analysis Using Parsimony) with Fitch parsimony. The strict consensus tree had a consistency index of 0.49 and a length of 299 steps.

Relationships described by the tree fit well with what little is already known about the genus and its evolution.

Taxon-specific chloroplast and ribosomal DNA fragments have been identified as molecular markers. They will be used to provide a greater understanding of the taxonomy of *Stylosanthes* and to identify parents of the polyploid species.

Analyse moléculaire de la diversité génétique et relations évolutives au sein du genre *Stylosanthes* (Aubl.) Sw.

Résumé

La taxonomie de Stylosanthes, *un genre de légumineuse tropicale, a toujours fait l'objet de controverses en raison de l'absence de caractères morphologiques stables. Etant donné l'importance agronomique de ce genre, il est indispensable de l'identifier avec précision afin de pouvoir améliorer ses variétés cultivées.*

Une analyse des polymorphismes de restriction de l'ADN des chloroplastes et des ribosomes a été utilisée pour déterminer les relations évolutives entre 18 taxums des deux sections du genre Stylosanthes.

La preuve a été faite sur 85% du génome des chloroplastes que 147 d'entre eux avaient des fragments communs utilisés dans une analyse cladistique. Douze arbres également *parsimonieux ont été produits en utilisant la méthode des "branches et des liens" de la PAUP (analyse phylogénique de parsimonie) avec la parsimonie de Fitch. L'arbre de consensus strict avait un indice de cohérence de 0,49 et comportait 299 niveaux.*

Les relations mises en évidence par cet arbre étaient en harmonie avec les rares données disponibles sur ce genre et son évolution. Des fragments spécifiques de l'ADN du chloroplaste et des ribosomes de Stylosanthes *ont été identifiés comme marqueurs moléculaires. Ils seront utilisés pour mieux connaître sa taxonomie et pour identifier les parents des espèces polyploïdes.*

Introduction

The genus *Stylosanthes* (Aeschynomeae, Papilionoideae) was first described by Swartz in 1788 with just two species, *S. procumbens* and *S. viscosa*. It has since grown to include some 30–40 species located in temperate, tropical and subtropical regions of South America, Africa, Asia and Australia (t'Mannetje, 1984). The major centre of diversity for the genus is South America (Stace, 1982).

The genus is split into two sections by the presence and absence of an axis rudiment and one or two inner bracteoles (Kirkbride and Garcia de Kirkbride, 1987). Section *Stylosanthes* is thought to be the more primitive as it contains only diploid species. Section *Styposanthes* contains both diploid and polyploid species and has a more widespread distribution. Polyploid Section *Styposanthes* species are suggested to be derived via hybridisation between diploid species from both sections (Stace and Cameron, 1984).

Considerable confusion exists over species divisions and relationships in *Stylosanthes* due to the high degree of plasticity of major morphological characters both within and between species. Two opposing theories for classifying species in the genus have led to further confusion. t'Mannetje (1984) based his classification on aspects of pod morphology, e.g. length and degree of curvature of the pod beak, while Ferreira and Costa (1979) focused on characters such as leaflet venation, growth habit and number of vascular bundles. The confusion creates problems for plant breeders as accurate species identification is essential in an agronomically important group of plants, such as *Stylosanthes*, to ensure the selection of new species for domestication and for transfer of desirable features from wild species to those already domesticated.

Studies which have attempted to resolve the taxonomic problems in *Stylosanthes* have utilised classical morphological techniques (t'Mannetje, 1977; Battistin and Martins, 1987), numerical analysis (t'Mannetje, 1967), *Rhizobium* affinities (t'Mannetje, 1969; Date and Norris, 1979), seed-protein patterns (Robinson and Megarrity, 1975; Hussain et al, 1988), morphological and agronomic (M.A.) characters (Burt et al, 1971), cytological studies (Cameron, 1967), crossing experiments (Sumberg and Miles, 1982) and isozyme patterns (Stace and Cameron, 1984). These studies tended to involve relatively few species or accessions of *Stylosanthes* and were not intended as full taxonomic investigations.

DNA analysis has been used increasingly to resolve taxonomic problems in different genera over recent years, with chloroplast and ribosomal DNA being of particular interest (Palmer, 1987; Jorgensen and Cluster, 1988). The chloroplast genome is a small circular molecule of approximately 150 kilobase pairs (kbp), its structure is well understood and it is usually maternally inherited (Palmer, 1985; Harris and Ingram, 1991). The slow rate of evolutionary change in chloroplast DNA (cp DNA) means little intraspecific variation is expected and makes it an ideal molecule for cladistic analysis (Palmer et al, 1988).

Chloroplast DNA analyses have been used to elucidate evolutionary relationships in a variety of genera. e.g. *Coffea* (Berthou et al, 1983); *Brassica* (Palmer et al, 1983a), *Triticum* (Tsunewaki and Ogihara, 1983), *Linum* (Coates and Cullis, 1987), *Oryza* (Dally and Second, 1990) and *Hordeum* (Doebley et al, 1992). Evolutionary relationships in higher taxonomic levels have also been considered using this molecule, e.g. Asteraceae (Jansen et al, 1990); and the loss of the inverted repeat in one group of genera in the Papilionoideae (Lavin et al, 1990).

The structure of nuclear ribosomal DNA (rDNA) is also well documented (Jorgensen and Cluster, 1988). The features that make rDNA ideal for use as a biosystematic marker are that: (i) it is present in the genome in high copy number, which means that it can be detected even in small amounts of DNA; (ii) different regions evolve at different rates, thus different taxonomic levels can be looked at with one gene sequence (Jorgensen and Cluster, 1988). Ribosomal DNA sequences have been used in a number of studies to elucidate phylogenetic relationships at the generic level, e.g. *Lisianthus* (Sytsma and Schaal, 1985). Ribosomal DNA markers are also used in the production of taxon-specific markers (e.g. Doyle and Beachy, 1985; Soltis and Soltis, 1989) and the screening of artificial hybrids (Rajora and Dancik, 1992).

The study reported here is a preliminary investigation of species divisions and evolutionary relationships in both sections of Stylosanthes based on an analysis of restriction fragment length polymorphisms (RFLPs) in chloroplast DNA. The study has also attempted to resolve taxon-specific molecular markers from cpDNA and rDNA. These will be used for identification of unknown taxa and to identify parents of the polyploid species.

Materials and methods

Plant material

Seeds supplied by the germplasm banks listed (Table 1) were scarified and germinated on damp filter paper at 28℃. Seedlings were transferred to pots containing a mixture of Ericaceous compost and gravel (1:1) and grown under controlled conditions (i.e. 28/25^{o}C day/night) with a photoperiod of 16 hours. Leaves were harvested when plants were at least four months old, destarched by leaving in the fridge overnight and stored at -20℃ until required. Material selected for the phylogenetic analysis encompassed both sections of the genus. One accession from each taxon was assayed, except in the case of *S. scabra* and *S. capitata*, where several accessions were included to investigate intraspecific cpDNA and rDNA variation.

DNA extraction and molecular techniques

Intact, total DNA was extracted from leaf tissue according to the method of Whittemore and Schaal (1991), with the following modifications; samples were incubated at 65℃ instead of 37^{o}C and extracted only once with dichloromethane. Samples were purified on caesium chloride gradients containing 0.75 g/ml caesium chloride and 200 g/ml ethidium bromide and centrifuged overnight at 20^{o}C at 50 000 rpm (Maniatis et al, 1982). DNA (500 ng aliquots) was digested with six units of the following 11 restriction endonucleases: (tetranucleotide cutters) HaeIII, HinfI, (hexanucleotide cutters) EcoRI, BglII, HindIII, BscI, ApaI, SacI, EcoRV, BamHI, DraI (purchased from GIBCO BRL and NBL). DNA fragments were separated using 1.0% (6-bp cutters) and 1.5% agarose gels (4-bp cutters) and an SEB buffer (0.04M Tris-HCl pH 7.85, 0.02M sodium acetate, 1mM EDTA-Na2). The gel was run at a constant current of 60 mA overnight and then blotted on to Amersham Hybond-N nylon membrane. Filters were irradiated with UV light for four minutes and then baked at 80^{o}C for two hours to permanently bind the DNA.

Filters were probed in turn with a library of probes comprising 85% of the mung bean chloroplast genome (Palmer et al, 1983b). Probes were radio-labelled by the random primer method (Feinberg and Vogelstein, 1983) using alpha ^{32}P-dCTP (3000Ci/mM, 10Ci). A prehybridisation treatment of the membranes with sonicated calf thymus DNA (10 g/ml)

Table 1. Stylosanthes *taxa included in the initial survey. The origins of material and germplasm banks from which it was obtained are listed.*

Taxon	Accession	Section	Origin	Supplier
S. guianensis var *vulgaris*	2335	Stylosanthes (2x)	Brazil	CENARGEN
S. giuanensis var *microcephala*	3674	Stylosanthes (2x)	Brazil	CENARGEN
S. guianensis var *pauciflora*	8098	Stylosanthes (2x)	Brazil	CENARGEN
S. humilis	2375	Stylosanthes (2x)	Brazil	CENARGEN
S. grandifolia	2308	Stylosanthes (2x)	Brazil	CENARGEN
S. leiocarpa	4392	Stylosanthes (2x)	Brazil	CENARGEN
S. hispida	2209	Stylosanthes (2x)	Brazil	CENARGEN
S. montevidensis	78490	Stylosanthes (2x)	Argentina	CSIRO
S. viscosa	50223	Stylosanthes (2x)	Texas, USA	CSIRO
S. gracilis	8359	Stylosanthes (2x)	Brazil	CENARGEN
S. angustifolia	2275	Stylosanthes (2x)	Brazil	CENARGEN
S. fruticosa	75151	Stylosanthes (4x)	Nigeria	CSIRO
S. calcicola	73525	Stylosanthes (2x)	Curacao	CSIRO
S. sympodialis	65961	Stylosanthes (4x)	Ecuador	CSIRO
S. scabra	3639^{+}, 8297 6829, 8122 8343, 6805 8207, 8170 6815, 8392, 8081	Stylosanthes (4x)	Brazil	CENARGEN
S. macrocephala	8107	Stylosanthes (2x)	Brazil	CENARGEN
S. hamata	49080	Stylosanthes (2x)	Colombia	CSIRO
	3772^{+}, 3805 8106, 6792, 4294			
S. capitata	7011, 6770	Stylosanthes (4x)	Brazil	CENARGEN

CENARGEN: Centro Nacional de Recursos Geneticos of the Brasilian EMBRAPA (Empresa Brasileira de Pesquisa Agropecuaria)

CSIRO: Commonwealth Scientific and Industrial Research Organisation Accessions of *S. scabra* and *S. capitata* marked with a $^{+}$ were used in the PAUP analysis. Remaining accessions were surveyed to give an indication of intraspecific variation of cpDNA and rDNA (see text).

Figures in brackets in the column headed 'Section' indicate the ploidy levels of the species (2n= 2x= 20, 2n= 4x= 40).

in Buffer III (0.6M NaCl, 10mM PIPES pH 6.8, 1mM EDTA pH 8.5, 10x Modified Denhardt's) was conducted over six hours at 65°C before hybridisation took place overnight in Buffer III at the same temperature. Filters were washed as described by Palmer (1986) then laid down for autoradiography at -70°C.

Filters were also probed with a nuclear ribosomal DNA fragment from wheat DNA (pTA71, a 9.1 kb fragment, cloned into an EcoRI site of pUC19; Gerlach and Bedbrook, 1979). The pTA71-probed filters were washed as described by Harris and Ingram (1992).

Analysis of chloroplast DNA data

DNA fragments were used as characters in a phylogenetic analysis. Presence and absence of shared fragments were scored and the data set analysed by PAUP (Phylogenetic Analysis Using Parsimony, version 3.0s; Swofford, 1991). The «Branch and Bound» approach was used with Fitch Parsimony (Swofford and Olsen, 1990). Mung bean was used as an arbitrary outgroup in the analysis, so that trees could be rooted.

Results

Stylosanthes DNA was successfully digested with the majority of the restriction enzymes used. The enzymes ApaI, SacI and DraI did not cut reliably and produced fully digested fragments for only some of the DNA's used; however, the fragments produced by these enzymes were still included in the analysis.

Chloroplast DNA data

The mung bean cpDNA probes hybridised with the *Stylosanthes* DNA on the membranes to reveal restriction fragment length polymorphisms (RFLPs) such as those illustrated in Figures 1a and 1b. The relative amount of RFLP variation detected with each probe is shown in Figure 2. Probe MB3, from the small single copy region of the chloroplast genome, was found to reveal the most polymorphism.

Figure 1a. Stylosanthes *chloroplast DNA digested with BscI and probed with MB3. Arrows indicate the fragments used in the phylogenetic analysis. This variation is produced by a single site mutation and the smaller fragment produced by the extra site is missing. A second site mutation in lane 5 is taxon-specific and not included in the phylogenetic analysis. From left to right: mung bean outgroup,* S. capitata, S. scabra, S. montevidensis, S. guianensis *var* microcephala, S. macrocephala, S. viscosa, S. angustifolia, S. leiocarpa, S. gracilis, S. calcicola, S. humulis, S. sympodialis, S. hamata, S. hispida, S. fruticosa, S. grandifolia; S. guianensis *var* vulgaris, S. guianensis *var* pauciflora.

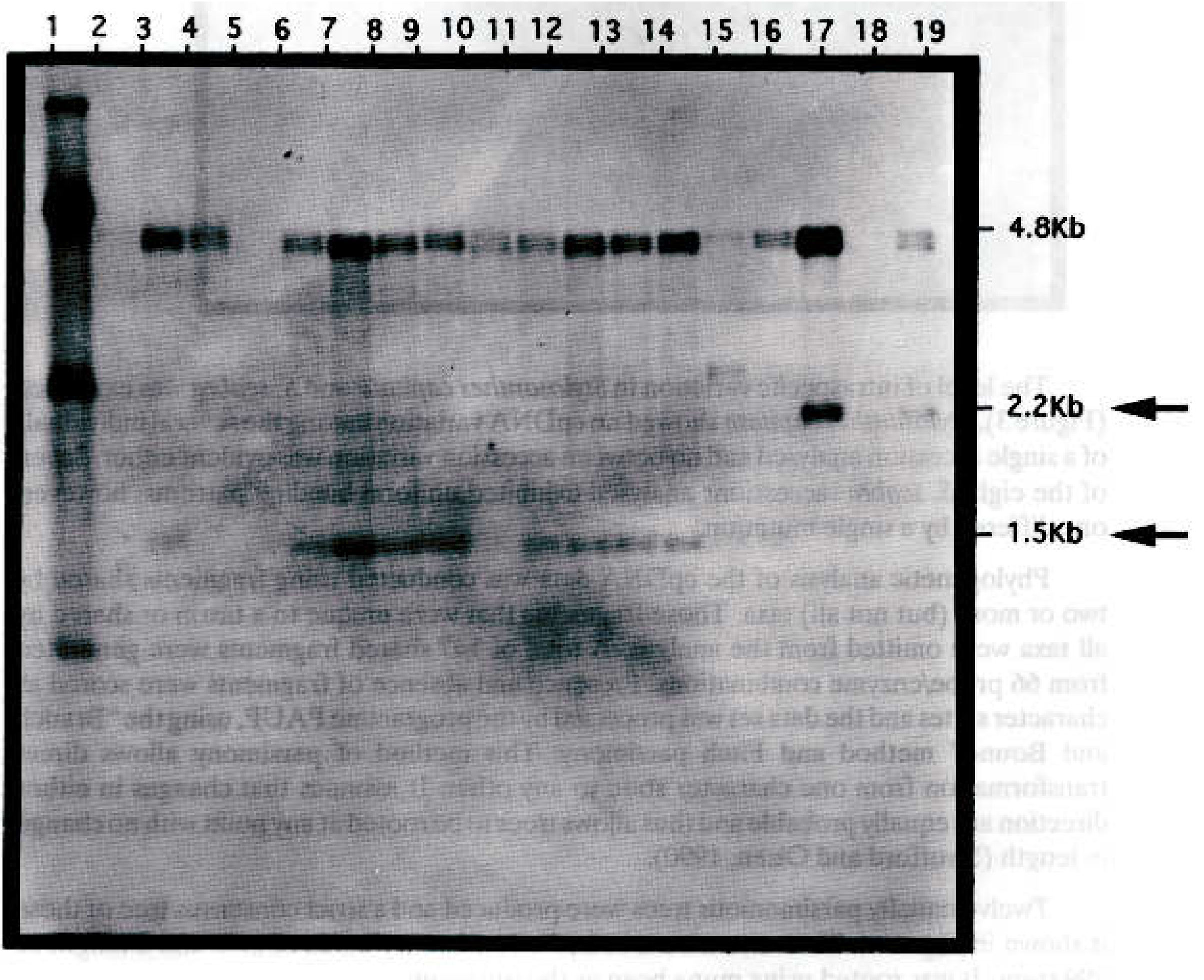
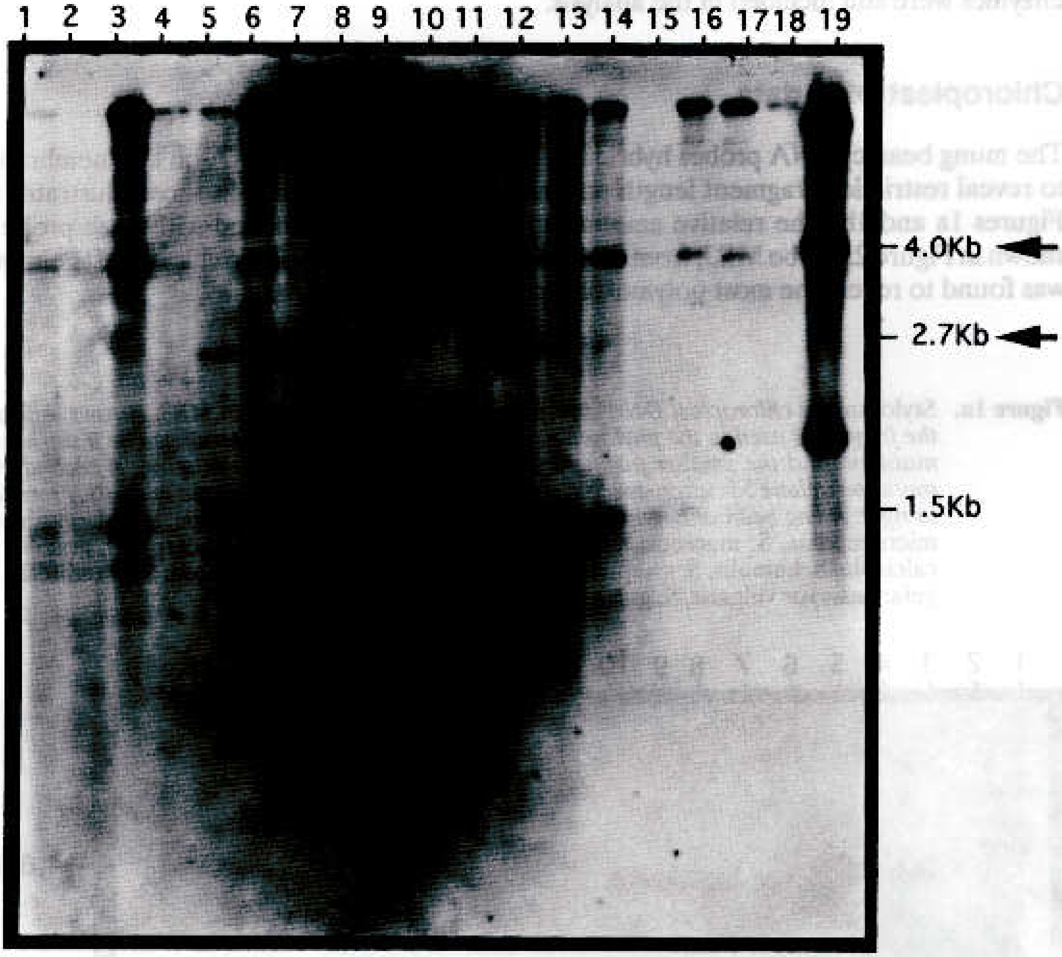


Figure 1b. Stylosanthes *chloropast DNA digested with HinDIII and probed with MB3. A site mutation provided the variation used in the analysis (arrows). The smaller fragment has comigrated with the 1.5 Kb fragment further down. From left to right:* S. guianensis *var* pauciflora, S. guianensis *var* vulgaris, S. grandifolia S. fruticosa, S. hispida, S. hamata, S. sympodialis, S. humilis, S. calcicola, S. gracilis, S. leiocarpa, S. angustifolia, S. viscosa, S. macrocephala, S. guianensis *var* microcephala, S. montevidensis, S. scabra, S. capitata, *mung bean outgroup.*

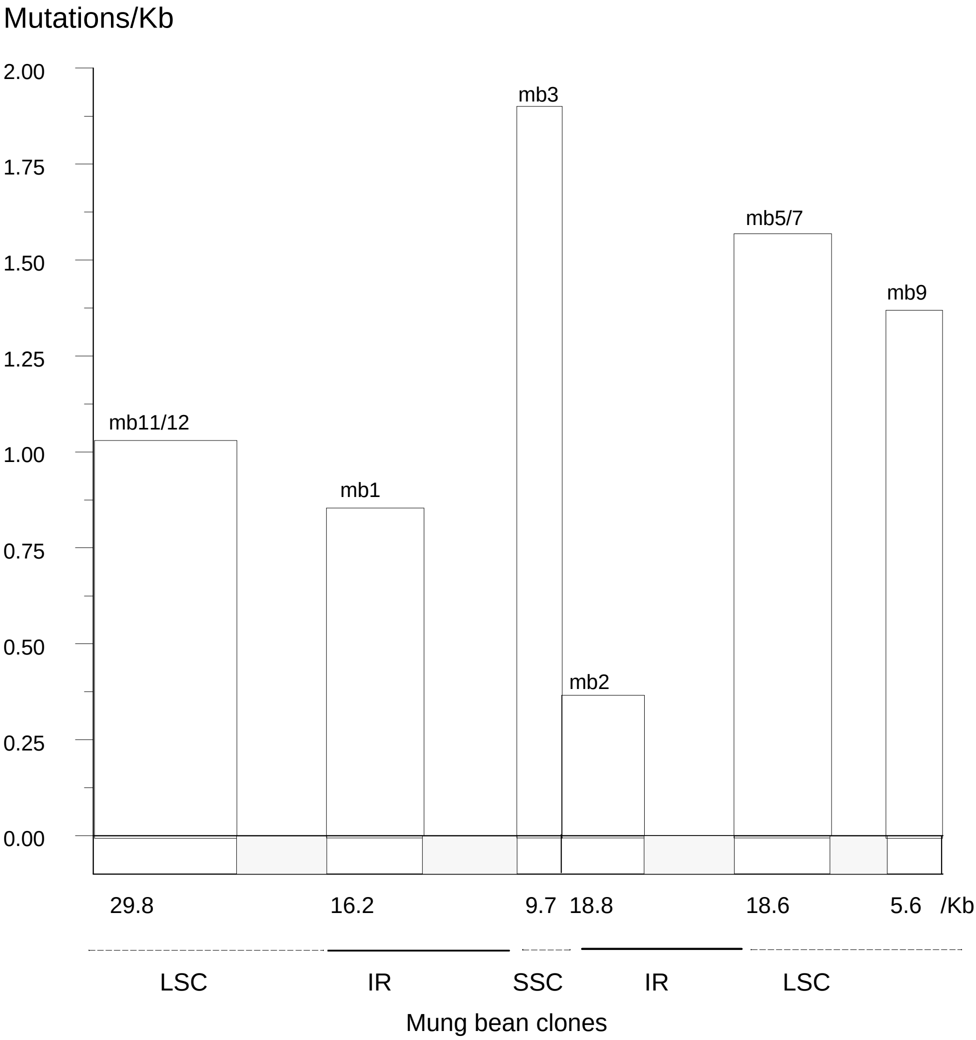


The level of intraspecifc variation in *Stylosanthes capitata* and *S. scabra* was examined (Figure 3). *Stylosanthes capitata* showed no cpDNA variation among the several individuals of a single accession analysed and no between accession variation was evident either. Seven of the eight *S. scabra* accessions analysed exhibited uniform banding patterns; however, one differed by a single mutation.

Phylogenetic analysis of the cpDNA data was conducted using fragments shared by two or more (but not all) taxa. Those fragments that were unique to a taxon or shared by all taxa were omitted from the analysis. A total of 147 shared fragments were generated from 66 probe/enzyme combinations. Presence and absence of fragments were scored as character states and the data set was processed by the programme PAUP, using the “Branch and Bound” method and Fitch parsimony. This method of parsimony allows direct transformation from one character state to any other. It assumes that changes in either direction are equally probable and thus allows trees to be rooted at any point with no change in length (Swofford and Olsen, 1990).

Twelve equally parsimonious trees were produced and a strict consensus tree of these is shown in Figure 4. The consensus tree had a consistency index of 0.49 and a length of 299 steps. It was rooted using mung bean as the outgroup.

Figure 2. *Relative variation detected by the different mung bean clones in the chloroplast DNA of* Stylosanthes.



Stylosanthes appears to be monophyletic, i.e. it is derived from a single ancestral taxon. The *S. guianensis* complex and related species are clearly separated from the rest of the genus and appear to represent a basal group.

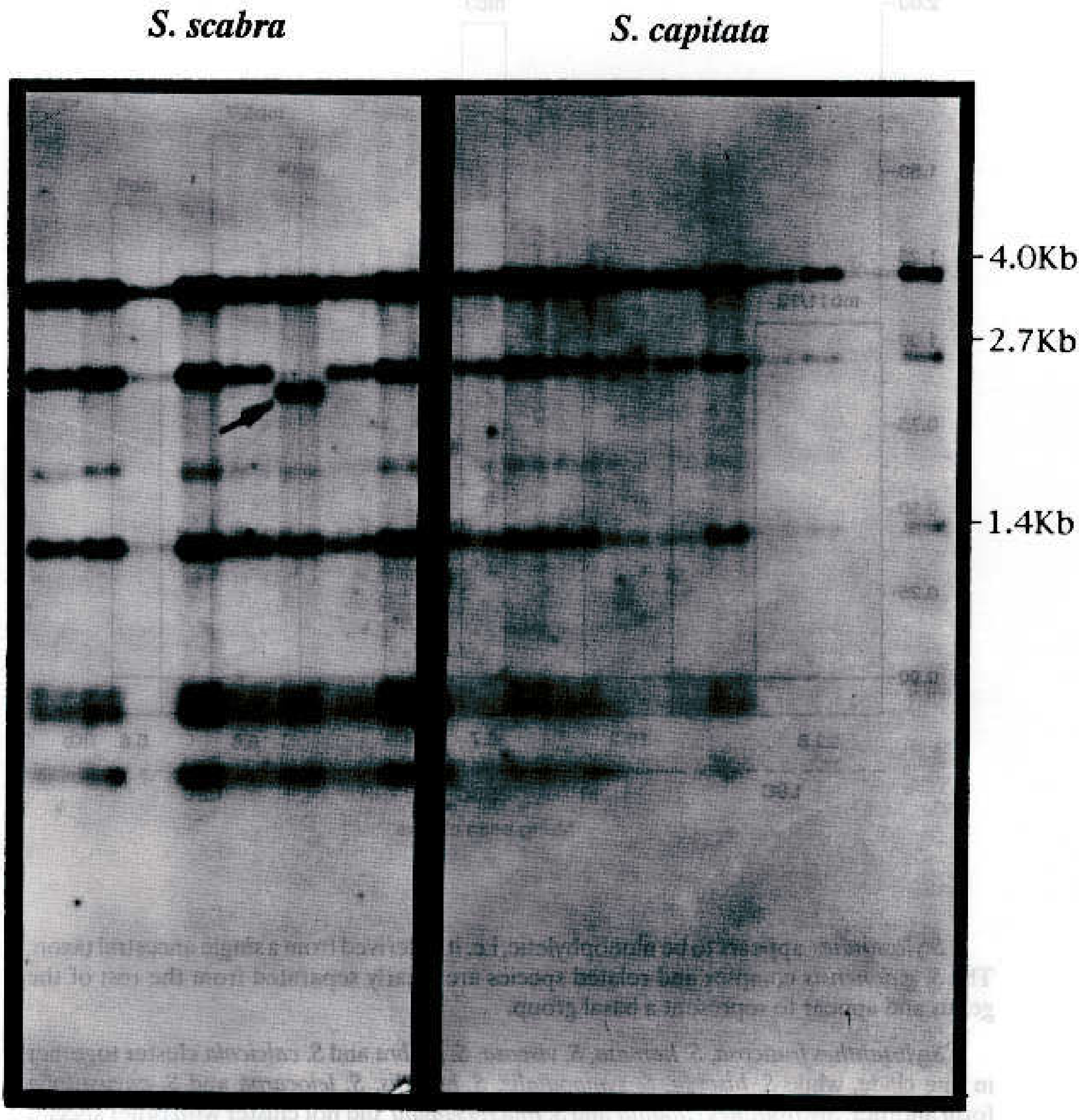
Stylosanthes fruticosa, *S. hamata*, *S. viscosa*, *S. scabra* and *S. calcicola* cluster together in one clade, while *S. hispida*, *S. sympodialis*, *S. humilis*, *S. leiocarpa* and *S. angustifolia* form another. *Stylosanthes capitata* and *S. macrocephala* did not cluster with other species but remained isolated at the base of the tree.

Taxon-specific cpDNA patterns and fragments from selected probe/enzyme combinations are listed in Table 2, with some of these patterns illustrated in Figure 6.

Ribosomal DNA data

Figure 5 illustrates some of the results produced by reprobing the membranes with pTA71. Bands produced as a result of partial digestion revealed considerable repeat length variation between taxa. The number of repeat lengths per individual also varied. There was little variation between taxa for other rDNA bands produced by complete digestion of the DNA and representing the different coding regions of the rDNA sequence.

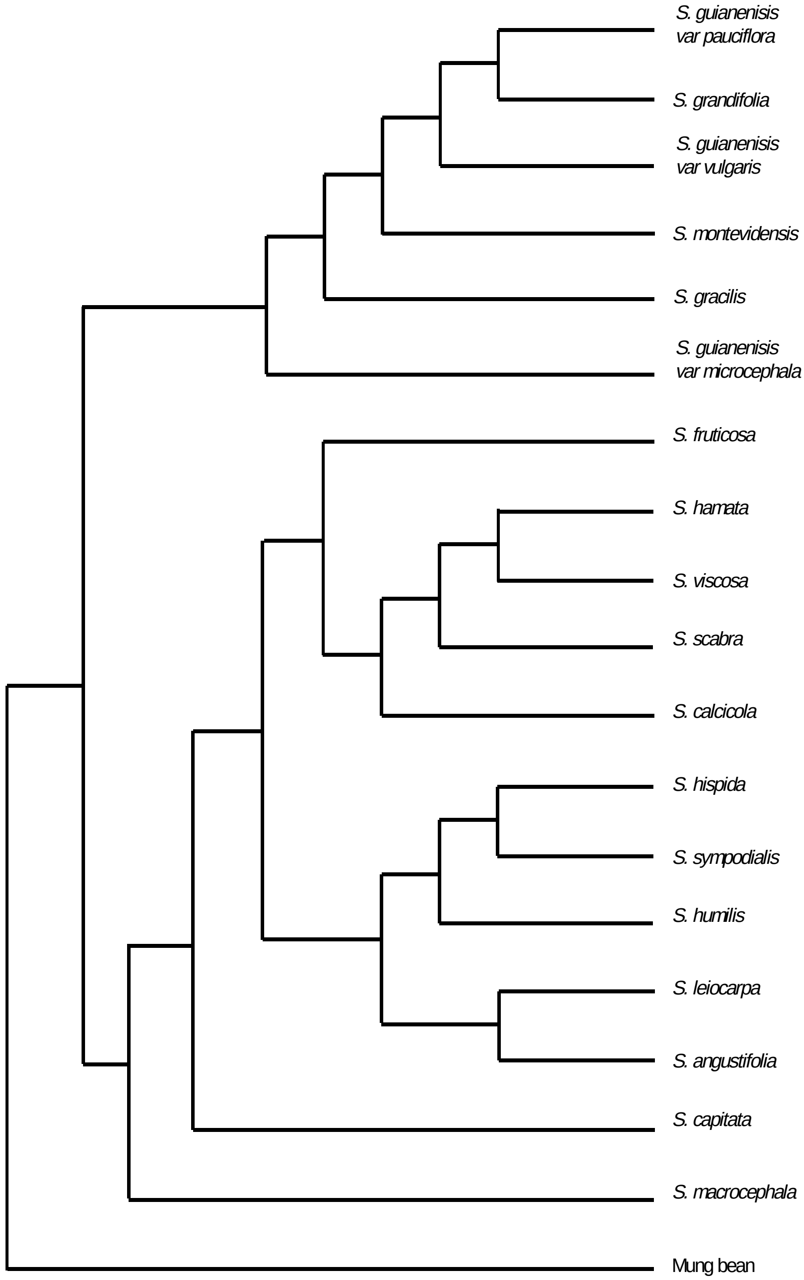
Figure 3. *Intraspecific variation for cloraplast DNA digested with EcoRI and probed with MB2. There was a single length mutation in one accession of* S. Scabra *(arrow), but no variation was evident in* S. capitata.



A between- and within-accessional investigation similar to that for cpDNA showed variation for repeat length both between and within accessions (not shown). All other bands, were uniform.

A phenetic clustering analysis using the rDNA data did not resolve differences between taxa as, despite extensive repeat length variation, the banding patterns were too similar. This analysis involved comparison of taxa for all bands present to produce genetic distances as described by Nei (1987) and was conducted using the programme RESTSITE (Miller, 1991). A phenogram produced by UPGMA (unweighted pair group method using

Figure 4. *Evolutionary relationships derived for* Stylosanthes *from chloroplast DNA data using PAUP. This tree is the strict consensus of twelve equally parsimonious trees from one analysis using the "Branch & Bound" approach and Fitch Parsimony. The tree has a consistency index of 0.49 and is 299 steps in length.*



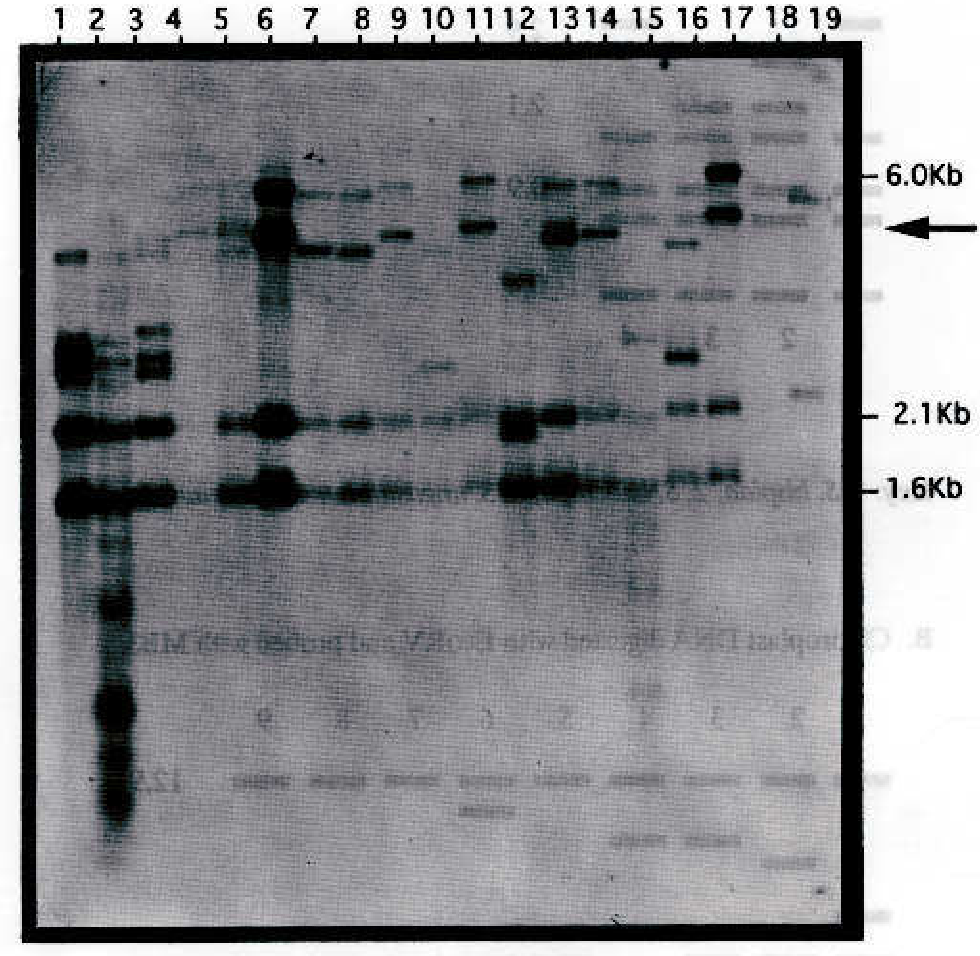
arithmetic averages) of the genetic distances clustered all species, except *Stylosanthes grandiflora*, together (results not shown).

Taxon-specific rDNA fragments and patterns were identified and are listed in Table 2, with some of these patterns illustrated in Figure 6.

Table 2. *Taxon-specific fragments identified as possible species markers. Markers consist of either (i) the presence of single unique bands, (ii) a unique banding pattern or (iii) the absence of single bands. Unique patterns are illustrated in Figure 6.*

Taxon	Probe/Enzyme combination	Unique bands (Kb)	Whole pattern unique (Kb)	Absent fragments (Kb)
S. hispida	MB3/BscI	2.6	–	4.6
	MB3/EcoRI	2.4	–	–
	MB3/EcoRV	–	+	–
	MB2/EcoRI	2.3.	–	–
	MB11 & 12/BscI	5.9	–	–
	MB1/BgIII	–	+	–
S. hamata	MB5&7/HaeIII	3.8	–	3.0
	MB5&7/BscI	2.5, 1.7	–	3.9
	MB3/Bam HI	5.2	–	–
	MB3/EcoRV	–	+	–
	MB9/BamHI	3.3	–	–
S. guianensis var *vulgaris*	MB11&12/EcoRV	3.0	–	–
	MB1/EcorV	0.7	–	–
	MB3/EcoRV	–	+	–
S. fruticosa	pTA71/EcoRV	2.9	–	–
	MB3/EcoRV	–	+	–
S. grandifolia	MB3/Hinfl	1.6	–	–
	pTAZ1/HaeIII	1.06	–	–
S. angustifolia	pTA71/HaeIII	–	–	1.03
	pTA71/ApaI	2.1	–	–
	MB5&7/HinDIII	–	–	6.5
	MBI/BgIII	–	+	–
	MB3/EcoRV	–	+	–
S. sympodialis	pTA71/BamHI	2.0	–	–
	pTA71/ApaI	2.7	–	–
	MB3/EcoRV	–	+	–
S. humilis	pTA71/BamHI	1.9	–	–
	MB3/EcoRV	–	+	–
S. leiocarpa	pTA71/BamHI	2.2	–	–
	MB1/BgIII	–	+	–
	MB3/EcoRV	–	+	–
S. montevidensis	pTA71/BamHI	3.0	–	–
	MB9/EcoRI	4.0	–	–
S. calcicola	MB3/EcoRI	–	–	3.6
	MB3/EcoRV	–	–	–
	MB1/BamHI	5.2	–	–
S. capitata	MB5&7/SacI	11.0	–	–
	MB1/BgIII	–	+	–
S. gracilis	MB3/EcoRV	–	+	–
S. viscosa	MB3/EcoRV	–	+	–
S. macrocephala	MB3/EcoRV	–	+	–
S. scabra	MB3/EcoRV	–	+	–

Figure 5. Stylosanthes *ribosomal DNA digested with SacI and probed with pTA71. Note the variation for repeat length between and within individuals (arrows). From left to right:* S. guianensis *var* pauciflora, S. guianensis *var* vulgaris, S. grandifolia, S. fruticosa, S. hispida, S. hamata, S. sympodialis, S. humilis, S. calcicola, S. gracilis, S. leiocarpa, S. angustifolia, S. viscosa, S. macrocephala, S. guianensis *var* microcephala, S. montevidensis, S. scabra, S. capitata, *mung bean outgroup.*



Discussion

Phylogenetic analysis

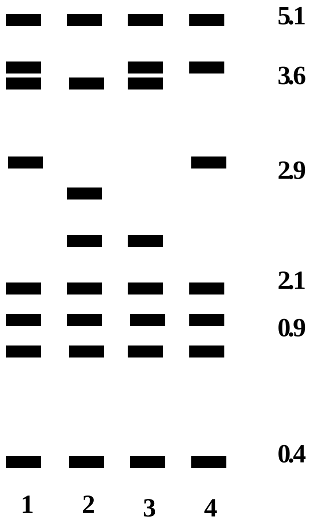
The phylogenetic tree produced by PAUP from the chloroplast DNA fragment data generally corresponds well with known species divisions and evolutionary relationships within this genus. The tree can be subdivided into four clusters for ease of discussion; (i) the *Stylosanthes guianensis* complex and related species, (ii) the *S. fruticosa – S. calcicola* cluster, (iii) the *S. hispida – S. angustifolia* cluster and (iv) *S. capitata* and *S. macrocephala*.

The *S. guianensis* complex and related species

The cluster which comprises the *Stylosanthes guianensis* complex and its related species (namely, *S. gracilis, S. grandifolia* and *S. montevidensis*) is clearly separate from the rest of the genus. It appears to have split away early in the evolutionary history of *Stylosanthes* and may be its basal group.

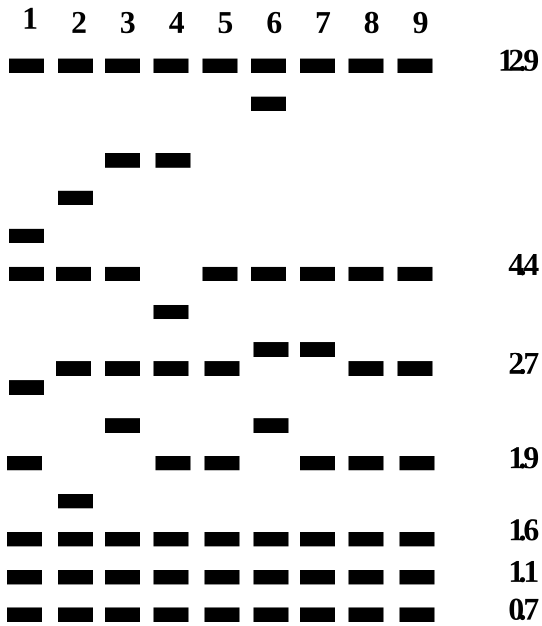
Figure 6. *Taxon-specific banding patterns identified as markers.*

A. Chloroplast DNA digested with BglII and probed with MB1.



Key: 1. *S. hispida*, 2. *S. leiocarpa*, 3. *S. angustifolia*, 4. *S. capitata*.

B. Chloroplast DNA digested with EcoRV and probed with MB3.



Key: 1. *S. guianensis* var *vulgaris*, 2. *S. fruticosa*, 3. *S. hispida*, 4. *S. hamata*, 5. *S. calcicola*, 6. *S. leiocarpa*, 7. *S. angustifolia*, 8. *S. viscosa*, 9. *S. scabra*

Stylosanthes guianensis is the most widely distributed species in the genus (t'Mannetje, 1977) and consists of a number of varieties. The confusion and controversy over the naming of these varieties was compounded by the revision of Mohlenbrock (1957) that combined all taxa into var *guianensis* and var *dissitiflora* despite their wide geographic distribution (t'Mannetje, 1969). This work has long since been rejected but there are still disagreements between the two opposing theories for naming the complex (Table 3).

Table 3. *The two opposing theories for naming of taxa in the* S. guianensis *complex (after t'Mannetje, 1984).*

t'Mannetje	Ferreira and Costa
S. guianensis	var *vulgaris*
var *guianensis*	*S. guianensis* var *canescens*
	var *microcephala*
var *gracilis*	*S. gracilis*
var *intermedia*	*S. campestris, S. hippocampoides*
var *robusta*	*S. grandifolia, S. aurea*
var *marginata*	*S. acuminata*
var *longiseta*	*S. longiseta*
var *dissitiflora*	

From the present phylogenetic analysis it appears that *Stylosanthes guianensis* var *microcephala* is the oldest member of the complex. *Stylosanthes guianensis* var *pauciflora* is of most recent origin with *S. grandifolia*, and *S. guianensis* var *vulgaris* is intermediate.

Stylosanthes grandiflora and *S. gracilis* have been changed to vars *robusta* and *gracilis*, respectively, by t'Mannetje (1984) because of their morphological similarities. This analysis supports a close relationship between these two taxa and the *S. guianensis* complex, but this may not be enough to warrant a change to the variety level. *Stylosanthes montevidensis*, which clusters in the same clade, is known to be related to the *S. giuanensis* complex (t'Mannetje, 1977). Vogel described *S. guianensis* var *intermedia* as a variety of *S. montevidensis* in 1838 and Mohlenbrock, transferred *S. guianensis* var *rostrata* to *S. montevidensis* in 1957 (t'Mannetje, 1977). There has been no suggestion, as yet, to reduce *S. montevidensis* to another subspecies in the *guianensis* complex.

Seed from *Stylosanthes campestris* and *S. acuminata* have recently been acquired from CIAT. As t'Mannetje considers that these should also be changed to subspecies of *S. guianensis*, future RFLP analyses will determine how they fit with existing data.

Recent work by Kazan, Manners and Cameron (personal communication; CSIRO, Cunningham Laboratory, 306 Carmody Road, St. Lucia, Queensland 4076, Australia), involving analysis of random amplified polymorphic DNA produced by the polymerase chain reaction (PCR), has looked at the *Stylosanthes guianensis* complex. Their study showed that the degree of differentiation between the subspecies was similar to that found between other species in the genus and they have concluded that the taxa should be treated as different species, thus supporting the divisions made by Ferreira and Costa (1979) based on morphological characters.

The *S. fruticosa* – *S. calcicola* cluster

The species in this cluster, namely *Stylosanthes fruticosa, S. hamata, S. viscosa, S. scabra* and *S. calcicola*, have been grouped together by other workers considering various aspects of phenetics within the genus (t'Mannetje, 1969; Burt et al, 1971; Robinson and Megarrity, 1975).

Stylosanthes fruticosa, the African species of *Stylosanthes,* is morphologically similar to *S. scabra*, a predominantly South American species. t'Mannetje (1984) has argued that based on morphology alone these two species cannot be clearly distinguished and should be considered as the same. Present data suggest that *S. fruticosa* is the oldest member of this cluster and that *S. scabra* evolved at a later date. Although there is some relationship between them (they cluster in the same part of the tree), it is not a close one. As the two taxa are not sister to each other, these data suggest that merging them into one species is questionable.

Based on morphological characters, t'Mannetje (1969) has grouped *Stylosanthes hamata* and *S. humilis*as sister taxa with *S. viscosa*, the next most closely related species. Data reported here indicate no close relationship between *S. humilis* and diploid *S. hamata* but indicate that *S. viscosa* and *S. hamata* are sister taxa.

It has been suggested that *Stylosanthes scabra* and *S. hamata* are closely related and hybrids formed from crosses between them have some fertility (Stace, 1982). However, the widely differing ADH patterns obtained for both species (Stace and Cameron, 1987) suggest that this interpretation should be treated with caution.

Results from work based on numerical pattern analysis of morphological and agronomic (M.A.) characters group *Stylosanthes scabra* and *S. viscosa* together (Burt et al, 1971) and support the relationship described by current data. A seed protein analysis performed by Robinson and Megarrity (1975) groups *S. calcicola* with *S. hamata* and *S. viscosa*, which also supports the relationships described in this report.

The *S. hispida – S. angustifolia* cluster

Stylosanthes sympodialis has resolved as a sister taxon for *S. humilis*, i.e. they are linked tightly together in this cluster (Figure 2), and are thus closely related. *S. hispida* groups with these two species and *S. leiocarpa* clusters closely with *S. angustifolia*. There has been nothing noted on relationships between these species in existing taxonomic analyses. The validity of other data in the present tree indicates that these relationships are also significant but further work (expanding the data set) will have to be done to confirm them.

S. capitata* and *S. macrocephala

t'Mannetje has suggested that *Stylosanthes macrocephala* and *S. capitata* are closely related (Lewis, 1987) as they are morphologically similar. The two species are considerably different in this analysis and, based on this molecular data, are not closely related to any other species in the genus.

Although DNA analysis is a powerful tool in studies of this sort it must be remembered that it does not provide the final answer to all taxonomic problems. It is merely another source of characters to be considered alongside the many others. The low level of intraspecific variation resolved means that selecting one accession to represent a taxon may be unsatisfactory. Further expansion of the number of accessions per taxon in the survey will be necessary.

Species markers

At this stage in the study it is possible to distinguish most taxa by either rDNA or cpDNA fragments from particular probe/enzyme combinations. Markers consist of the presence of unique bands, the absence of bands that are present in all other taxa and the occurrence of a complete banding pattern that is not present in any other taxa for that probe/enzyme combination. Continued expansion of the data set is required in order to confirm these markers as taxon-specific.

Molecular markers of this sort are necessary in an agronomically important genus, like *Stylosanthes,* with high levels of morphological variation for the identification of unknown taxa. The markers will be further used to identify parents of the polyploid species in Section *Styposanthes*. For example, it has been suggested that *Stylosanthes viscosa* is one of the parents of *S. scabra* (Stace and Cameron, 1984). Analysis of molecular markers will either confirm or reject this.

Determination of the mode of plastid transmission will be essential in the identification of hybrid parents. Kazan, Manners and Cameron (personal communication) have some evidence to suggest that inheritance in *Stylosanthes* is maternal. This information will be useful in determining the maternal and paternal parents of the hybrids. The technique of PCR-RAPDs (Random Amplified Polymorphic DNA) is currently being developed in this lab to further the development of taxon-specific markers. Kazan, Manners and Cameron (personal communication) are already making good progress with this technique for producing RAPD markers to be used in future plant breeding programmes.

Conclusions

This preliminary study of chloroplast DNA and ribosomal DNA variation in *Stylosanthes* is the first such use of this molecular approach to consider evolutionary relations and species divisions within the genus. The few relations already described, mostly from morphological analyses, support the results found in this study and indicate the validity of this molecular approach as a tool for taxonomic analysis at the species level. It is hoped that this form of RFLP analysis will be of use in achieving a greater understanding of species classification in this difficult genus, where species are morphologically very similar.

To summarise results from the phylogenetic analysis, the *Stylosanthes guianensis* complex and its related species are clearly distinct from the rest of the genus. *Stylosanthes fruticosa, S. hamata, S. viscosa, S. scabra* and *S. calcicola* form one cluster whilst *S. hispida, S. sympodialis, S. humilis, S. leiocarpa* and *S. angustifolia* form another. *Stylosanthes capitata* and *S. macrocephala* are not closely related to any other species.

Taxon-specific markers have been identified. These will be of use in the identification of parents of the polyploid species and the naming of unknown taxa. They will also be helpful in future plant breeding programmes.

Acknowledgements

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Genetic resources of *Stylosanthes* species

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Abstract

The genus *Stylosanthes* contains about 30 species of which most are native to South and Central America, except for *S. erecta* and *S. fruticosa* which are native to Africa. The seven major species that have been used as livestock feed have been widely collected and their germplasm stored in genebanks. Currently ILCA, CIAT and CSIRO hold about 4000 distinct accessions of *Stylosanthes* species in their genebanks. The available germplasm shows considerable variability in adaptation to agro-ecological zones and soil pH. This germplasm is available free of charge for use in forage research and development programmes, but only about 25% has been screened for adaptability as an animal feed in West Africa. Several accessions have been identified as promising and have been incorporated into fodder banks for protein supplementation of livestock feeds. There is considerable potential for further selection and use of this valuable germplasm as part of sustainable crop–livestock systems in sub-Saharan Africa.

Ressources génétiques des espèces de *Stylosanthes*

Résumé

Le genre Stylosanthes *comprend plus de 30 espèces pour la plupart originaires d'Amérique du Sud et d'Amérique centrale excepté* S. erecta *et* S. fruticosa *qui sont originaires d'Afrique. Une vaste collection de matériel génétique des sept principales espèces utilisées dans l'alimentation du bétail est conservée dans des banques de gènes. Ainsi, le CIPEA, le CIAT et le CSIRO détiennent aujourd'hui quelque 4 000 acquisitions de* Stylosanthes. *Ce matériel génétique adapté à de nombreuses zones agro-écologiques et à des pH du sol extrêmement variés peut être obtenu gratuitement pour des programmes de recherche-développement agrostologique. 25% de ce matériel a été évalué dans l'alimentation du bétail en Afrique de l'Ouest. Plusieurs acquisitions identifiées comme prometteuses ont été introduites dans des banques fourragères comme source de complément protéique des aliments du bétail. Beaucoup reste encore à faire en matière de sélection et d'utilisation de ce précieux matériel pour promouvoir des systèmes mixtes durables en Afrique subsaharienne.*

Introduction

Stylosanthes is an important forage legume that has been widely used for livestock feed. The genus contains about 30 species, but most research programmes have concentrated on a fairly narrow range of germplasm and species. Most species are native to South and Central America, including the Caribbean, except for *S. fruticosa* and *S. erecta*, which have their centre of origin in Africa. Interest in *Stylosanthes,* which began about 70 years ago, was stimulated by the species *S. humilis* and *S. guianensis* due to their adaptability to drought and low fertility acid soils and their persistence in pastures.

The use of *Stylosanthes* as a forage legume in Africa increased in the 1960s when several new improved cultivars, developed in Australia, were introduced into West Africa. The germplasm used to develop these cultivars came from a very narrow genetic base. For example, the germplasm used to develop *S. guianensis* cultivar Schofield originally came from one accession collected in Brazil. To widen the genetic base of the breeding material, the Centro Internacional Agricultura Tropical (CIAT) commenced collection and evaluation in 1972 (Schultze-Kraft et al, 1984).

Early research in West Africa was based on the cultivars of *S. hamata*, *S. guianensis* and *S. humilis* to select material with improved feed quality during the dry season (Agishi and de Leeuw, 1986). As new germplasm became available, additional accessions were introduced and evaluated. However, the *S. guianensis* cultivars Cook and Schofield and *S. hamata* cultivar Verano have remained the most widely used germplasm in the region.

These early cultivars proved susceptible to anthracnose and additional germplasm was evaluated to identify accessions with resistance to this major disease. Research at CIAT has focused on the identification of anthracnose tolerant accessions of *S. guianensis*; some accessions which showed a degree of tolerance were identified. These were introduced for testing in the International Livestock Centre for Africa (ILCA) subhumid zone programme in Kaduna in 1987 and although all but two accessions showed symptoms, several were able to maintain growth (Mohamed-Saleem and Adeoti, 1989).

Available germplasm for selection

A wide pool of germplasm is essential for characterisation, evaluation and selection of accessions showing adaptation to disease and environment. Early collections (Schultze-Kraft et al, 1984) focused mainly on *S. guianensis* and *S. scabra*, with fewer accessions of *S. hamata* and *S. humilis*. Collections in 1986 by the Commonwealth Scientific and Industrial Research Organization (CSIRO) in collaboration with CIAT and with additional funds from ILCA concentrated on *S. hamata* in Colombia and Venezuela. ILCA has also collected *S. fruticosa* in Africa. Currently major germplasm collections of *Stylosanthes* are held by two International Agricultural Research Centres working with tropical forages, CIAT and ILCA, and by one national institute, CSIRO (Table 1). These collections cover a wide range of species within the genus, although the largest number of accessions are from those species of interest as livestock feed.

Storage and dissemination

The seeds held in the genebanks of these three centres are stored in suitable storage conditions to maintain their viability and are available for distribution to scientists wishing to utilise them. The germplasm at ILCA is stored in the active collection. Seeds are dried to about 5% moisture content, sealed in laminated aluminium foil packets and stored at temperatures of 8℃. CIAT maintains its germplasm in medium-term storage under conditions of 50% relative humidity and 5–8℃. However, much of their germplasm is now being stored under long-term conditions of 5–7% moisture content at between –10 and –20℃ (Schultze-Kraft and Toledo, 1990). The CSIRO collection is maintained in medium-term storage under conditions of 25% relative humidity at 5℃ at Samford. In addition, seeds are stored in the long-term store in Canberra at low moisture contents and –20℃ (Williams, 1990).

Considerable duplication of accessions exists between ILCA, CIAT and CSIRO, but it is estimated that over 4000 distinct accessions are held among them. Duplication of accessions is important to avoid loss of germplasm and also to ensure adequate distribution of material for utilisation.

Table 1. *Collections of* Stylosanthes *at CIAT, CSIRO and ILCA.*

Species	Number of accessions stored		
	CIAT	CSIRO	ILCA
S. acuminata	3	7	
S. angustifolia	31	2	
S. aurea	1	2	
S. biflora	6	3	
S. bracteata	1	3	
S. campestris	1	22	
S. calcicola	14	122	1
S. capitata	304		49
S. cayennensis	1		
S. erecta	2		
S. fruticosa	55	176	201
S. grandifolia	4	13	
S. guianensis	1528	552	224
S. hamata	160	485	285
S. humilis	219	188	40
S. ingrata		10	1
S. leiocarpa	41	25	2
S. macrocarpa		1	5
S. macrocephala	111	108	42
S. mexicana	1	16	2
S. montevidensis	8	14	1
S. pilosa	13	10	
S. scabra	745	382	164
S. sp	35	36	3
S. subsericea	3		
S. sympodialis	9	14	
S. viscosa	265	109	107
Total	3561	2300	1127

The ILCA genebank distributes small quantities of seeds free of charge to forage research and development workers for evaluation and utilisation. Over 250 accessions from all major species have been distributed in response to 59 requests from national agricultural research systems (NARS) in West Africa. In addition, over 700 accessions have been distributed to ILCA zonal research programmes in the region for evaluation of agronomic potential, nutritional quality and adaptability for use as animal feeds (Table 2).

Ecological adaptation and variation

Of the 30 species held in genebanks, only seven have been widely evaluated and utilised. The accessions collected come from several countries in their centres of origin and are adapted to a wide range of environmental conditions and agro-ecological zones (Table 3). The environmental adaptation of these accessions will determine the areas in which they can be used. The major information used in selecting accessions for evaluation in different agroclimatic zones is rainfall, temperature (altitude) and soil pH (Table 4). Soil pH data are only available for a limited number of accessions. However, most germplasm was collected from the low pH and high aluminium soils with low organic matter and fertility found in much of Central and South America.

Table 2. *Number of accessions of the major species evaluated in ILCA zonal research programmes in West Africa.*

Species	Semi-arid (Niger)	Semi-arid (Mali)	Subhumid	Humid	Total
S. capitata	0	6	10	0	16
S. fruticosa	11	0	18	2	31
S. guianensis	6	12	145	6	169
S. hamata	3	8	447	2	460
S. humilis	0	5	9	0	14
S. macrocephala	0	1	3	0	4
S. scabra	0	5	18	8	31
S. viscosa	0	0	0	2	2

Table 3. *Number of accessions of major species of* Stylosanthes *collected in agro-ecological zones and stored in the ILCA and CIAT genebanks.*

Species	Agro-ecological zone					
	Arid[1]	Semi-arid2	Sub humid[3]	Humid4	Unknown	Total
S. capitata	1	32	86	70	119	308
S. fruticosa,	2	55	78	2	84	221
*S. guianensis**	0	46	380	675	444	1545
S. hamata	68	127	76	25	125	421
S. humilis	3	22	64	66	72	227
S. scabra	12	154	257	223	135	781
S. viscosa	4	48	125	60	38	275

* Includes *S. gracilis*.

1. Arid zone: growing period < 75 days, < 500 mm rainfall per annum.

2. Semi-arid zone: growing period 75–180 days, 500 to 1000 mm rainfall per annum.

3. Subhumid zone: growing period 180–270 days, 1000 to 1500 mm rainfall per annum.

4. Humid zone: growing period > 270 days, > 1500 mm rainfall per annum.

Table 4. *Range of rainfall, altitude and soil pH of the collections of major* Stylosanthes *species in the ILCA and CIAT genebanks.*

Species	Rainfall (mm)	Altitude (m)	Soil pH
S. capitata	190–2150	50–1220	4.3–6.2
S. fruticosa	382–1580	10–2080	4.5–8.0
*S. guianensis**	635–9050	5–2000	4.5–5.8
S. hamata	310–2500	2–1600	5.4–8.5
S. humilis	410–4030	10–1000	5.1–5.3
S. scabra	400–2890	5–1660	4.0–5.8
S. viscosa	230–3200	5–1200	4.0–6.5

* Includes *S. gracilis*.

S. capitata, S. viscosa and *S. humilis* have been collected mainly from Brazil and Venezuela over a wide range of climatic conditions at lower altitudes in semi-arid to humid areas. *S. humilis* shows high survival over a long dry season due to being a heavy seeding annual species. The three species are well adapted to extremely acid soils with high aluminium content. *S. capitata* is well adapted to dry, sandy acid soils and plants may fail to nodulate on more alkaline soils. *S. humilis* is very susceptible to anthracnose, but *S. capitata* is more resistant and several highly resistant accessions have been selected.

S. guianensis, which includes *S. gracilis* following the classification of t'Mannetje (1984), and *S. scabra* collections were made in Brazil, Colombia and Venezuela, mostly from low to middle altitudes in subhumid to humid regions. Some accessions of *S. guianensis* have been collected from altitudes as high as 2000 m in the Andes of Colombia. These two species are represented in genebanks by large numbers of accessions and have been widely evaluated and used to develop a considerable number of important commercial cultivars. Cook, Schofield, Graham and Endeavour cultivars were developed from *S. guianensis* var *guianensis*, whilst Oxley cultivar was developed from var *intermedia*. Seca and Fitzroy cultivars were selected from *S. scabra* (Skerman et al, 1988).

S. hamata occurs mostly in coastal regions around the Caribbean and major collection missions have focused on Antigua, Colombia and Venezuela. It is a lowland species and very few samples have been collected above 500 m. This is the most drought-resistant species of *Stylosanthes* and germplasm has been found growing in areas with an annual rainfall as low as 300 mm in Venezuela. It also shows tolerance to anthracnose.

S. fruticosa is the only major African species of *Stylosanthes* that has been widely collected. Most of the germplasm at ILCA comes from the middle altitude semi-arid and subhumid areas of Ethiopia. The species has not been widely evaluated, mainly due to its susceptibility to anthracnose, although germplasm at ILCA was characterised by Hakiza et al (1988). This species is very drought-tolerant and is being evaluated by ILCA for use as livestock feed in semi-arid areas of West Africa, although its out-crossing nature makes maintenance of distinct accessions difficult.

Initial evaluation in ILCA zonal programmes

Most of the initial evaluation by ILCA zonal programmes has been done in the subhumid and semi-arid areas. ILCA began evaluating germplasm of *Stylosanthes* in 1982 using *S. guianensis, S. capitata* and *S. macrocephala* at Kaduna in the subhumid zone of Nigeria. Yields of over seven tonnes total dry matter were recorded for three accessions of *S. guianensis* and over four tonnes for one accession each of *S. macrocephala* and *S. capitata* (Mohamed-Saleem and Otsyina, 1984). From these results *S. guianensis* looked very promising and a wider range of germplasm of this and *S. hamata* was introduced in 1985. Despite these promising yields, anthracnose was identified as a major constraint to the use of *S. guianensis* in the subhumid zone and over 130 accessions were then screened for resistance to this important disease (ILCA, 1988). A further 15 accessions, that had been identified as showing some resistance to the disease by CIAT, were introduced in 1987 and tested in this programme.

Screening in the semi-arid zone began in 1986 in Mali with a limited range of accessions of the major *Stylosanthes* species. *S. hamata* was identified as a useful species for fodder banks in semi-arid areas and had a significant effect on the grain yield of the subsequent crop (ILCA, 1990). This was followed by screening a representative number of accessions of *S. fruticosa* from the ILCA genebank and some germplasm collected locally in 1989 in Niger. The results from these studies indicated that *S. fruticosa* could be successfully intercropped with millet (ILCA, 1992).

Future opportunities

Only about 25% of the available biodiversity within the species stored in the genebanks at ILCA and at CIAT has been evaluated in West Africa. There is obviously the possibility to study more of the existing germplasm to identify superior accessions for development as animal feeds. However, insufficient seeds of many accessions stored in genebanks has been a major constraint to the evaluation and subsequent use of germplasm (Lazier, 1984). In addition, there is a need to collect germplasm from the centres of origin to further broaden the genetic base and seek specific traits such as resistance to anthracnose or other important diseases or pests.

There is also the opportunity to incorporate new germplasm from other species into the farming system in the area. Most of the work on fodder banks has relied on *S. hamata* which is well adapted to the region. However, species diversification in fodder banks is essential to prevent widescale losses of forage due to disease. There is also the opportunity to select promising germplasm for incorporation into other farming systems in West Africa. Smallholder dairy production is gaining more importance in the region and *Stylosanthes* species could be considered for use as high protein forage for dairy animals. The incorporation of *Stylosanthes* would also contribute to soil fertility as part of a sustainable crop-livestock farming system.

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Screening *Stylosanthes* in Latin America: The CIAT-RIEPT experience

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Abstract

A large collection of more than 3500 accessions of *Stylosanthes* germplasm has been assembled at CIAT. A considerable proportion was screened, in co-operation with the regional research system RIEPT, in the subhumid savannah region and the humid tropics of Latin America for adaptation to the prevailing acid, low-fertility soils and for resistance to anthracnose.

In both the isohyperthermic and isothermic savannahs (the *Llanos* in Colombia and Venezuela and the *Cerrados* in Brazil, respectively), *S. capitata* and *S. guianensis* var *pauciflora* are the best adapted to the soil and they exhibit the highest disease tolerance. In Colombia, *S. capitata* cv Capica was released and *S. guianensis* cv Bandeirante was released in Brazil. Another acid-soil adapted species is *S. macrocephala* (cv Pioneiro) in Brazil. However, it flowers too early and is not sufficiently persistent. In the humid tropics, some anthracnose-tolerant lines within the "common" forms of *S. guianensis* were identified; in Peru *S. guianensis* CIAT 184 was released as cv Pucallpa. Screening of the large collections of *S. scabra* and *S. viscosa* has not resulted in the identification of accessions with sufficient disease and insect tolerance.

Evaluation du *Stylosanthes* en Amérique latine: l'expérience conjointe CIAT-RIEPT

Résumé

Le CIAT détient une vaste collection de matériel génétique de Stylosanthes *comprenant plus de 3 500 acquisitions. Une bonne partie de ce matériel a été évaluée en coopération avec le RIEPT, une institution régionale de recherche. Effectué dans la savane subhumide et les régions tropicales humides d'Amérique latine, ce programme était destiné à évaluer l'adaptation de* Stylosanthes *aux sols acides pauvres fréquents dans ces régions et la résistance à l'anthracnose.*

Que ce soit dans la savane isohyperthermique — les Llanos de Colombie et du Venezuela — ou dans la savane isothermique — les Cerrados du Brésil, S. capitata *et* S. guianensis *var. pauciflora ont démontré une plus grande adaptation aux sols acides et une meilleure résistance à l'anthracnose. Ainsi,* S. capitata *cv. Capica et* S. guianensis *cv. Bandeirante ont été vulgarisés respectivement en Colombie et au Brésil. Quant à* S. macrocephala *(cv. Pioneiro), il était également adapté aux sols acides au Brésil mais fleurissait précocement et était peu persistant. Dans les régions tropicales humides, certaines lignées résistantes à l'anthracnose ont été identifiées parmi les variétés "courantes" de* S. guianensis*; au Pérou, l'acquisition CIAT 184 de* S. guianensis *a été vulgarisée sous forme de cv. Pucallpa. Enfin, l'évaluation*

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d'une vaste collection de S. scabra *et de* S. viscosa *n'a permis d'identifier aucune acquisition suffisamment résistante aux maladies et aux insectes pour susciter de l'intérêt.*

Introduction

Stylosanthes research in Latin America has a history of about 50 years and concentrated initially on Brazil. The first published work dates back to the comprehensive forage plant investigations in the (now) Rio de Janeiro State (Otero, 1952). Later, significant work was done by the Instituto de Pesquisas IRI (the former IBEC Research Institute) at Matao, Sao Paulo State. It led to the development of a commercial *Stylosanthes guianensis* cultivar (IRI 1022) in the 1960s (Shock et al, 1979). In other Latin American countries, earlier *Stylosanthes* research was essentially limited to including one or two Australian lines or cultivars in general legume evaluation, e.g. in the 1950s in Colombia (Crowder et al, 1958). It is interesting to note that some of this early work referred to key topics that have dominated Latin American *Stylosanthes* research from the 1970s, i.e. anthracnose (Otero, 1952) and germplasm collection (Hymowitz, 1971; Shock et al, 1979).

From 1972, research on *Stylosanthes* has been a major component of the work at the Centro Internacional de Agricultura Tropical (CIAT), Colombia, within the objective of its Beef Production Program (later renamed Tropical Pastures Program) to develop low-input, legume-based pasture technology for acid, infertile soil regions of the lowland tropics in Latin America. From the very beginning, anthracnose was identified as the major constraint to *Stylosanthes* potential, and the necessity to build up a large *Stylosanthes* germplasm base was recognised. This led to comprehensive germplasm collection missions throughout Latin America from 1973 and to the corresponding screening and evaluation work.

In 1979, the International Tropical Pastures Evaluation Network (RIEPT[2)], was created as a cooperative research and communication system covering most Latin American countries. The regional trials system of this network is closely connected with CIAT's germplasm evaluation at major screening sites (Toledo et al, 1989). Therefore, essentially all *Stylosanthes* developments during the past 15 years in Latin America are the result of cooperative CIAT-RIEPT research endeavours.

Species distribution and germplasm collection

Stylosanthes has a wide distribution in Latin America. Almost all species originate in the New World; only four out of the 35–40 recognised species are native to Africa (*S. erecta*, *S. fruticosa* and *S. suborbiculata*) and Asia (*S. fruticosa* and *S. sundaica*) (Williams et al, 1984). The major species diversity can be found in Brazil and the major *S. guianensis* variability is found in Colombia.

Activities to collect *Stylosanthes* germplasm began in the late 1940s and were undertaken mainly by Australian scientists during the 1960s and early 1970s. In 1973, a period of intensive germplasm collection throughout Latin America was initiated by CIAT and collaborating national research organisations (Schultze-Kraft et al, 1984a). As a result, CIAT now holds a very large and diverse *Stylosanthes* collection with a total of 3500–4000 accessions representing 29 distinct species (Table 1).

This collection is the world's largest germplasm collection of a tropical forage legume in terms of number of accessions. In other major germplasm centres such as the Australian Tropical Forage Genetic Resource Centre (ATFGRC) of the Commonwealth Scientific and Industrial Research Organisation (CSIRO), Brisbane, Australia, and the International Livestock Centre for Africa (ILCA), Addis Ababa, Ethiopia, the numbers of *Stylosanthes*

2. RIEPT = Red Internacional de Evaluación de Pastos Tropicales.

Table 1. Stylosanthes *germplasm in the CIAT collection, 30 September 1992.*

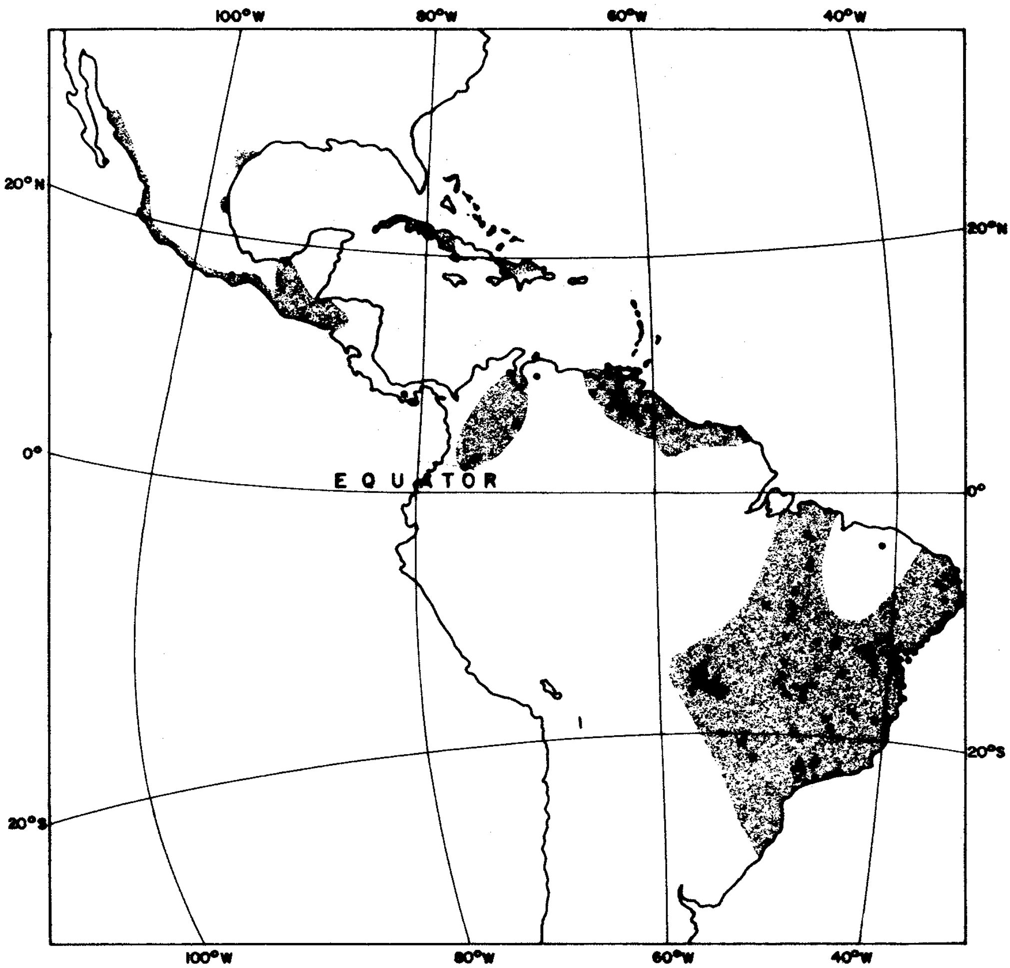
Species	No. of accessions		
	Registered	Conserved	Multiplied for distribution
S. acuminata	3	3	1
S. angustifolia	34	31	15
S. aurea	1	1	0
S. biflora	7	6	0
S. bracteata	5	1	0
S. calcicola	14	14	13
S. campestris	1	1	1
S. capitata	331	304	304
S. cayennensis	1	1	1
S. erecta	2	2	1
S. fruticosa	68	55	13
S. gracilis	139	132	87
S. grandiflora	5	4	3
S. guianensis	1583	1400	1019
S. hamata	183	161	121
S. hippocampoides	3	0	0
S. humilis	271	217	161
S. leiocarpa	42	41	32
S. linearifolia	1	0	0
S. macrocarpa	1	0	0
S. macrocephala	132	127	127
S. mexicana	1	1	1
S. montevidensis	13	8	6
S. pilosa	18	16	12
S. ruellioides	1	1	0
S. scabra	790	746	633
S. subsericea	6	3	3
S. sympodialis	10	9	9
S. viscosa	278	266	207
S. spp (unidentified)	87	34	33
Total	4031	3585	2803

accessions top those of all other tropical forage genera (B. Pengelly and J. Hanson, personal communication).

In Table 1 the large numbers of accessions in *S. guianensis, S. scabra, S. capitata, S. viscosa* and *S. humilis* are noteworthy. Within these species, the germplasm collections that are now available seem to adequately represent the known geographical distributions. As an example, in Figure 1, the natural distribution and original germplasm collection sites of *S. viscosa* are presented.

Figures in Table 1, however, also suggest that the large total number of accessions concentrates mainly on only 11 species with more than 20 accessions each. In 14 species less than five accessions are conserved. Finally, out of the 35–40 *Stylosanthes* species that are presently recognised (t'Mannetje, 1984; Ferreira and Costa, 1979), 25% are not even represented in the CIAT collection. Consequently, during the past 15 years *Stylosanthes* evaluation in Latin America was based only on a limited range of species but on very broad intraspecific collections.

Figure 1. *Natural distribution of* Stylosanthes viscosa *and locations of collection sites of germplasm accessions in the CIAT collection.*



Source: Keller-Grein and Schultze-Kraft (1992).

Evaluation strategies and evaluation environments

The major components of the strategy to evaluate and screen the *Stylosanthes* collection were:

1. Centralised characterisation, seed increase and preliminary evaluation (Category 1) of all new germplasm at CIAT–Quilichao, a research station close to the CIAT headquarters in Colombia. Plant characterisation and preliminary evaluation include a variable number of parameters ranging from growth habit to plant earliness and sometimes even to relative acceptability by cattle.

2. Agronomic evaluation of whole or core collections under exposure to environment-specific stresses (Category 2) at screening sites representing the three major agroclimatic zones of tropical America:

- ICA[3] Research Centre at Carimagua, Colombia: Tropical isohyperthermic savannahs (*Llanos*) in northern South America;

3. ICA = Instituto Colombiano Agropecuario.

- EMBRAPA–CPAC[4] Research Centre at Planaltina, Brazil: Tropical isothermic savannahs (*Cerrados*) in Brazil;
- INIPA–IVITA[5] Research Centre at Pucallpa, Peru: Colonisation zones in the Latin American humid tropics.

All these research sites are characterised by fairly high rainfall but severe dry seasons, and by very acid and highly aluminium-saturated, infertile Oxisols and Ultisols (Table 2).

At these sites, *Stylosanthes* germplasm was screened mainly for adaptation to soil and biotic stresses and for dry-season performance. Selected accessions were then tested within the regional trials network of RIEPT which extends throughout Latin America over a variable number of several dozen sites, from almost 23°N in Cuba to 27°S in southern Paraguay (Toledo et al, 1989).

Such multi-locational testing of germplasm essentially consisted of adaptation trials (Regional Trials A) and seasonal productivity trials (Regional Trials B). In the adaptation trials, evaluation of a relatively large number of entries is performed based on simple observations. The seasonal productivity trials have fewer entries and plant performance is assessed based on measurements and yield samplings. Evaluation methodologies are uniform throughout the network and results are pooled in a centralised RIEPT data base for subsequent multilocational analyses.

After agronomic evaluation and screening for tolerance to environment-specific stresses, production-system specific research was performed with selected *Stylosanthes* germplasm. This research consisted essentially of sward-productivity and legume-persistence trials with *Stylosanthes*/grass mixtures (Category 3, Regional Trials C) and, at a later stage, animal-production experiments on selected stylo/grass pastures (Category 4, Regional Trials D) (see Miles et al, pp. 27–35). At all evaluation stages research was accompanied by efforts to produce seed of the best-performing accessions.

Main biotic constraints

During the agronomic-evaluation stages and the subsequent production-system specific research and seed production, several biotic constraints in the form of diseases and insect pests were identified for *Stylosanthes* germplasm. The major constraints are anthracnose, rhizoctonia foliar blight, stem borer and bud worm.

Anthracnose

(*Colletotrichum gloeosporioides*). This fungal disease is, throughout all agroclimatic zones of the Latin American tropics, the major limiting biotic factor in all *Stylosanthes* species. However, significant ecosystem differences due to physiological races of the pathogen have been identified (Lenné, 1985). An important example is the difference between anthracnose resistance of *S. capitata* in the Colombian *Llanos* and in the Brazilian *Cerrados*. Whereas in Colombia as much as 94% of the collection was classified as resistant, in Brazil this was only true for 15% (Table 3).

Another important ecosystem effect is the anthracnose tolerance of many *S. guianensis* “common” genotypes in the humid tropics, in contrast with their susceptibility in the savannah ecosystems (the *Llanos* and *Cerrados*). Evidence suggests that in the humid tropics anthracnose infection does occur but remains latent mainly because of the presence of antagonistic bacteria and diurnal temperature fluctuations (Lenné, 1985). In general,

4. EMBRAPA–CPAC = Emperesa Brasileira de Pesquisa Agrpercuaria–Centro de Pesquisa Agropecuaria dos Cerrados.
5. INIPA–IVITA = Instituto Nacional de Investigacion Agropecuaria–Insituto Veterinaro de Investigaciones Tropicales y de Altura.

Table 2. *Climate and soil at major* Stylosanthes *screening sites in tropical America.*

Location	Altitude (m asl)	Mean temp. (^0C)	Mean precip. (mm/year)	No. of dry months	pH (H_2O)	OM (%)	P (ppm)	Al sat. (%)	Ca (meq/100g)	K
Quilichao, Colombia (tropical semi-evergreen seasonal montane forest— naturalised *Paspalum/Axonopus* grassland; Oxisol - Ultisol)	990	24	1800	2+ 2[1]	3.9	5.5	2.0	88	0.43	0.12
Carimagua, Colombia (tropical isohyperthermic savannah —"Llanos"; Oxisol)	150	27	1900	3–4	4.5	3.4	1.5	82	0.20	0.10
Planaltina, Brazil, (Tropical isothermic savannah —"Cerrados"; Oxisol)	1000	22	1550	5–6	5.0	3.6	1.3	85	0.30[2]	0.08
Pucallpa, Peru, (tropical semi-evergreen seasonal forest — humid tropics colonisation zone; Ultisol)	250	27	1770	3	4.4	1.0	2.0	81	0.72	0.08

1. Bimodal rainfall distribution.

2. Ca + Mg.

Table 3. *Field anthracnose screening of 121 accessions of* Stylosanthes capitata *in Colombia and Brazil.*

Country	Reaction to anthracnose	
	Resistant (%)	Susceptible (%)
Colombia (*Llanos*)	94.2	5.8
Brazil (*Cerrados*)	14.9	85.1

Source: Lenné (1985).

the best anthracnose tolerance has been found only in three *Stylosanthes* species, namely *S. capitata, S. guianensis* var *pauciflora* and *S. macrocephala*.

Rhizoctonia foliar blight *(Rhizoctonia sp)*

This fungal leaf disease has so far only been observed in *S. macrocephala* and only in the Colombian *Llanos*. Here, however, it had a devastating effect on 108 out of 111 accessions (CIAT, 1988).

Stem borer *(Caloptilia sp* — Lepidoptera*)*

The stem borer has been reported to severely affect the persistence of several *Stylosanthes* species, mainly *S. scabra* in the Colombian *Llanos* (Calderón, 1983; Thomas and Díaz, 1989). Symptoms appear on old plants and this makes germplasm evaluation for stem borer resistance somewhat difficult as the eventual effect of the pest can be confused with natural death of old plants.

Bud worm *(Stegasta bosquella* — Lepidoptera*)*

The bud worm can very significantly affect seed production of all *Stylosanthes* species in all agroclimatic zones.

It should be pointed out that *vis-à-vis* anthracnose, all other biotic constraints are, in general, considered to be of secondary importance in tropical America and have not therefore received major research attention.

Evaluated species

Most *Stylosanthes* germplasm in the CIAT collection has been evaluated within the CIAT screening system and, partly, the RIEPT network. This includes the whole collections of *S. guianensis, S. capitata, S. macrocephala, S. scabra* and *S. viscosa* and selected accessions of most of the other species.

Stylosanthes guianensis

Since the inception of tropical forage research, *S. guianensis* has been one of the few better-known legumes in tropical America. During the initial phase of CIAT's legume introduction and evaluation work in the early 1970s in the subhumid tropics of Colombia, *S. guianensis* showed good drought tolerance and excellent adaptation to very acid, low-fertility Oxisols and Ultisols, but it also responded well to higher fertiliser inputs. Its productivity and potential use, however, were constrained by its susceptibility to anthracnose. This was not only true for the Australian commercial varieties tested at the beginning of *Stylosanthes* evaluation in tropical America but also for most of the very comprehensive germplasm collection that was assembled between 1973 and 1988 (CIAT, 1974–1989).

This screening for anthracnose resistance in the subhumid tropics showed a particular *S. guianensis* type to be consistently more disease-tolerant than any other *S. guianensis*: a late-flowering, many-branched and fine-stemmed type with narrow leaflets; leaves and stems with viscid hairs (and, consequently, of low palatability); and inflorescences with very few flowers. This distinct group was for some time referred to as *S. guianensis* "tardío", in contrast with the "common" forms of the species, and was later described as a new botanical variety, *S. guianensis* var *pauciflora*. In RIEPT trials in the subhumid savannah regions, it proved to be particularly well adapted to the Brazilian *Cerrados* where it showed the best dry-season performance of the tested *Stylosanthes* species (Table 4).

Table 4. *Seasonal dry-matter (DM) yields of 16* Stylosanthes *spp accessions and two* Centrosema *species at eight RIEPT trial sites in the "Cerrados" of Brazil.*

CIAT accession	Species	DM yield (t/ha/12 weeks)	
		Rainy season	Dry season
2039	*S. macrocephala*	4.38 a[1]	237 cde
2053	*S. macrocephala*	4.36 a	156 e
2244	*S. guianensis* var *pauciflora*,	4.04 ab	597 a
1281	*S. macrocephala* cv *Pioneiro*	3.60 bc	159 e
2252	*S. capitata*	3.56 bc	217 cde
2243	*S. guianensis* var *pauciflora* cv Bandeirante	3.46 bc	555 ab
2191	*S. guianensis* var *pauciflora*	3.42 bc	499 ab
2732	*S. macrocephala*	3.39 bc	254 cde
1019	*S. capitata*	3.28 bc	271 cd
1079	*S. capitata*	3.27 bc	303 c
1094	*S. viscosa*	3.21 c	185 de
1095	*S. guianensis* var *pauciflora*	3.20 c	465 b
2746	*S. guianensis* var *vulgaris*	3.15 c	572 ab
2203	*S. guianensis*	3.08 c	482 b
1318	*S. capitata*	3.03 c	229 cde
2245	*S. guianensis* var *pauciflora*	2.95 c	602 a
5112	*C. acutifolium*	1.18 d	275 cd

1. a,b,c,d and e: Significant differences at P = 0.05.

Source: RIEPT, unpublished data.

One accession (CIAT 2243 = BRA–003671) was subsequently released by EMBRAPA as cv Bandeirante. Its adoption, however, is constrained by a low seed-production potential. A plant breeding project to combine the anthracnose resistance of *S. guianensis* var *pauciflora* with the considerably higher seed production and higher palatability of "common" forms of the species, is fairly advanced (CIAT, 1991). Another anthracnose-tolerant *S. guianensis* that is currently generating considerable interest in the Brazilian *Cerrados*, is a distinct form of *S. guianensis* var *vulgaris* from Minas Gerais.

In contrast with the subhumid savannah regions, *S. guianensis* "common" shows remarkable anthracnose tolerance in the humid tropics. This anthracnose tolerance was not only observed at the major screening site, Pucallpa, Peru, but also at a wide range of RIEPT trial sites throughout the Latin American humid tropics (Amézquita et al, 1991). In Peru, accession CIAT 184 was released in 1985 as cv Pucallpa; Table 5 gives a summary of its agronomic performance over 32 RIEPT sites.

Table 5. *Agronomic performance of* Stylosanthes guianensis *CIAT 184 over 32 RIEPT trial sites in the humid tropics of Central and South America.*

Parameter	Mean	s.d.	CV	Range
Clover at 12 weeks (%)	63.7	31.6	50	8–100
Plant height at 12 weeks (cm)	39.5	17.1	43	7– 66
Yield under maximum rainfall (t/ha/12 weeks)	4.38	2.35	54	0.8–10.54
Yield under minimum rainfall (t/ha/12 weeks)	4.07	3.84	94	0.56–16.94
Reaction to anthracnose (0–4 scale)	1.6	1.1	74	0–4

Source: Amézquita et al (1991).

Stylosanthes capitata

The promise of this species was identified in the mid-1970s mainly because of its anthracnose tolerance in Colombia (Table 6).

Table 6. *Reaction of 22* Stylosanthes capitata *accessions and of* S. macrocephala *to inoculation with anthracnose* (Colletotrichum gloeosporioides).

Species, accessions	Anthracnose range	Rating[1] mean
S. capitata (21 accessions)	1.0–1.7	1.1
S. macrocephala (1 accession)	1.1	1.1
S. guianensis (2 commercial "common" control varieties)	3.2–4.8	4.0

1. 1 = no disease; 5 = plant death.

Source: Adapted from Grof et al (1979).

The adaptation of *S. capitata* is restricted to subhumid savannah environments with sandy, acid soils. It has very low nutrient requirements and is less responsive to higher fertiliser inputs than *S. guianensis*. In 1983, the remarkable anthracnose tolerance in the isohyperthermic savannah environments (*Llanos* in Colombia and Venezuela) led to the release, by ICA, of a cultivar (cv Capica) that consists of a blend of five accessions (CIAT 1315, 1318, 1342, 1693 and 1728).

In the isothermic savannahs (the Brazilian *Cerrados*), *S. capitata* is also well adapted but less drought-tolerant than *S. guianensis* (Table 4). Here, the species in general shows less anthracnose tolerance than in the isohyperthermic savannahs (Table 3); this has hindered the release of a Brazilian cultivar.

The nutritive value of *S. capitata*, including its palatability, is medium to high (12-19% crude protein; 55–60% DM digestibility). The seed production potential is very high and allows for permanent seedling recruitment. Dry-season performance of *S. capitata*, however, is sub-optimal; future plant improvement and selection projects should concentrate on this trait and on improving anthracnose tolerance for the Brazilian *Cerrados*.

Stylosanthes macrocephala

The adaptation of this species is very similar to that of the closely related *S. capitata* in that it grows well on very acid, infertile soils in subhumid savannah environments. In contrast with *S. capitata*, however, the anthracnose tolerance of *S. macrocephala* extends to both the isohyperthermic and isothermic savannah ecosystems (the *Llanos* and *Cerrados*, respectively). In addition, with 14–22% crude protein and 66–75% DM digestibility of leaves, *S. macrocephala* has a higher nutritive value than *S. capitata*.

At the major screening site, EMBRAPA–CPAC Planaltina, and throughout RIEPT trials in Brazil, *S. macrocephala* performed well under *Cerrados* conditions, particularly during the wet season (Table 4). A Brazilian accession (CIAT 1281 = BRA–003697) was released by EMBRAPA–CPAC as cv Pioneiro in 1983 but its adoption has been mainly constrained by poor dry-season performance. It is considered that less early flowering genotypes are required for the northern part of the Brazilian *Cerrados*. Systematic screening of a major germplasm collection has shown considerable intraspecific variation in this respect but further germplasm collection is indicated (Schultze-Kraft et al, 1984b).

In the isohyperthermic savannahs (*Llanos* in Colombia and Venezuela), *S. macrocephala* was initially also considered as promising until almost the entire germplasm collection was severely affected by rhizoctonia foliar blight (CIAT, 1988).

Stylosanthes scabra

A very comprehensive and very variable germplasm collection has been assembled and was characterised at the CIAT–Quilichao Research Station, Colombia (Maass and Schultze-Kraft, 1993). At the major savannah screening site, EMBRAPA-CPAC Planaltina, performance of pre-selected accessions was, after some initial promise, too poor to consider further evaluation (CIAT, 1982). At the other savannah screening site, ICA–Carimagua, considerable variation was observed within a 94-accession core collection (Thomas and Díaz, 1989), but accessions identified as promising were not sufficiently outstanding to justify further research for the time being. Consequently, no major regional testing was carried out with *S. scabra* germplasm.

The main constraints to the potential use of *S. scabra* in tropical America are susceptibility to anthracnose, little-leaf mycoplasma and the stem borer. The species seems to have a wider soil adaptation (including somewhat heavier soils) than *S. guianensis*, *S. capitata* and *S. macrocephala*, although it grows well on acid, infertile soils. Furthermore, *S. scabra* in general seems to be more suited to environments that are somewhat drier than the major *Stylosanthes* screening sites (see Table 2).

Stylosanthes viscosa

As in the case of *S. scabra*, the germplasm collection of *S. viscosa* was characterised and evaluated with respect to adaptation to edaphic and biotic stresses at CIAT–Quilichao. That work revealed considerable variation in a series of morphological and agronomic traits, amongst them anthracnose tolerance and palatability to cattle (Keller-Grein and Schultze-Kraft, 1992). As a result, a core collection of 31 accessions was identified for further regional testing.

Based on the limited experience from tropical America, *S. viscosa* seems to have climatic requirements similar to those of *S. scabra*, i.e. it is more suited to somewhat drier environments.

Soil adaptation is possibly not as wide as that of *S. scabra* but *S. viscosa* grows well on light-textured, acid soils of low fertility. Suggested major constraints to the potential use of *S. viscosa* are susceptibility to anthracnose, low productivity and low palatability due to plant stickiness.

Other species

Germplasm evaluation of limited numbers of accessions performed at the same subhumid-to-humid CIAT-screening sites (see Table 2) with some other, potentially important, *Stylosanthes* species can be summarised as follows:

S. humilis:	Potential limited by annuality and anthracnose susceptibility.
S. hamata:	Insufficient adaptation to acid, low-fertility soils; too short-lived.
S. sympodialis:	Insufficient adaptation to acid, low-fertility soils.
S. fruticosa:	High anthracnose susceptibility.
S. leiocarpa:	Some tropical forms from Bahia, Brazil, with rhizomes and anthracnose tolerance; low productivity is a major constraint.

Conclusions

Considerable efforts to assemble and screen a large and very variable *Stylosanthes* germplasm collection were undertaken by CIAT and collaborating national institutions in tropical America. High-potential species for acid, infertile soil conditions in the humid tropics are *S. guianensis* ("common"), while in the subhumid savannah regions they are *S. capitata* and *S. guianensis* var *pauciflora*. Species warranting regional evaluation in somewhat drier environments, yet with acid, low-fertility soils, are *S. macrocephala*, *S. scabra* and *S. viscosa*. Susceptibility to anthracnose is the major constraint in the genus.

Further germplasm collection missions in tropical America are indicated mainly to broaden the available genetic base of species which so far have been collected only poorly or not at all.

Breeding projects may well be necessary if there are constraints that cannot be overcome through screening within a sufficiently broad natural variability. An example of this is the *S. guianensis* project at CIAT which aims at combining the anthracnose resistance of *S. guianensis* var *pauciflora* with the seed production potential of "common" *S. guianensis*. However, the lack of major breakthroughs in *Stylosanthes* breeding projects that have been carried out so far, suggests that breeding *Stylosanthes* (and other wild legumes) is not an easy task. Therefore, and in view of the fact that breeding is generally a costly, long-term commitment, any breeding plan should be preceded by a careful analysis of the project and alternative options.

Stylosanthes screening in tropical America has always been directed towards the development of traditional, extensive-pasture, low-input cattle production systems on acid, low-fertility soils. As new systems such as integrated crop–livestock production and ley-farming emerge, it might be timely to reconsider the potential role of the various *Stylosanthes* species, and to revise evaluation objectives (including soil adaptation and nutrient requirements) and methodologies.

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Stylosanthes accessions for medium-altitude acid soils

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Abstract

Thirty-four *Stylosanthes scabra*, 20 *S. guianensis* and 66 *S. hamata* accessions were compared for biomass production on an acid soil in a medium-altitude subhumid environment in southern Ethiopia. Accessions *S. scabra* (ILCA 12555, 11625, 11599 and 11608), *S. guianensis* (ILCA 11737 and 11776) and *S. hamata* (ILCA 167) outyielded existing commercial cultivars and are recommended for further agronomic evaluation and animal feed trials in similar environments in sub-Saharan Africa.

Performances des acquisitions de *Stylosanthes* sur sols acides dans des régions d'altitude moyenne

Résumé

Une étude comparative de la production de biomasse de 34 acquisitions de Stylosanthes scabra*, 20 de* S. guianensis *et 66 de* S. hamata *a été effectuée sur sol acide dans une région subhumide d'altitude moyenne du sud de l'Ethiopie. La poursuite d'essais d'évaluation agronomique et d'alimentation animale dans des milieux analogues en Afrique subsaharienne a été recommandée pour les acquisitions ILCA 12555, 11625, 11599, 11608 de* S. scabra, *ILCA 11737 et 11776 de* S. guianensis *et ILCA 167 de* S. hamata*, dont les performances étaient supérieures à celles des cultivars commerciaux.*

Introduction

In the search for *Stylosanthes* germplasm adapted to the different edaphic and climatic conditions in sub-Saharan Africa, the genebank of the International Livestock Centre for Africa (ILCA) in Ethiopia has acquired several accessions of native and exotic *Stylosanthes* species (Hanson and Lazier, 1988; Kidest et al, 1992). However, only a few accessions have been evaluated for their adaptation to the acid soils of sub-Saharan Africa (Lazier, 1986; Hakiza et al, 1988; Larbi et al, 1992). Screening is needed to identify best-bet accessions for further evaluation by national agricultural research systems (NARS). This paper reports biomass production of *Stylosanthes scabra, S. guianensis* and *S. hamata* accessions grown on an acid soil at Soddo in southern Ethiopia.

Materials and methods

The studies were conducted from 1988 to 1990 at the ILCA Research Site at Soddo (6°50'N, 37°45'E, altitude 1950 m asl), southern Ethiopia. The site has a subhumid climate; annual rainfall averages 1060 mm, and occurs mainly from May to October with a marked dry season from mid-December to late March. Total annual rainfall during the study period was 1234, 1269 and 1045 mm for 1988, 1989 and 1990, respectively. The soil at the experiment site is a Nitosol with pH of 4.4 (H_20), 0.19% total nitrogen, 5.1% organic matter and 1.2 ppm (Bray II) available phosphorus.

Three experiments were conducted to compare biomass production of *S. scabra, S. guianensis* and *S. hamata* accessions on acid soil.

S. scabra

Thirty-four Brazilian *S. scabra* accessions were evaluated with commercial cultivars Seca and Fitzroy included as controls. The treatments were replicated six times in a randomised block design using a plot size of 3 x 0.5 m. Each plot received an annual application of 10 t farmyard manure/ha and 40 kg P/ha as triple superphosphate which were broadcast before planting and hoed into the surface soil. Thereafter, scarified seed was drilled at 4 kg/ha.

Cuts for biomass estimation were made on April 19 and August 1, 1990 using a 1 x 0.5 m quadrat per plot harvested at 10 cm height above ground level. Subsamples were oven-dried at 65^{o}C for 48 hours to estimate dry matter (DM). After each harvest, plots were grazed with native cattle for 3–5 hours at a mean stocking rate of 50 animals/ha using a mob-grazing technique (Mislevy et al, 1981).

S. guianensis

The trial was conducted on existing swards of 18 new accessions of *S. guianensis* with commercial cultivar Cook as control. Plots measuring 2 x 2 m were planted in June 1988 using a randomised block design with four replications and a seeding rate of 4 kg/ha. All plots were cut back to ground level in October, 1989 after which 40 kg P/ha as triple superphosphate was broadcast to each plot and raked into the surface soil.

A 1 x 0.5 m quadrat was harvested at 5 cm height above ground from each plot to estimate biomass on January 24, June 27 and October 26, 1990. Subsamples were oven-dried at 65^{o}C for 48 hours to estimate DM. Dry-season samples were analysed for nitrogen (Gallaher et al, 1975). Plots were mob-grazed with native cattle after each harvest (Mislevy et al, 1981).

S. hamata

One hundred and sixty-six accessions were planted in June 1988 in 1 x 1 m plots using a randomised block design with two replicates. Four plants were planted per plot, spaced 50 cm apart. Plants were harvested to 5 cm above ground at six-weekly intervals to determine biomass production. Subsamples were oven-dried at 65^{o}C for 48 hours to estimate DM.

Results and discussion

There were significant differences in DM yield among the accessions of *S. scabra*. Dry-matter yield of the top ten accessions is presented in Table 1. Accessions ILCA 12555, 11625, 9267, 11599 and 11608 produced more DM than Seca partly due to differences in plant vigour estimated as spread of stolons from the middle of the plot and tolerance to grazing. Edye et al (1976) reported similar variations in yield among four *S. scabra* accessions in central Queensland. No accession was superior to Fitzroy.

Mean DM yield of the 20 accessions of *S. guianensis* ranged from 4.0–8.3 t/ha. The Brazilian ecotypes ILCA 11737 and 11776 produced more DM than the commercial cultivar Cook (Table 2). Differences in grazing tolerance may be partly accountable. These findings confirm reported variations in DM yield between accessions of *Stylosanthes* species (Edye et al, 1991).

Table 1. *Mean dry-matter yields of 10 promising Brazilian accessions of* Stylosanthes scabra *on an acid soil, Soddo, southern Ethiopia.*

Accession number		
ILCA	CIAT	Yield[1] (t DM/ha)
12555	–	2.10
11625	1090	1.93
9267	–	1.84
11599	1084	1.82
11608	2554	1.75
11300	1908	1.67
11281	1313	1.63
Fitzroy[2]	–	1.34
Seca[2]	–	1.19
6854	–	1.15
LSD (P< 0.05)		0.73
Range(34 accessions)		2.10–2.50

1. Mean of three cuts.

2. Commercial cultivars.

Crude-protein concentrations in leaves during the dry season also differed among *S. guianensis* accessions (Table 2). Leaves of cultivar Cook had a significantly higher CP than ILCA 11765 presumably due to differences in leaf-to-stem ratio. Similar differences in CP content among *Stylosanthes* accessions were reported in Australia (Edye et al, 1976). The range (83–127 g/kg) of CP reported in this study was above the minimum level of 8% known to inhibit intake of tropical forages (Minson, 1980), suggesting that these accessions could be useful in protein banks to supplement dry season grazing.

Table 2. *Mean dry-matter yields (t DM/ha) and crude-protein concentrations (g/kg DM) of 10 promising accessions of* Stylosanthes guianensis *on an acid soil, Soddo, southern Ethiopia.*

Accession Number				
ILCA	CIAT	Origin	Yield[1] (t DM/ha)	CP[2] (g/kg DM)
11737	1684	Brazil	8.25	108
11776	1808	Brazil	8.03	108
6995	–	Zimbabwe	6.96	111
11765	10243	Brazil	6.64	99
11876	1401	Colombia	6.43	102
11840	1492	Venezuela	6.33	98
11878	1424	Brazil	5.92	103
11732	1970	Colombia	5.88	109
11733	1972	Colombia	5.72	114
Cook[3]	–	–	4.07	123
LSD (P< 0.05)			3.00	31
Range (20 accessions)			3.96–8.25	83–127

1. Mean of three cuts.

2. Dry season crude-protein content.

3. Commercial cultivar.

Biomass production of the top 10 *S. hamata* accessions is presented in Table 3. Accession *S. hamata* ILCA 167 produced about twice as much dry matter as most of the promising accessions probably due to early establishment and faster regrowth after defoliation.

Table 3. *Mean dry-matter yields (t DM/ha) of 10 promising* Stylosanthes hamata *accessions on an acid soil, Soddo, southern Ethiopia.*

Accession number		Yield[1] (t DM/ha)
ILCA	CPI	
167	–	7.05
15857	110046	3.29
15866	110060	2.85
15935	110166	2.76
15850	110038	2.70
15932	110157	2.68
15893	110095	2.68
15860	110050	2.65
15933	110158	2.63
Verano[2]		1.70
LSD (P< 0.05)	–	1504
Range (166 accessions)		0.53–7.05

1. Mean of eight cuts.

2. Commercial cultivar.

Conclusions

From the results accessions: *S. scabra* ILCA 12555, 11625, 11599, 11608; *S. guianensis* ILCA 11737, 11776 and *S. hamata* ILCA 167 appeared to be adapted to the Nitosols of southern Ethiopia and probably similar environments in eastern and western Africa. These accessions merit further agronomic evaluation and animal-feed trials. Studies on yield and quality of accessions in drier environments may be worthwhile since dry season feed deficit is the major problem facing livestock production in sub-Saharan Africa.

Outbreak of anthracnose (*Colletotrichum gloeosporiodes*) is seen as a major disadvantage to using *Stylosanthes* accessions. However, in the present and earlier trials new *S. guianensis* and *S. scabra* accessions were relatively tolerant to anthracnose attack compared with the commercial cultivars.

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Species screening and multi-locational testing of *Stylosanthes* species in West Africa

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Abstract

The evaluation of *Stylosanthes* species has featured prominently in ILCA's forage evaluation programme in the subhumid zone of Nigeria. The evaluation of over 200 accessions within the genus using a series of evaluation stages ranging from small plot observation trials through to full-scale grazing trials is described. Accessions which are as good or better than *S. hamata* cv *Verano*, which is currently being used for pasture developments, included two *S. guianensis* accessions (ILCA 164 and 15557) and one *S. hamata* accession (ILCA 15876).

Travaux d'évaluation et essais multilocaux sur des espèces de *Stylosanthes* en Afrique de l'Ouest

Résumé

Volet extrêmement important des travaux du CIPEA dans la zone subhumide du Nigéria, l'évaluation des espèces de Stylosanthes *dans cette région a porté sur plus de 200 acquisitions et plusieurs stades, allant d'essais d'observations en petites parcelles à des travaux sur pâturage. Les acquisitions dont les performances étaient analogues ou supérieures à celles de* S. hamata *cv. Verano, actuellement utilisé dans la mise en valeur des parcours, comprennent deux lignées de* S. guianensis *(ILCA 164 et 15557) et une de* S. hamata *(ILCA 15876).*

Introduction

Stylosanthes species have been used widely in West Africa and almost every country in the region has attempted to use *Stylosanthes* to establish pastures e.g. in Mali (ILCA, 1989) and in Cameroon (Tarawali and Pamo, 1992). In the subhumid zone of Nigeria, the International Livestock Centre for Africa (ILCA) followed on from the work with *Stylosanthes* initiated at the National Animal Production Research Institute (NAPRI), Shika, Zaria, to develop the "fodder-bank" package (Mohamed-Saleem and Suleiman, 1986). *Stylosanthes guianensis* (Aubl.) Sw. cv Cook and cv Schofield and *S. hamata* (L.) Taub. cv Verano were used at first. However, the incidence of anthracnose (caused by *Colletotrichum gloeosporiodes* (Penz.) Sacc.) on the *S. guianensis* accessions subsequently rendered the fodder-bank package dependant only on *S. hamata* cv Verano. Despite this fodder banks, based on Verano, have been widely used in northern Nigeria (Bayer and Waters-Bayer, 1989).

Recognising the dependance of the pasture package on a single cultivar to be an unstable position, ILCA initiated a forage legume evaluation programme to identify other material that may complement or replace Verano in fodder banks (Mohamed-Saleem and Otsyina, 1984; Tarawali et al, 1989; Tarawali, 1991). This paper reports on the performance of the *Stylosanthes* accessions included within the evaluation programme.

Materials and methods

Evaluation site

Unless indicated otherwise, the experiments described below were carried out at ILCA's Kurmin Biri research site (7°55'E, 10°10'N 700 m asl) on a Ferric Luvisol. General features of the top 20 cm of soil are presented in Table 1. The site is in the subhumid zone of Nigeria (Northern Guinea Savannah) where rains begin in April, are steady by June and end in October; rainfall during the experimental period (1988 to 1991) is summarised in Figure 1. Mean monthly temperature range is from 22°C in December/January to 28°C in April.

Table 1. *Chemical and physical parameters of the top soil (0–20 cm) for ILCA's experimental sites at Kurmin Biri.*

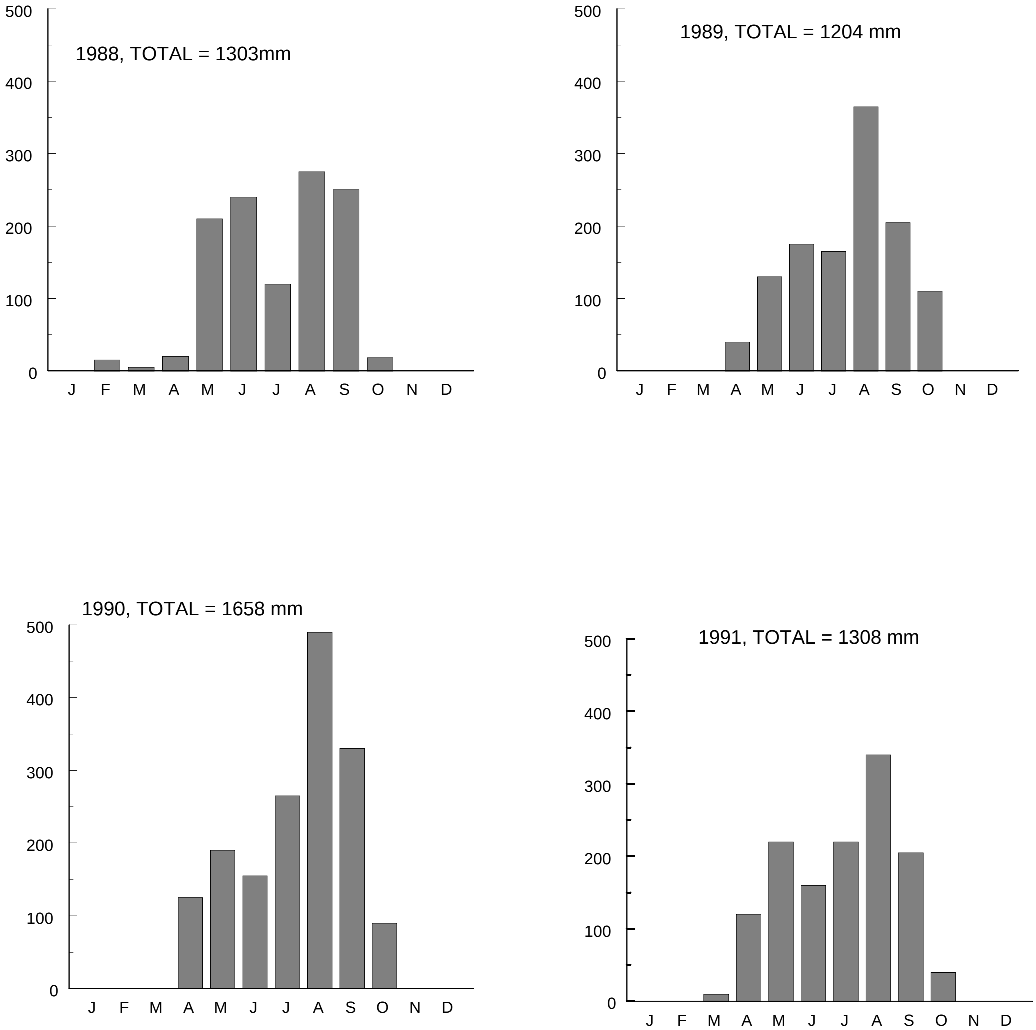
Parameter	Minimum	Maximum
pH (H_2O)	4.7	5.7
Carbon (%)	0.99	1.41
Total N (%)	0.06	0.08
Available P (Bray)	0.42	2.19
Cations, Meq/100 g soil		
K	0.14	0.23
Ca	1.60	2.36
Mg	0.30	0.76
Na	0.04	0.05
Texture (%)		
Sand 2.00–0.02 mm	65	72
Silt 0.02–0.002 mm	14	16
Clay < 0.002 mm	13	19

Source: Peters (1992); for more details on soil characteristics see Tening et al, pp. 115–124.

The evaluation procedure

A stepwise sequence of evaluation stages was used. All accessions were included in the initial stages after which unsuitable material was progressively eliminated. *Stylosanthes hamata* cv Verano was included at all stages for comparison. The evaluation stages are summarised in Figure 2.

Figure 1. *Rainfall (mm) at experimental areas in Kurmin Biri, 1988–1991.*



Acquisition (Stage 1)

Accessions were obtained from (Centro Internacional Agricultura Tropical (CIAT), Cali, Colombia), the Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia, from ILCA, Ethiopia (see Hanson and Heering, pp. 55–61) and from national institutes in West Africa.

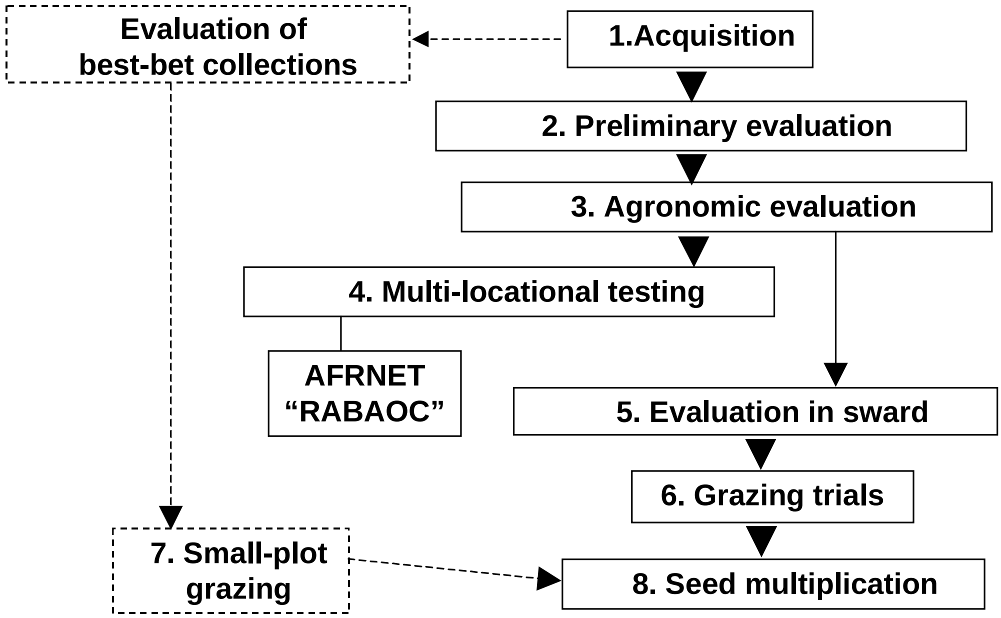
Preliminary evaluation (Stage 2)

This stage, lasting two growing seasons, encompassed observations of general growth parameters and collection of seeds for future trials. At the beginning of the wet season, scarified seeds were sown in single rows on the centre of plots 0.5 x 2.0 m in size, with two replications; the plots were hand-weeded regularly throughout the experimental period. Growth, flowering time (month when 50% of the plants has flowers), seed production (monthly totals), disease incidence (“score”, % incidence and severity) and drought tolerance (“score”, % of plot that is green) were monitored for two years.

Agronomic evaluation (Stage 3)

At the start of the wet season, scarified seeds of promising material selected from Stage 2 were sown on 2 x 3 m plots in a randomised complete block design with three replications. Single superphosphate (SSP) at 150 kg/ha was applied at planting and the plots were hand-weeded throughout. At the end of the wet season, two 1 m^2 quadrats were harvested

Figure 2. *The sequential evaluation procedures of legumes species used in the subhumid zone of Nigeria.*



Summary of the evaluation stages used at the ILCA subhumid zone research site, Nigeria. The dotted lines indicate stages introduced in 1991 to try to speed up the evaluation process by combining other stages. “Best-bet collections” were similar to preliminary evaluation but included cutting to measure yield, thereby partly including the agronomic evaluation. *Stylosanthes* accessions were not included in this evaluation stage. Small-plot grazing is described in the text and did include *Stylosanthes* accessions.

from each plot, the dry-matter (DM) yield determined and samples of the dry material were ground and analysed for crude protein (CP). Other observations were as described for Stage 2. Trials were monitored for two to three years.

Multilocational testing (Stage 4)

Selected material was evaluated for four years at various sites in northern Nigeria using the Stage 3 method but without CP analysis (Table 2). Plots were kept weed-free for the first two years, then weeds were allowed to invade for the following two years. Selection for use at this stage was based on recommendations derived from earlier evaluation stages. Nine accessions were planted at each site, including *S. hamata* cv Verano, which was planted at all sites; *S. humilis* ILCA 7363 (Townsville) was planted as a control at Maiduguri and Katsina and *S. scabra* ILCA 441 (cv Seca) at Makurdi, Jos, Katsina and Bauchi.

Performance in sward (Stage 5)

The performance in swards (dry-matter yield, nutritional value through the dry season, seed production, drought tolerance, disease incidence and regeneration) of material selected from Stage 3 trials growing in competition with the natural vegetation under different management regimes was assessed. The effects of phosphorus application (0, 150 and 300 kg/ha SSP) and management (cutting, weeding and no weeding) were compared in a split-plot experiment (Peters, 1992).

Table 2. *Sites used for multi-locational testing of forage legumes in northern Nigeria.*

Site	Longitude	Latitude	Zone	State
Makurdi	8^o 35'E	7^o 44'N	Subhumid	Benue
Jos	8^o 53'E	9^o 54'N	Subhumid	Plateau
Bauchi	9^o 47'E	10^o 20'N	Semi-arid	Bauchi
Rano	8^o 32'E	9^o 55'N	Semi-arid	Kano
Maiduguri	13^o 16'E	11^o 53'N	Semi-arid	Borno

Performance under grazing (Stage 6)

Selected material (*Stylosanthes hamata* cv Verano; *Centrosema pascuorum* cv Cavalcade and *Chamaecrista castia rotundifolia* cv Wynn) was planted on 0.4 ha paddocks and managed as fodder banks (Otsyina et al, 1987). Two heifers were allowed to graze the paddocks as a supplement (two to three hours grazing per day) during the dry season. Pasture productivity was assessed and animal performance was monitored by fortnightly weighing and condition scoring for two years (ILCA, 1991).

Small plot grazing trial (Stage 7)

This stage commenced in June 1991 in an attempt to reduce the number of stages involved in the evaluation and include grazing livestock animals earlier in the process. It was intended to replace Stages 5 and 6 (Figure 2). Scarified seeds of selected material were sown onto cleared, well prepared plots of 4.0 x 5.0 m in a randomised block design with four replications. At sowing, 150 kg/ha SSP was mixed with the seeds. The plots were weeded only once soon after sowing to ensure good establishment. Four young steers grazed the plots down to about 15 cm height every six weeks from September 1991 to January 1992. Immediately before and after grazing, one 1 m^2 quadrat was cut from each plot, separated into sown legume, grass and forbs, weighed and dried to determine the dry-matter yield of each component. All plots were uniformly clipped to 15 cm after grazing and sampling.

Seed multiplication (Stage 8)

The potential for seed production, in particular with different weed-control practices (manual and chemical) was evaluated for promising material (*Stylosanthes hamata* cv Verano; *Centrosema pascuorum* cv Cavalcade and *Chamaecrista rotundifolia* cv Wynn). Details are reported by Kachelriess and Tarawali (pp. 287–297) and Kachelriess et al (1991).

Plant material

Stylosanthes hamata cv Verano was included in all the experiments described above. During the evaluation, several other *Stylosanthes* species and accessions were tested as described below. *Stylosanthes guianensis* CIAT 136 and 184 (ILCA 163 and 164) were obtained in 1987 from Société de développement des production animales (SODEPRA), Côte d'Ivoire, where they were being tested for pastures as anthracnose-resistant accessions of *S. guianensis*.

In 1988 a collection of *S. guianensis* from ILCA headquarters, Addis Ababa, Ethiopia, together with six accessions each of *S. fruticosa* and *S. scabra* from the same source and one *S. guianensis* accession from the University of Florida were included. Also in 1988, a collection of 163 *S. hamata* accessions received from CSIRO were evaluated in a separate experiment.

In 1990 31 accessions of *S. guianensis* selected as being anthracnose-tolerant were introduced from the ILCA genebank in Addis Ababa. An additional eight accessions supplied by Professor J. Brolmann from the University of Florida were also introduced in 1990.

RABAOC[1] trials

In 1990, a trial was established as part of ILCA's Animal Feed Resources Network (AFRNET) in conjunction with CIAT and Institut d'Elevage et de Médicine Vétérinaire des Pays Tropicaux (IEMVT), France. The trial was based on the multi-locational design used by CIAT in South America (Toledo and Schultze-Kraft, 1982). Amongst the 21 herbaceous legumes, the following *Stylosanthes* species were included: *S. capitata* CIAT 10280 ("Capica"), *S. guianensis* CIAT 184 and 10136, *S. hamata* cv Verano and CIAT 147, *S. macrocephala* CIAT 1281 and *S. sympodialis* CIAT 1044. Accessions were evaluated during the wet and dry seasons for two years as described by Schultze-Kraft and Toledo (1990).

Results

S. guianensis CIAT 136 and 184

Both accessions performed well in the preliminary evaluation trial (Stage 2) and showed some tolerance of anthracnose; some black spots were observed but they did not spread nor damage the overall growth. Both accessions were included in a Stage 3 agronomic evaluation trial. Dry-matter, seed- and crude-protein yields for three years are shown in Table 3. Both accessions yielded well and had good crude-protein contents. CIAT 184 flowered in October, and CIAT 136 in November. In subsequent years, flowering and seed production was about six weeks earlier for both accessions. Both accessions seemed to tolerate anthracnose, but a greater incidence and severity (up to 10%) was recorded on CIAT 136 than CIAT 184 (up to 5%). They retained some green leaves up until the end of January when some leaf drop started to occur. In all three years, they were among the top four best accessions being evaluated from the 1987 introductions.

CIAT 184 was used in a Stage 5 experiment (Peters, 1992). In the small plot grazing trial CIAT 184 (ILCA 164) performed well, and showed a good regeneration capacity after grazing (Figure 3); even in the dry season it produced 372 kg/ha dry matter of regrowth in the six weeks between the December and January grazing periods. It was the best of the eight accessions used in this trial.

Table 3. *Dry-matter, and seed yields of* S. guianensis *CIAT 136 and 184.*[1]

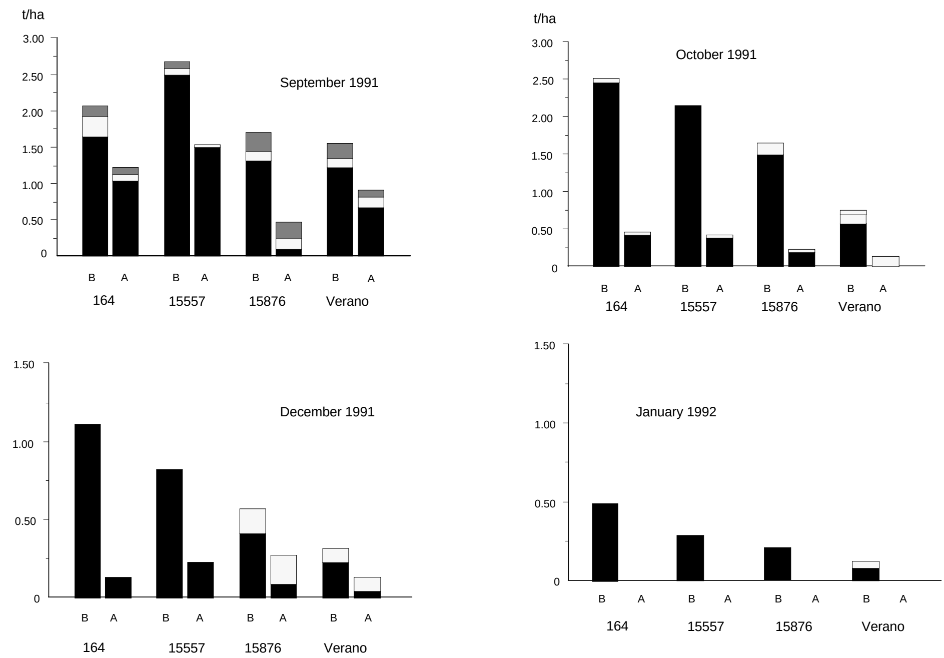
Year	Yield t DM/ha[2]		Seed kg/ha	
	CIAT	CIAT	CIAT	CIAT
	136	136	136	136
1988	2.70	3.69	27	43
1989	10.14	9.56	145	117
1990	2.36	4.27	60	104

1. CIAT 136 = ILCA 163; CIAT 184 = ILCA 164.

2. Plots were harvested at the end of the wet seasons, 1988 to 1990. The crude-protein means for the three years are 13.6% for CIAT 136 and 10.1% for CIAT 184.

1. RABAOC: Réseau de recherche sur l'alimentation du bétail en Afrique occidentale et centrale.

Figure 3. *Dry-matter yields of two stylo accessions (164 and 15557) and two* S. hamata *(15876 and cv Verano) before (B) and after (A) grazing in the late wet and early dry season during 1991–1992.*



1988 introductions

Of the *S. guianensis*, *S. fruticosa* and *S. scabra* collection, the *S. guianensis* accessions grew best in the Stage 2 trial. All *S. fruticosa* accessions flowered in September but seed production was poor with a maximum of 24 g/m^2 from ILCA 10322. Twelve *S. guianensis* accessions flowered in October, five in September and five in November; seed production was poor from the late-flowering accessions, but others gave up to 31 g/m^2 (ILCA 15568). Two *S. scabra* accessions flowered in September and four in October; maximum seed production was about 30 g/m^2 (ILCA 11247). All material showed ability to retain green leaves through the dry season but all had some symptoms of anthracnose. *S. guianensis* ILCA 15557 showed resistance to anthracnose at times when adjacent accessions were severely affected. On the basis of the overall performance three *S. guianensis* accessions, one of *S. fruticosa* and one of *S. scabra* were selected for inclusion in a Stage 3 trial.

Dry-matter, seed- and crude-protein yields from the Stage 3 trial are shown in Table 4. All accessions had high crude-protein contents. In terms of dry-matter yield, *S. fruticosa* performed poorly throughout the three-year period. *S. guianensis* ILCA 15557 and *S. scabra* ILCA 11247 yielded best, the latter having particularly high seed yields. *S. guianensis* ILCA 15557 was again the most anthracnose-tolerant; incidence and severity did not exceed 10% throughout the trial period, as compared to the other accessions which reached up to 25%. *S. guianensis* ILCA 15557 was used in the small plot grazing trial (Figure 3) where it performed well, yielding only slightly less than ILCA 164.

Table 4. *Dry-matter, seed- and crude-protein yields of selected 1988 introductions in a Stage 3 trial over three years.*

Accession	DM yield (kg/ha)			Seed yield (kg/ha)			CP
	1989	1990	1991	1989	1990	1991	mean (% DM)
S. fruticosa[1]	0.44	0.29	0.12	105	10	13	14.2
S. guianensis ILCA 15557	1.84	3.35	3.04	60	157	110	15.3
ILCA 15562	1.22	2.75	1.81	85	122	106	13.3
IF 8288	1.31	2.02	0.94	100	100	155	14.9
S. scabra[2]	1.06	2.84	3.44	290	120	272	13.5

1. ILCA 10322.

2. ILCA 11247.

S. hamata collection, 1988

All 163 of the accessions established well although only 0.2 g of seeds of each was planted; germination ranged from 4 to 54% of the seeds planted. All flowered in August beginning 54 to 69 days after planting. Seeds were produced mostly from October to November although some were collected up to January. The majority of the accessions (98) had a semi-erect growth habit, 40 were erect and 25 prostrate. Anthracnose symptoms were recorded on all accessions, but the majority (139) had less than 10% incidence while the remainder had up to 50%. All the cultivars dried up during the dry season, although over half of them retained over 50% of their leaves up to mid-dry season.

Table 5. *Dry-matter, seed- and crude-protein (CP) yields of selected* S. hamata *accessions in a Stage 3 trial.*

Accession (ILCA no.)	Dry matter (kg/ha)			Mean	Seed yield (kg/ha)			CP
	1989	1990	1991		1989	1990	1991	mean (% DM)
15868	2.99	5.12	5.00	(4.37)	38	82	87	11.8
15876	3.08	4.77	4.33	(4.06)	43	85	109	11.2
15861	3.00	3.24	3.54	(3.26)	45	89	137	11.3
15959	1.78	3.50	2.90	(2.72)	26	98	89	13.6
15908	1.28	3.51	3.16	(2.65)	42	126	98	12.6
15895	1.93	3.32	1.93	(2.39)	25	117	97	14.1
15924	1.44	3.18	2.45	(2.35)	17	124	85	10.9
15932	1.46	3.38	2.00	(2.28)	17	66	77	10.8
15892	1.75	2.91	1.97	(2.21)	22	90	62	13.3
15936	1.19	2.77	1.60	(1.85)	13	75	61	12.2
15938	0.82	1.65	1.02	(1.16)	10	64	67	11.2
15926	1.04	1.63	1.13	(1.27)	12	66	50	10.4
Verano	1.18	1.34	0.69	(1.07)	n/a	110	67	12.3
15925	0.63	0.64	1.43	(0.90)	9	59	91	10.8
SD (0.05)	1.02	1.49	1.01		12	35	39	–

n/a = not available.

Thirteen promising accessions were used in a Stage 3 trial. Dry-matter, seed- and crude-protein yields from this trial are presented in Table 5. All contained more than 10% crude protein, whilst cv ILCA 15868 and 15876 had the best dry-matter yields. Seed yields were low in the first year, but increased subsequently. Anthracnose was recorded up to 50% incidence and 25% severity; only ILCA 15876 did not exceed 25% incidence. This accession was therefore selected for evaluation in the small plot grazing trial where its performance was considerably better than Verano stylo although not as good as the two *S. guianensis* accessions (Figure 3).

S. guianensis collection 1990

All 31 of the accessions were established in a Stage 2 trial. Flowering started from September (ILCA 129) with most accessions flowering in October (15) or November (13); one cv, ILCA 7291, flowered in December and ILCA 7285 failed to flower. Most seeds were produced from November to January. Anthracnose was present on all accessions; some showed only slight symptoms in the first year, but were destroyed completely in the second year (e.g. ILCA 11735). All accessions but ILCA 11771 retained over 60% of the leaves to the mid-dry season. Because of anthracnose intolerance, none of these accessions were used for further trials.

The eight accessions received from Florida established well; seven flowered in September and one in October (FP-GS-3); seed production was good for the early-flowering accessions, ranging from 36 g/m^2 (FP 6832) to 21 g/m^2 (FP-PC-21) but only 7 g/m^2 for the late-flowering accession. Dry-season persistance was good, with all the accessions retaining more than 60% of their leaves for more than half of the dry season. Anthracnose disease was present on all accessions; incidence and severity were 10% or less for the first season, but all accessions showed severe symptoms in the second season, reaching over 50% incidence and severity; this precluded their use in further trials.

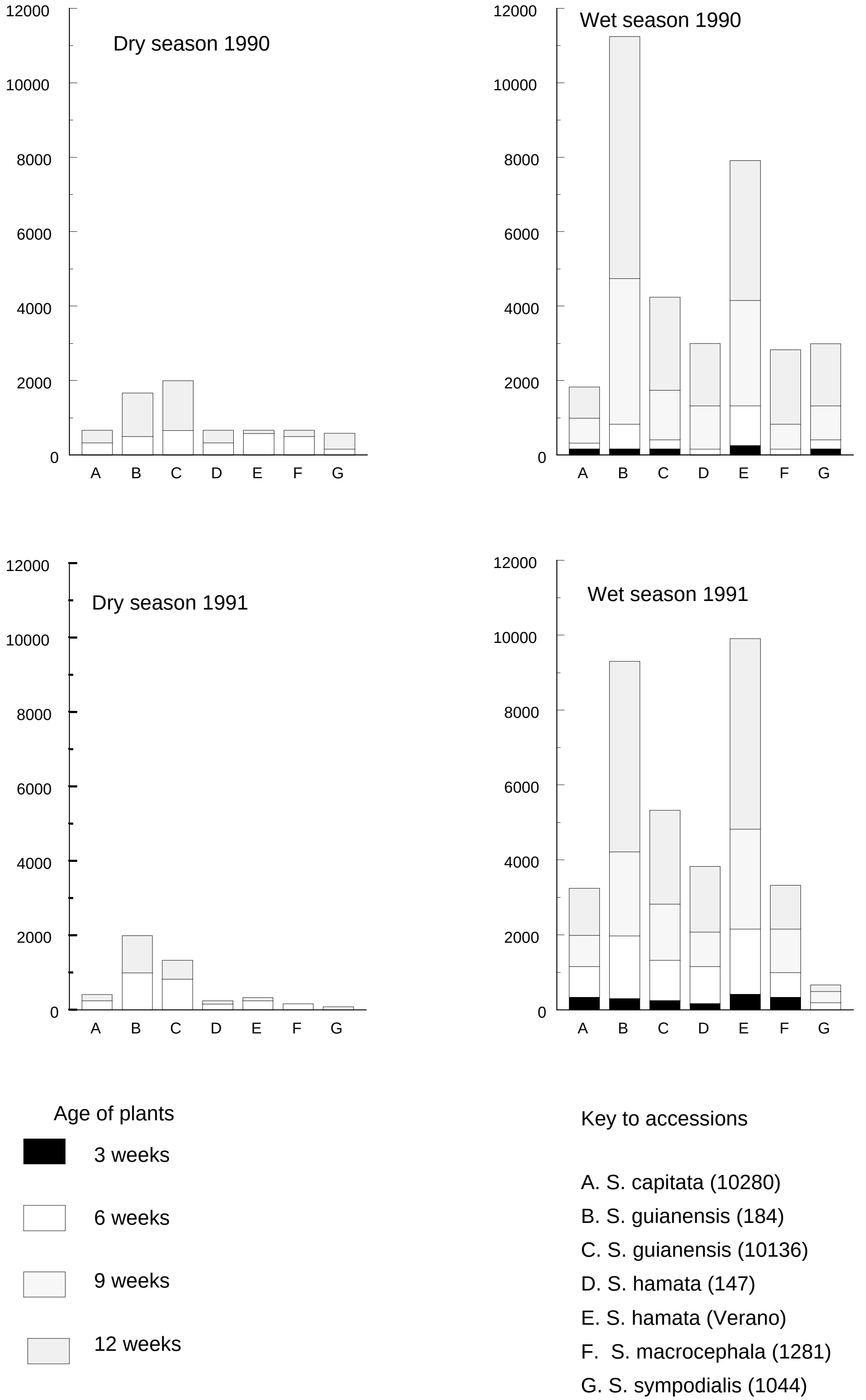
RABAOC trial

Stylo CIAT 184 (ILCA 164) was outstanding throughout the trial period; although anthracnose was recorded, it did not exceed 10% incidence or severity (Figure 4). Stylo CIAT 10136 and Verano stylo also performed well, although the former showed severe anthracnose symptoms during the first 12 weeks. The symptoms reached an incidence and severity of 50% but it subsequently recovered and anthracnose symptoms did not exceed 10% again. *S. hamata* CIAT 147 did not perform as well as Verano while *S. capitata, S. macrocephala* and *S. sympodialis* all grew poorly. *S. capitata* had the best seed production (Table 6). Of the 21 herbaceous legumes in the trial, *S. guianensis* CIAT 184 and *S. hamata* cv Verano performed best.

Multi-locational testing

S. humilis grew poorly at Katsina, but persisted well in Maiduguri even in the presence of weeds (1990 and 1991 yields). *S. scabra* grew well at all sites when weeded during the first two years; it was overgrown by weeds at Bauchi. In Jos its performance was second only to *Macroptilium atropurpureum* cv Siratro, while it was the best accession in Makurdi. *S. hamata* persisted at all sites; even in the presence of weeds, it was one of the best accessions at Maiduguri and second to *S. scabra* in Makurdi. *S. hamata* ranked seventh at Jos while at Bauchi *Centrosema brasilianum* were best; *S. hamata* grew poorly when unweeded. At Rano, *S. hamata* was again one of the best accessions, along with *Macroptilium atropurpureum* (Table 7).

Figure 4. *Cumulative wet-and dry-season yields of* Stylosanthes *accessions from 1990 to 1992.*[a]



a. Yields shown are the total for each plot and represent the sum of the two harvests (6 and 12 weeks) in the dry season of 1990 and 1991, respectively, and four harvests (3, 6, 9 and 12 weeks) in the wet season 1991 and 1992, respectively.

Table 6. *Seed production of* Stylosanthes *accessions in RABAOC trial.*

Accession	Peak flowering	Seeds (g/plant)
Early-flowering		
S. macrocephala, CIAT 1281	August	7
S. hamata, CIAT 147	September	2
S. hamata, cv Verano	September	3
S. sympodialis, CIAT 1044	September	6
Late-flowering		
S. capitata, CIAT 10280	October	14
S. guianensis, CIAT 184	October	7
S. guianensis, CIAT 10136	November	1

Table 7. *Dry-matter yields (kg/ha) of accessions used for multi-locational testing in northern Nigeria.*

Site	*S. hamata* cv Verano				*S. humilis* ILCA 7363				*S. scabra* ILCA 441			
	1988	1989	1990	1991	1988	1989	1990	1991	1988	1989	1990	1991
Makurdi	4345	8071	5739	3858	not planted				9327	21825	5337	2215
Jos	927	1425	3057	131	not planted				2594	11855	907	1258
Bauchi	5102	2447	1890	747	not planted				4441	2140	36	0
Rano	1050	1652	2636	697	not planted				not planted			
Maiduguri	910	5927	2220	1577	722	4072	1613	1236	not planted			
Katsina	98	1507	n/a	n/a	432	473	n/a	n/a	431	3304	n/a	n/a

n/a = not available.

Stylosanthes hamata cv Verano

Performance in sward (Stage 5)

A full report of the performance of Verano Stylo in these experiments can be found in Peters (1992). Application of SSP up to 300 kg/ha improved dry-matter yield and resistance to drought. In the fertilised plots, yields between over 2 t/ha and over 5 t/ha in comparison to less than 1.6 t/ha in the unfertilised plots were achieved (Table 8). Although no additional fertiliser was applied, the positive response to P fertiliser was still visible in the second growing season (1990/91). Competition from the companion vegetation usually led to a decline in legume growth; cutting the vegetation had no advantage over the non-weeded treatment. The dry-matter yield in both years remained largely constant over the dry season but dry-matter yields in the second season were much lower than in the establishment year (Table 8). Crude-protein contents decreased from 8.3% at the start of the dry season to 5.4% in the second half of the dry season (Table 9). Digestibility of *S. hamata* fell from about 45% to 40% and the stem had very low digestibility (35%). Digestibility of *S. guianensis* ILCA 164 was lower than *S. hamata* when subjected to the same treatments Table 9). Despite dropping their leaves, Verano plants were able to survive the dry season and about 25 perennating plants/m^2 were recorded (Table 8).

Table 8. *Dry-matter yields (kg/ha) of* S. hamata *cv Verano and* S. guianensis *ILCA 164 in swards as affected by management and three levels of superphosphate (SSP) fertilisation in the early and late dry season.*

	S. hamata cv Verano											
	1988–89						1989–90					
	Early dry SSP			Late dry SSP			Early dry SSP			Late dry SSP		
	0	150	300	0	150	300	0	150	300	0	150	300
Weeded	1.38	2.07	1.91	0.72	1.15	1.49	1.83	2.51	1.94	0.78	1.16	1.82
Non-weeded	1.01	1.26	1.42	0.64	0.87	1.23	0.20	0.33	0.20	0.26	0.63	0.83
Cut1	0.87	1.10	1.33	0.71	0.92	1.06	0.38	0.24	0.33	0.44	0.58	0.61
Mean	1.09	1.48	1.55	0.69	0.98	1.26	0.80	1.03	0.82	0.49	0.79	1.09
	S. guianensis ILCA 164											
Weed-free	1.60	3.89	4.81	1.27	2.61	4.71	1.06	1.40	1.28	0.53	0.71	1.10
Non-weeded	0.72	2.23	3.90	0.76	2.62	3.26	0.34	0.22	0.73	0.82	1.37	1.22
Cut 1	0.66	2.43	5.31	0.66	3.05	4.06	0.33	0.35	0.86	0.43	0.64	0.74
Mean	0.99	2.85	4.67	0.90	2.76	4.01	0.58	0.66	0.96	0.59	0.91	1.02

Cut in the early wet season.

Table 9. *Crude-protein (CP) concentrations and* in vitro *dry-matter digestibility (IVDMD: whole plant samples) of* S. hamata *and* S. guianensis *in the early and late dry season.*

	S. hamata cv Verano	
	Early dry	Late dry
CP (% of dry matter)	10.4	6.1
IVDMD (%)	50.8	48.2
	S. guianensis ILCA 164	
CP (% of dry matter)	8.3	5.4
IVDMD (%)	45.1	39.8

Performance under grazing (Stage 6)

Verano stylo performed well in the grazing trial; although in the establishment year it yielded below the other two accessions, it was the best in subsequent years. Pasture yield at the beginning of the first dry season was 2.4 t/ha (72% legume) and this fell to 0.72 t/ha (58% legume) at the end of the grazing period. At the end of the second wet season, productivity of the pasture was 5.15 t/ha (58% legume) falling to 0.64 t/ha after grazing. Heifers on Verano pasture during the dry season lost less weight than those on natural pasture, particularly in the second season when animals on natural pasture lost almost twice as much weight as those on Verano.

Small plot grazing trial (Stage 7)

Verano yielded below the other tested *Stylosanthes* accessions. However, it was well grazed with about half the legume being eaten during the first grazing period and well over 50 % in subsequent grazing periods. There was little regrowth in the dry season after the grazing in December.

Seed multiplication (Stage 8)

Weeding was necessary to obtain good yields of high-quality (pure) seeds of Verano; manual weeding and herbicide application (Trifluralin, Imazethapyr and Bentazon/Cycloxidim mixtures) gave good results and the timing of this was flexible (Kachelriess and Tarawali, pp. 287–297). Yields of up to 500 kg/ha pure seeds were obtained with weeding, as opposed to only 100 kg/ha without weeding.

Discussion

Mohamed-Saleem and Otsyina (1984) indicated that *S. capitata* may be promising for the subhumid environment; subsequently it was found that nodulation is poor (Tening et al, pp. 113–122). The later evaluations showed that *S. guianensis* CIAT 136 and 184 (ILCA 163 and 164) grew well, although ILCA 164 was superior and therefore used in further trials. These accessions were also promising in Côte d'Ivoire in terms of yield (up to 12 t/ha per annum from two harvests) and anthracnose resistance (Buxant and Kouamé, 1986). In the RABAOC trial, ILCA 164 was outstanding in both wet and dry seasons and also proved the best in the small plot grazing trial.

In the 1988 evaluations, *S. guianensis* ILCA 15557 was the most promising due to its outstanding anthracnose resistance in the preliminary observation trials; it was therefore maintained in subsequent trials (Figure 4). Out of the *S. hamata* material from CSIRO, all selections used in the Stage 3 trial came from Venezuela, with ILCA 15876 as the most promising.

Despite being considered anthracnose-resistant in Ethiopia, *S. guianensis* material introduced in 1990 was highly susceptible in the Nigerian subhumid zone. This indicates that it is necessary to test accessions on several sites rather than selecting them directly from the genebank and that several accessions showed promise in the first year but later on succumbed. It is therefore risky to draw conclusions about disease resistance too early in a screening programme.

The RABAOC trial showed that *S. hamata* cv Verano can perform very well, as it did in the multi-locational trials, probably due to good regeneration from seeds and from perennating plants. Yields of Verano reported in the grazing trial (Stage 6) are similar to those reported in Côte d'Ivoire (Cesar and Dulieu, 1987) and northern Nigeria (Shehu et al, 1979).

In Côte d'Ivoire the performance of various *Stylosanthes* accessions has been reported (Messager and Samson, 1981); *S. hamata* and *S. humilis* behaved as annuals and *S. guianensis* accessions were susceptible to anthracnose although cvs Cook and Endeavour tolerated the disease better than cv Schofield. In Senegal, *S. hamata* cv Verano and *S. scabra* cv Seca grew well (Roberge and Diop, 1982), but *S. guianensis* was destroyed by anthracnose (Pichon et al, 1981).

In contrast to the few accessions tested throughout West Africa, 237 *Stylosanthes* accessions, covering eight different species have been evaluated at Kaduna, some material proved as good or better than *S. hamata* cv Verano. Out of these, two accessions of *S. guianensis* (ILCA 164 and 15557) and one of *S. hamata* (ILCA 15876) are the most promising. Seeds of these accessions are currently being multiplied at Kaduna to enable further testing and distribution. Also, the *S. scabra* (ILCA 11247) may also be worth further investigation.

Given the diversity of *Stylosanthes* accessions, it may be worthwhile to consider "mixed-accession pastures" to exploit the various advantages of accession combinations. For example, *S. hamata* accessions that do not yield well in the first year can be combined with an *S. guianensis* accession with good yield in the first season.

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An evaluation of some accessions and varieties of *Stylosanthes* introduced in Adamawa Plateau, Cameroon

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Abstract

An evaluation of the adaptability and productivity of several accessions of *Stylosanthes* species was carried out at the Animal Research Station in Wakwa on the Adamawa Plateau, Cameroon. Before the field study a germination trial was conducted on seeds of each accession. The field study included three yield assessments: (i) seed production, (ii) cumulative yield from cuts at 60-day intervals during the wet season and (iii) uninterrupted growth at the end of the following dry season. Yields of 394 kg/ha, 357 kg/ha and 256 kg/ha of seed were recorded for *S. guianensis* FAO 46004, FAO 46482 and FAO 46484, respectively. *S. guianensis* FAO 46004 also ranked first for productivity with 5.1 t DM/ha while *S. guianensis* FAO 46497 gave a biomass production of 5.3 t DM/ha at the end of the dry season.

Evaluation de certaines acquisitions et variétés de *Stylosanthes* introduites sur le plateau de l'Adamaoua au Cameroun

Résumé

L'adaptabilité et la productivité de plusieurs acquisitions de Stylosanthes *ont été évaluées à la station de recherche zootechnique de Wakwa sur le plateau de l'Adamaoua (Cameroun). Précédée d'un essai de germination des semences, l'étude en milieu réel comportait trois volets, à savoir 1) la production de semences; 2) l'évaluation de la production cumulée de coupes effectuées à 60 jours d'intervalle pendant la saison humide; et 3) l'évaluation de la croissance jusqu'à la fin de la saison humide suivante. Les acquisitions FAO 46004, FAO 46482 et FAO 46484 de* S. guianensis *ont produit respectivement 394, 357 et 256 kg de semences par hectare. Par ailleurs, l'acquisition FAO 46004 de* S. guianensis *venait en tête pour la productivité avec une production de 5,1 t de MS/ha tandis que FAO 46497 également de* S. guianensis *avait produit 5,3 t de MS/ha à la fin de la saison sèche.*

Introduction

The alternation of dry and rainy seasons in the savannah region of West Africa has a great impact on the productivity of rangelands. During the rainy season, range plants grow fast and although their quality may be adequate early in the season, they mature rapidly with a resulting decline in nutritive value (Pamo and Pieper, 1992, unpublished). This constrains the productivity of ruminant livestock that depend mainly on rangelands.

Pastoralists try to overcome this shortage of quality feed by practising nomadism and transhumance. However, these strategies are inadequate as cattle still lose 15–20% of their body weight during the dry season (Otchere, 1986; Mani et al, pp. 155–165), milk yields are low, calf mortality is high and many cows are unable to conceive because of nutritional anoestrus.

Legumes are desirable components in pasture where soil nitrogen is limiting and there is a need to increase crude-protein levels in herbage for dry-season grazing. A research programme was initiated at the Wakwa Animal Research Station in 1976 to identify legume species adapted to the Adamawa region to improve the quality and productivity of natural pastures. This paper presents some preliminary results obtained from the introduction of different *Stylosanthes* accessions between 1981 and 1983.

Materials and methods

The study was conducted at Wakwa Research Station situated about 8 km from Ngoundere, the Adamawa provincial capital, at about 1200 m above sea level. The long-term mean annual rainfall of the region is 1700 mm (Pamo and Yonkeu, 1986). The rainy season lasts for about seven months (April–October) with a rainfall peak during August and September.

The experimental site has a dark basaltic soil with pH of 5.4, organic–matter content of 4.9%, total nitrogen of 2.3% and an adequate amount of available phosphorus (92 ppm according to Olsen et al, 1954), but with low cation exchange capacity (Yonkeu et al, 1986).

The various accessions and species of *Stylosanthes* tested came from different international organisations (Office de la recherche scientifique et technique outre-mer (ORSTOM), Centro Internacional de Agricultura Tropical (CIAT), FAO etc). Before field seeding, an indoor germination trial was carried out on all accessions in 1980. Two hundred seeds of each cultivar were selected and divided into two halves. One half was treated by dipping in hot water (60°C) for three to five minutes. Treated and untreated seeds were further divided into two replicates of 50 seeds each. The seeds were scattered in petri-dishes with wet blotting paper and covered with lids. Every morning for 10 days, germinated seeds were recorded and removed. At the end of this period, the percentage of germinated seeds from treated and untreated seeds was calculated.

Each accession was grown on a 12 x 7.5 m main plot divided in three subplots (A, B and C) with two replicates of 3 x 3 m for the evaluation of seed and forage production. The following were performed in the three subplots:

- In subplot A, cumulative yield was measured during the rainy season by cutting every 60 days.
- In subplot B at the end of the dry season, biomass was cut and weighed, and effects of diseases, parasites and predators were assessed.
- In subplot C, seed yield and phenological events were recorded.

Forage was cut at about 15 cm above ground level and weighed immediately. A 500 g sample was oven-dried for dry-matter determination. At maturity, seeds were hand-harvested in a known surface area, cleaned and weighed.

Results and discussion

Germination

The best germination rates were recorded with treated seeds (Table 1). Treated Stylo cv 46004[1] recorded a 98% germination rate while untreated Stylo 46498 ranked first with a

1. All accessions are referred to by their FAO numbers; Stylo is *S. guianensis*.

germination rate of 44%. Untreated Stylos 46492, 46489 and *S. hamata* 46007 recorded the poorest germination rate (1%). These results are in agreement with previous results (Skerman, 1977). Accessions FAO 46502 and 46572 did not perform well even when treated; this may have been due to poor-quality seed since in the field trial cv 46502 performed relatively well.

Seed yield

High seed yield is an important attribute of success because it has an impact on the cost of commercial seed and on soil seed reserves for recruitment of new seedlings in pastures. Due to variable growth rates, some accessions had good potential for seed production: *Stylo* 46004, 46482 and 46484 ranked highest with 394 kg, 357 kg and 256 kg/ha of seed, respectively, while cv 46489, 46500 and 46492 show promise and should be kept under close observation (Table 1). These results are better than those obtained in Zaire by Risopoulos (1966) or in Queensland where seed yields reached 330 kg/ha (Gilchrist, 1967). Skerman (1977) reported an average *Stylosanthes* seed production of between 90 and 100 kg/ha.[2]

Table 1. *Seed yield and germination percentage of treated and untreated seed of FAO accessions of* Stylosanthes.

Accessions	Germination(%)		Seed yield (kg/ha)
	Treated	Untreated	
46004	98	5	394
46482	83	2	357
46484	73	10	256
46489	53	1	162
46500	80	4	148
46492	83	1	107
46499	80	2	99
46491	63	6	98
46498	96	44	52
46481	83	2	–
46493	76	10	–
46497	31	5	–
46502	2	8	–
46495	–	5	–
S. capitata 46009	69	2	80
S. subsericia 46512	1	5	51
S. hamata 46009	–	–	80
46007	–	1	21

Seed production of the other *Stylosanthes* species was much lower than for stylo accessions. Yields of *S. hamata* were surprisingly low in view of the high yields reported by Agishi (pp. 275–285).

Forage production

The rainy season forage production of the different stylo cultivars was highly variable (Table 2). *Stylosanthes guianensis* 46004 was best followed by 46482 and 46493. These yields are in agreement with some studies cited by Skerman (1977), but are lower than the 11 t DM/ha of DM recorded by Gilchrist (1967) in Queensland and the 19–20 t DM/ha obtained

2. Seed yields are comparable to those reported by Kachelries and Tarawali (pp. 291–301), but much lower than the yields summarised by Agishi in Table 2 (p. 286).

Table 2. *Wet- and dry-season yields (t DM/ha) of* Stylosanthes guainensis *accessions over three years, 1981–83.*

Accession	1981		1982		1983		Mean	
	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
46004	4.62	–	4.28	4.08	6.26	1.19	5.01	–
46482	3.05	5.50	5.40	4.76	5.71	2.70	4.70	4.32
46484	2.61	11.38	2.77	7.36	6.48	1.65	3.96	6.80
46489	3.85	5.20	1.75	2.86	5.62	1.39	3.74	3.15
46481	0.63	–	3.67	6.01	6.46	1.48	3.59	–
46491	1.97	5.36	3.50	0.49	3.68	0.75	3.05	2.20
46498	2.28	4.09	2.77	4.68	3.93	1.37	2.99	3.38
46497	2.12	6.58	3.17	6.17	3.54	3.24	2.94	5.33
46503	1.36	–	2.33	–	2.35	–	2.01	–
46499	3.00	–	2.21	–	–	–	–	–
46500	–	–	5.80	2.41	4.91	1.27	–	–
46502	–	–	–	0.85	–	0.71	–	–
46493	–	5.31	–	3.56	–	1.93	–	3.60

by Pamo and Yonkeu (1989) in the Faro lowlands of the Adamawa plateau. Nevertheless, these yields appear promising especially as no phosphorus fertiliser was applied.

The other *Stylosanthes* species (*hamata*, *capitata* and *fructicosa*) also showed variable results and yielded less than most of the stylo cultivars both during the rainy and the dry seasons (Table 3). The general decline in forage production in 1983 was due to the severe dry season. No specific disease, parasite or predator effects were recorded.

Table 3. *Wet- and dry-season yields of accessions of* S. capitata, S. fruticosa *and* S. hamata *over three years, 1981–83.*

Accession	1981		1982		1983		Mean	
	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
S. capitata								
46009a	1.08	2.64	0.90	2.56	1.18	0.65	1.06	1.92
460096	1.08	2.43	0.90	2.56	3.21	1.23	1.37	2.07
S. fruticosa[1]	–	–	3.62	1.42	3.38	1.81	–	–
S. hamata[2]	2.03	1.62		1.24		1.63		

1. FAO 46477.

2. FAO 46007.

Evaluating Stylo cultivars on three major attributes — seed, wet-season yield under cutting and end of dry season yields over a three-year period — appears sound (Table 4). This evaluation identified three cultivars (46482, 46484, 46004) that excelled in all attributes, whereas others performed poorly when cut, but yielded better in the dry season (e.g. 46489, 46497). Some other cultivars (46406, 46493, 46500) showed promise but did not undergo the entire screening procedure. Other attributes such as persistence may be added; the best cultivars persisted well, while others (46406, 46491) showed poor dry-season performance. Appraisal by attributes may be useful when recommending mixtures. This is particularly important when year-round use is envisaged including grazing, cut and carry in the wet season and hay-making for the dry season. If a final attribute like anthracnose tolerance were added, mixtures could be "balanced" for risk-spreading.

Table 4. *Production scores of the six most promising* S. guianensis *accessions.*

FAO accession	Seed production		Rainy season production		Dry season production		Total score
	Yield (kg/ha)	Score	Yield (t/ha)	Score	Yield (kg/ha)	Score	
46482	357	5	4.70	5	4.32	5	15
46484	256	4	3.95	4	6.80	6	14
46004	394	6	5.05	6	1.76	2	14
46489	162	3	3.74	3	3.15	4	10
46491	98	1	3.05	1	2.20	3	5
46500	148	2	3.57	2	1.22	1	5

This preliminary evaluation has clearly shown the adaptability and high potential for stylo production in the Adamawa region for improved pastures. The environmental conditions of this area appear favourable for high forage yields. However, more research is needed to identify the best agronomic practices and management techniques to improve and sustain these yields. Few other species of *Stylosanthes* were included in the evaluation, hence screening and evaluation of a broader range of legumes is recommended.

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Section 3

The dynamics, nutrient requirements, pests and diseases of *Stylosanthes* species

Population dynamics and yield of *Stylosanthes hamata* cv Verano pastures in northern Nigeria

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Abstract

Detailed investigations were carried out in 1977 on the plant population biology of *S. hamata* pastures at the National Animal Production Research Institute (NAPRI) research station near Zaria in Nigeria. Population densities were monitored in pastures aged one to three years from germination to the end of the growing season. Effects of the temporal density changes on seedling mortality, plant growth and flowering behaviour are reported in this paper.

In all pastures seed stocks were high giving initial seedling densities of 300–10 000 plants/m^2 and producing final yields of 4–8 t DM/ha. Due to this good initial establishment, competition from volunteer vegetation was low and final yields contained 60–80% of legume. These results confirm that *S. hamata* can retain long-term productivity provided a large seed pool is kept intact across growing seasons.

Dynamique de la population et production des parcours de *Stylosanthes hamata* cv. Verano dans le nord du Nigéria

Résumé

La biologie des plantes des parcours à S. hamata *a été minutieusement étudiée en 1977 à la station de recherche du National Animal Production Research Institute (NAPRI) près de Zaria (Nigéria). La densité des plantes sur des parcours établis depuis un à trois ans a été régulièrement enregistrée de la germination à la fin de la saison de croissance. L'effet des variations de la densité au cours du temps sur la mortalité des plants, la croissance des plantes et les caractéristiques de la floraison est décrit.*

Le stock semencier était important sur tous les parcours, avec des densités initiales de plants de 300 à 10 000 pieds/m^2 *et des chiffres de production finale de 4 à 8 t de MS/ha. Compte tenu de cette bonne occupation initiale, la proportion de plantes adventices était faible et la production finale contenait 60 à 80% de légumineuses. Ces résultats montrent que* S. hamata *peut demeurer productif pendant longtemps à condition de disposer d'un bon stock semencier d'une saison de croissance à l'autre.*

Introduction

Understanding the population dynamics of *Stylosanthes* species in mixed grass–legume pastures is a necessary prerequisite for designing effective methods of establishment and developing biologically sound management strategies aimed at sustainable long-term yields with high legume content. In Katherine (Australia) research over a 10-year period showed that differences in performance among several stylo species in response to different stocking rates and phosphorus (P)-fertiliser applications were related to the amount of seed in the soil (Mott et al, 1989; Winter et al, 1989a; 1989b). This research also demonstrated that the superior yield performance of *S. hamata* cv Verano was due mainly to its consistently large seed pool.

In the subhumid zone of Nigeria high seed and seedling densities in fodder banks were closely associated with successful establishment and satisfactory production levels for periods of up to five years. Suitable establishment techniques (late burning, pre- and post emergence heavy grazing) combined to achieve seedling densities of 120–140 plants/m^2 in perennial stylo cv Cook (Mohamed-Saleem, 1986: 337). These studies also indicated why Cook stylo was ousted by Verano stylo over time; although anthracnose attacks may have played a role, seedling densities of Verano were five to eight times as high as those of Cook (260 vs 42/m^2, Mohamed-Saleem, 1986: 348). Likewise, in productive fodder banks seed reserves of Cook stylo varied from 80–800 seeds/m^2 as compared to 1500–2600 seeds/m^2 in Verano (Mohamed-Saleem, 1986: 348). In older fodder banks (two to four years) recorded seed stocks ranged from 650–3000 seed/m^2 with total biomass yields of 4.2–7.2 t DM/ha containing 50–70% legume herbage (Mohamed-Saleem, 1986: 326–350). These seed stocks are similar to those reported by Mott et al (1989: 1238) and like in Nigeria, produced legume yields of 2–4 t DM/ha.

In Shika (NAPRI) the population biology of *S. humilis* and *S. hamata* was studied in detail during the 1977 growing season. This research was undertaken because during the early 1970s *S. humilis* was extensively evaluated for improvement of communal rangelands. This evaluation included studies on establishment (tillage methods, ant control), competitive ability, yield performance and nutritive value (de Leeuw, 1974; de Leeuw and Brinckman, 1974). When *S. hamata* cv Verano was shipped from Queensland to Shika (Agishi, 1982), its superiority over *S. humilis* was rapidly recognised prompting comparative studies (Roeleveld, 1978).

Roeleveld (1978) compared germination and establishment of both species in the laboratory and in pots confirming similar growth performance. However, field trials demonstrated the superiority of *S. hamata* due to higher seedling survival, more flexible flowering behaviour and higher seed yields. This paper deals with the population dynamics of three differently aged *S. hamata* pastures to further demonstrate why *S. hamata* has performed well in many different circumstances from fodder banks to intercropping with millet in Niger (Garba and Renard, 1992) and maize and sorghum in Nigeria (Tarawali et al, pp. 81–95).

Results

Effect of sowing date on first-year establishment and yield

Stylo pods were sown on five dates during the 1977 growing season in small plots (0.9 x 1.8 m) in four replicates. Sowing was done after sufficient rain had fallen to wet the soil surface. Rainfall during the week after each sowing varied from 27 to 45 mm (Table 1). Treated pods (soaked in warm water (75°C) for five minutes) were broadcast after shallow hand cultivation at an equivalent of 12 kg/ha or about 270 pods/m^2. Seedling density, flowering behaviour and plant cover were monitored throughout the growing season.

Initial plant density varied from 37 to 134 seedlings/m^2 and was influenced by both total rainfall and number of rainy days following seeding. The highest densities occurred at the last date when 37 mm fell during the night before sowing. Seedling mortality was high in the earlier sowings due to a dry spell in early July. Due to good rains in August lower mortality was observed in populations from the last two sowing dates. A similar trend in plant density was apparent at the end of the growing season in that differences between maximum and final plant density declined with later sowings (Table 1). Initial germination percentages ranged from 14 to 50%; for the last sowing maximum germination per cent reached 59% of pods sown.

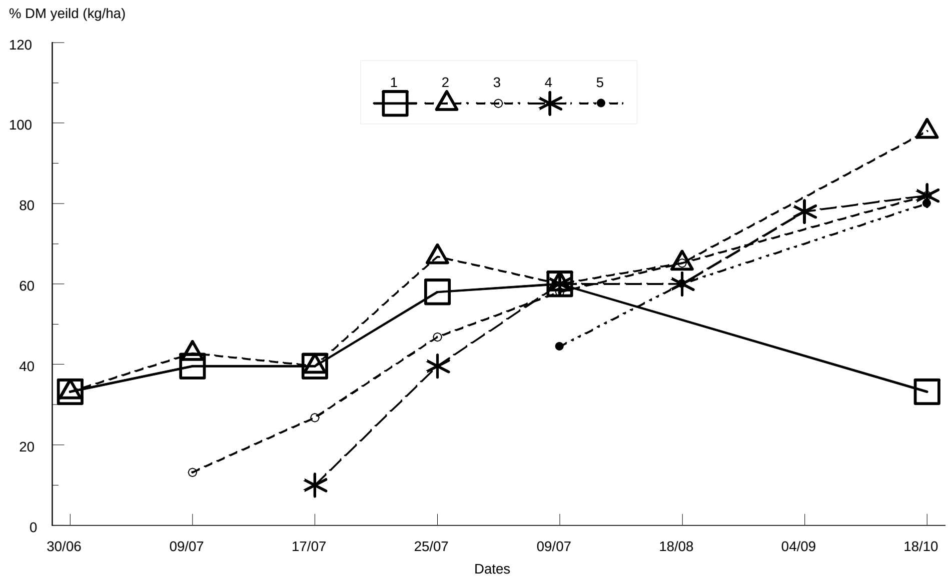
Table 1. *Effect of sowing date on plant density of Verano stylo in the establishment year.*

Sowing date	Rain[4] (mm)	Plants/m^2 +		
		Initial[1]	Maximum[2]	Final[3]
31 May	41(3)	75	109	44
6 June	27(1)	37	83	49
14 June	32(4)	48	87	80
24 June	31(7)	130	130	94
19 July	47(3)	134	159	153

1. After initial germination wave, one week after sowing.
2. In mid-August, when seedling densities stabilised.
3. On 18 October, when final yields were determined.
4. Rainfall during the week of the initial germination; the number of rainy days in brackets.

After seeding, plant cover developed rapidly to 40% within the first 30–40 days and to almost complete cover at the end of the season for all but the first sowing (Figure 1). Total and stylo yields for the first four sowings were not significantly different with legume percentages amounting to 67–71%. Despite a growing season of only 90 days both stylo and volunteer weed yields were highest in stands sown on 19 July (Table 2). The plots that were sown early had volunteer vegetation consisting mainly of annual grasses in contrast

Figure 1. *Evolution of total plant cover during the first season for five sowing dates[1] for Verano stylo.*



1. Sowing date is represented by plant cover of 0%.

Table 2. *Effect of sowing date on final yield of Verano stylo in the establishment year (t DM/ha).*

Sowing date	Stylo	Weeds	Total	Stylo (%)
31 May	3.75	1.87	5.62	(67)
6 June	4.45	1.89	6.34	(70)
14 June	4.41	1.37	5.78	(76)
24 June	3.87	1.54	5.41	(72)
19 July	4.86[1]	2.36	7.22[1]	(67)

1. Only stylo and total yields of the 5th sowing (19 July) were significantly different from those in earlier sowings.

to forbs which dominated in the plots sown later. Age at first flowering decreased from about 60 days in plants sown in early June to 45 days in stylo established in mid-July. Since final plant populations increased with delayed sowing and end of season yields differed little (Tables 1 and 2), plant weight declined from 8.5–9.0 g for the first two sowing dates to 3 g per plant for the last sowing date, representing plant ages of 123–130 and 90 days of growth, respectively.

Establishment and yield in a second-year Verano stylo

Seedling development, plant cover and final yield were also monitored in second-year Verano stylo stands. In 1976 Verano stylo was sown in rows after thorough seedbed cultivation and an application of 375 kg/ha of single superphosphate. During the first growing season plots were weeded twice to facilitate seed harvesting in the following dry season. In May 1977, all standing herbage was removed before monitoring started.

Seedling emergence began after 17 mm of rain fell on 30–31 May 1977. Two weeks later a dense sward of Verano had developed with seedling densities ranging from 4500 to 13 500 plants/m^2 (mean: 10 300). Fifty days later (on 22 July) the original seedling population had declined by 30% to 7400/m^2, but new germination waves added another 2200 plants/m^2 thereby retaining densities close to the maximum reached earlier. In mid-November, about one month after the end of the rains, the population had declined to 4800 plants/m^2.

Total plant cover developed rapidly reaching 50% within six days in the most densely populated patches of the sward (Table 3) and remained at 52–56% green cover up to 22 July despite the doubling of the seedling population. During the first 15 days the ratios between number of seedlings and plant cover remained constant, with 1000 plants occupying about 340 cm^2 of space. In late July plant:space ratios diverged from 730 cm^2/1000 plants at the low density to 450 cm^2 at the high density. Cover of volunteer vegetation remained low indicating that although sufficient bare ground was available (32–65% in late July), moisture competition from the dense stylo patches may have prevented establishment of weeds.

Table 3. *Relationship between seedling density, stylo and weed cover in the establishment phase of a second-year Verano stylo stand during the first 60 days of growth in 1977.*

Density[1] class	6 June			15 June			22 July		
	Seedling cover (%)								
	('000/m^2)	Stylo	Weeds	('000/m^2)	Stylo	Weeds	('000/m^2)	Stylo	Weeds
1	2.5	13	3	4.5	15	3	3.4	25	10
2	4.2	27	1	8.3	29	2	8.1	43	6
3	5.7	54	1	13.5	52	2	12.4	56	12

1. To account for stand heterogeneity, sample plots were stratified in three density classes.

At 85 days of age stylo yielded 1.6 t DM/ha, equivalent to a daily growth rate of 19 kg DM/ha. Over the following two months, from late August, this rate increased to 90 kg DM/ha per day showing a maximum standing stylo crop of 7.2 t DM/ha on 27 October. Due to leaf and seed fall, yield dropped by 20% to 5.7 t in mid-November.

Stand density remained high throughout the growing season falling from 6100 plants in early August to 4800 plants/m^2 in mid-November. Given an available space of about 0.5 cm^2 per plant, most plants remained single-stemmed and expanded vertically rather than laterally. In mid-September 40% of the plants were < 10 cm tall while only 30% were over 20 cm in height. Plant weight remained low increasing from 0.1 g/plant in mid-September to 0.2 g at maximum legume yield in late October.

Establishment and yield in third-year Verano stylo

In 1975 a small grass pasture (0.2 ha) was converted to Verano stylo for seed production. The area was hand-hoed in May and stylo was sown in rows at a seed rate of 6 kg of pods per hectare; 100 kg of single superphosphate was applied. In 1975 the area was weeded twice but not thereafter. Seed was harvested in the dry seasons of 1975 and 1976. In December 1976 all stylo plants had died and all litter was removed after seed harvest.

Germination started on 1 June 1977 and within 10 days seedling density rose to 4000 plants/m^2. Although plant density declined by 20% during July, surviving stylo plants expanded rapidly tripling their cover within a 65-day period and covering about half the available space (Table 4). As in the two-year-old stand, competition from volunteer grass and weeds was limited and up to the end of July 80% of the green cover consisted of stylo (Table 4).

Table 4. *Relationships between plant density and plant cover in a third-year Verano stylo stand during the establishment phase.*

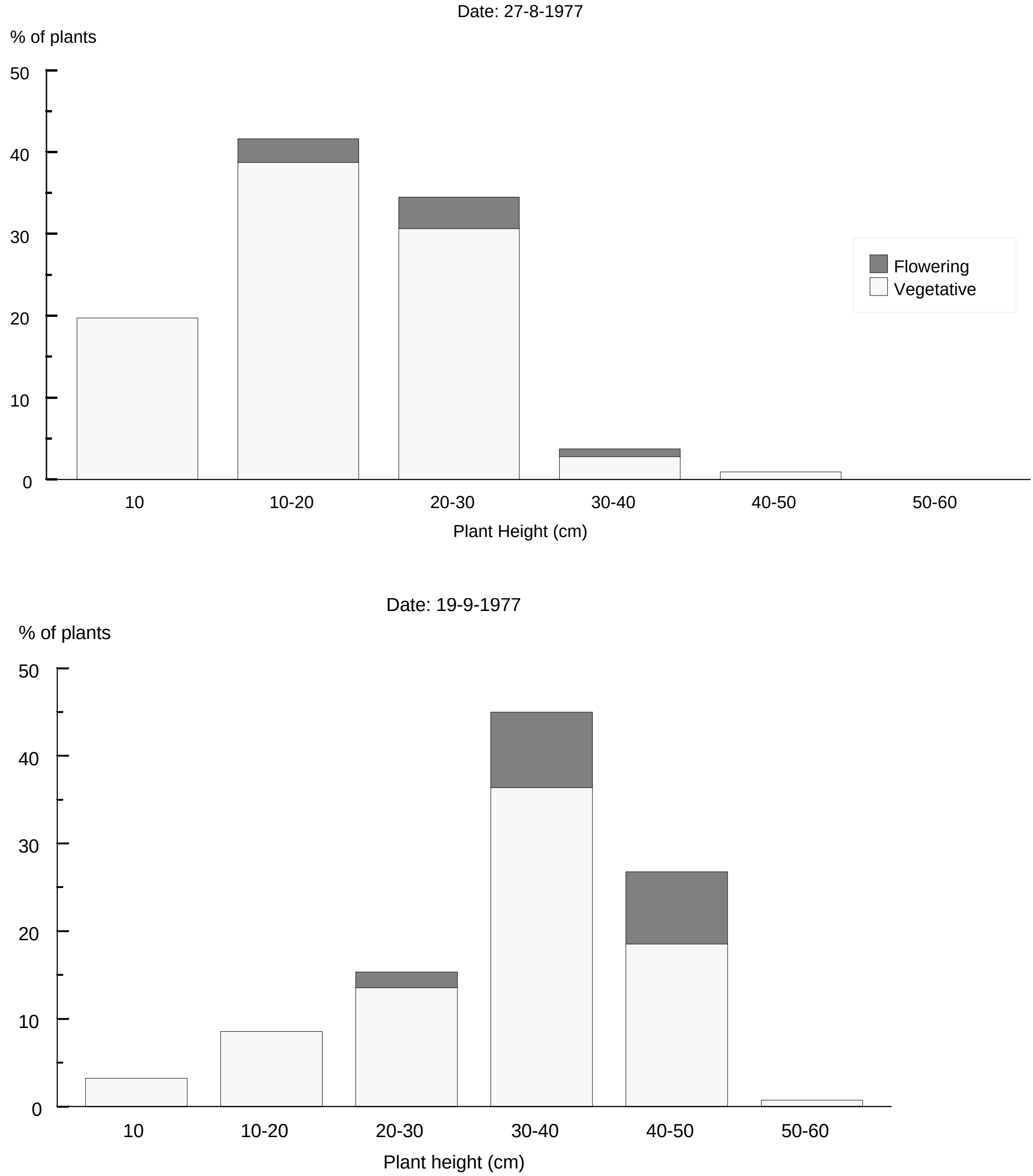
Parameters	10 June	15 June	3 July	18 July	22 July
Stylo density ('000/m^2)	3.8	3.6	4.0	3.2	3.1
Stylo cover (cm^2/1000 plants)[1]	390	720	1050	1120	450
Plant cover (%)					
Stylo	15	26	42	36	45
Grasses and herbs	3	4	8	9	12
Dry litter	22	14	7	7	2
(Bare ground)	(62)	(57)	(49)	(46)	(42)

1. Calculated from stylo density and cover per cent.

Later in the growing season, plant density dropped rapidly to 2360/m^2 at the end of August and to 1270/m^2 on 19 September. At those dates dry stylo yields were 1.85 t/ha and 3.81 t/ha, respectively. These yields converted to an average plant weight of 0.1 g and 0.3 g DM, respectively. Most plants were single-stemmed; in late August, 60% were less than 20 cm tall and only 7% were flowering. Three weeks later half of the plants were over 30 cm tall and the flowering fraction reached 19% (Figure 2), indicating that despite the low average weight, the taller plants managed to flower.

Growth rates resembled that of the dense two-year stands: from 20 kg DM/ha per day during the first three months, but accelerating to 70 kg DM/ha per day during the last 40 days. In early October stylo yield reached 4.7 t DM/ha. Competition from grasses remained low and legume content in the total biomass remained fairly constant at 70–75%.

Figure 2. *Distribution of plant height (cm) in flowering and non-flowering stylo plants on two dates in a 3-year-old stand.*



Discussion

In the establishment year neither date of planting nor seedling density had much effect on final legume yields (Tables 1 and 2), indicating that *S. hamata* is extremely flexible, can adapt to variable lengths of growing season and fill available space through plant expansion. Apparently, 90 days of growth was sufficient to produce 5 t DM/ha and explained its success in the semi-arid zone in Niger where in good rainfall years, it flowers, sets seed and can produce up to 16 t DM/ha (Garba and Renard, 1992).

In older pastures, surprisingly high plant densities were retained up to the end of the growing season, demonstrating that seedlings can survive high between-plant competition throughout the growing season and cope well with the invasion of other species (Tables 3 and 4). Despite low plant weight, a proportion of plants managed to flower (Figure 2). However, whether seed was produced is not certain. Given the satisfactory yields at those high densities, the negative relationship between plant density and Verano content in the total yield as reported by Gardener (1984:338) was not found.

The maintenance of high plant density may have been related to the absence of grazing. The beneficial effects of grazing during the growing season have been widely reported (e.g. Agishi, 1982; Mott et al, 1989) and are usually attributed to reducing the competition from aggressive volunteer grasses. Following preferential grazing, longer-term effects of grazing may cause changes in the seed pool. Patch grazing of Verano may increase diversity in plant size promoting greater seed yields than in more homogenous high-density populations. However, while Mott et al (1989) showed increased number of Verano plants and higher yields in grazed patches, seed stocks were also adequate in ungrazed patches (8700 vs 5200/m^2) and unlikely to impede subsequent regeneration. Yield stability may be further enhanced by the survival of larger plants into the next growing season, which did not happen in the homogenous dense stands reported here.

Due to low leaf:stem ratios, dense stands of Verano are unlikely to produce high-value dry season feed for livestock. It can thus be concluded that while this research showed the high vigour and adaptability of Verano stylo, for sustained productivity, sward manipulation by grazing during the growth period should be an essential component of overall fodder bank and ley pasture management.

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Management and nutrient requirements of *Stylosanthes* in pasture and cropping systems in the subhumid zone of Nigeria: A review

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Abstract

During the 1980s, the management and nutrient requirements of *Stylosanthes* in pastures and cropping systems were investigated at several ILCA research sites in northern Nigeria. While *Stylosanthes guianensis* cv Cook and cv Schofield responded to phosphorus (P), *Stylosanthes hamata* cv Verano did so to a lesser extent. Results from nutrient omission trials showed that the soils of one specific experimental area were deficient in most of the essential nutrients. Application of *Kanwa* (a local mineral salt) of up to 100 kg/ha on old and newly established Verano stylo increased dry mater (DM) yield significantly. Good growth of *Stylosanthes capitata* was associated with low pH and calcium, but high levels of organic carbon and total nitrogen (N) in the top soil. On sites with indurated or poorly drained subsoils, disc-harrowing followed by sub-soiling lowered bulk density and increased water storage as compared to ridging or no second tillage; it also resulted in a higher DM yield of Verano stylo.

Revue des recherches sur la gestion et les besoins en éléments nutritifs du *Stylosanthes* dans les parcours et les systèmes agraires dans la zone subhumide du Nigéria

Résumé

Au cours des années 80, la gestion et les besoins en éléments nutritifs du Stylosanthes *ont été étudiés dans les parcours et les systèmes culturaux sur plusieurs sites de recherche du CIPEA dans le nord du Nigéria. L'application de phosphore avait un effet significatif sur* Stylosanthes guianensis *cv. Cook et cv. Schofield mais peu d'influence sur* S. hamata *cv. Verano. Il ressort des résultats des essais d'omission d'éléments nutritifs que la plupart des éléments essentiels manquaient dans les sols d'une région donnée. L'application du* kanwa, *un sel minéral local, à une dose inférieure ou égale à 100 kg/ha sur des parcours de Verano installés récemment ou depuis longtemps augmentait significativement la production de matière sèche.* Stylosanthes capitata *croissait bien lorsque le pH et la teneur en calcium étaient faibles et les niveaux de carbone organique et d'azote total élevés dans l'horizon supérieur du sol. Sur les sites au sous-sol induré ou mal drainé, un hersage suivi d'un sous-solage permettait,*

par rapport à un billonnage ou à un seul labour, de réduire la densité apparente et d'accroître la capacité de rétention d'eau; par ailleurs, cela augmentait la production de matière sèche du Verano.

Introduction

The subhumid zone in Nigeria covers an area of 455 000 km^2, has an annual rainfall ranging from 1000 to 1500 mm and a crop growing season of 180–270 days (Nord, 1982). In this zone, low abundance of indigenous legumes and the rapid decline in the quality of native grasses when approaching maturity contribute directly to low livestock productivity. To overcome dry season feed constraints, *Stylosanthes* species were introduced to improve fodder quality and quantity. However, forage yields are often lower than those obtained in northern Australia where similar climatic conditions prevail. This poor performance is mainly caused by the low fertility and poor physical characteristics of the predominant soils (Mohamed-Saleem and von Kaufmann, 1986). For instance, several soil types in the zone tend to form hard surface crusts after the first rains, preventing penetration of water and seedling emergence. Most soils contain clays with a predominantly kaolinitic structure and are moderately acid, low in organic matter and cation exchange capacity (CEC) and deficient in nitrogen (N) and phosphorus (P) (Kadeba, 1978; Lombin, 1979). In settled agricultural systems, soil fertility declines rapidly following continuous cultivation (Wild, 1971; Heathcote, 1972; Lombin et al, 1985).

The soils of the Nigeria's subhumid zone are predominantly developed over parent materials of the Pre-cambrian Basement Complex. The major soil groups include ferruginous tropical soils (or Luvisols) covering about 50% of the zone. These soils are characterised by a sandy surface horizon overlying a somewhat indurated or poorly drained layer of weakly structured clay accumulation. They have a very low CEC, but a relatively high base saturation and pH. Though rated by FAO (1966) as relatively highly fertile, these soils are sensitive to erosion and have a low water-holding capacity. Ferralsols, occupying much of the rest of the subhumid zone, are deep and strongly weathered with a friable consistency. They have a low CEC, low pH and low nutrient content, but because of their resistance to erosion and good physical properties they are suitable for a wide range of crops.

Lithosols, mainly located in the north and central parts of the zone, are shallow, moderately leached with low organic matter, low CEC and low moisture storage capacity. Vertisols are found mainly in the eastern part of the zone; they crack deeply when dry, become waterlogged when moist and are of medium productivity, despite being generally high in nutrients. Alluvial soils are mostly found along the Niger and Benue rivers; they show accumulation of organic matter, are often flooded or waterlogged during the rainy and suitable mainly for the growing of rice.

Phosphorus and sulphur (S) are considered the most deficient minerals throughout the zone. Deficiency of potassium (K), as a result of intensive cropping, may become an important factor limiting crop and forage yields (Heathcote, 1972). Calcium (Ca) levels are relatively high in contrast to magnesium (Mg) which is often deficient (Lombin, 1979). In most of the subhumid zone, soils are high in iron (Fe) and manganese (Mn), but deficient in copper (Cu) and to a lesser extent zinc (Zn) (Mohamed-Saleem and Otsyina, 1987).

Materials and methods

Experimental sites

Most of the trials were conducted on ILCA's main research site located at Kurmin Biri (Latitude 10^o18'N, Longitude 7^o19'E). This site is characterised by a mean annual rainfall of about 1200 mm, falling from May to October with a single peak in July–August (Tarawali et al, pp. 81–95). The physical and chemical properties of the respective trial sites are given in Table 1. Other trials were conducted at Abet (9°40’N, 8°10’E) and Ganawuri (9°0’N, 8°35’E) with climatic conditions similar to those at Kurmin biri, but located on different soil types.

Table 1. *Some chemical and physical properties of soils on experimental sites.*

Parameters	Trials					
	P[1]	NC[1]	KAN[1]	TM1	CAP[2]	KAN[3]
pH (H_2O)	5.2	5.2	5.4	6.3	5.3	5.4
Organic C (%)	0.58	0.58	-	1.48	0.21	–
Total N (%)	0.07	0.07	0.08	0.11	0.09	0.10
Available P (ppm)	3.9	3.9	4.5	1.4	1.8	3.9
Ca (meq/100g)	1.12	1.12	1.12	–	–	0.91
Mg (meq/100g)	0.37	0.37	–	–	–	–
K (meq/100g)	0.13	0.13	0.16	–	0.13	0.28
CEC (meq/100)	–	–	–	3.6	–	–

1 = Kurmin Biri; 2 = Abet; 3 = Ganawuri.

P – Phosphorus trials (Mohamed-Saleem and von Kaufmann, 1986).

NC – Nutrient changes trials (Mohamed-Saleem et al, 1986).

KAN – *Kanwa* as fertiliser (Mohamed-Saleem and Otsyina, 1987).

TM – Tillage methods (Adeoye and Mohamed-Saleem, 1990); 8% clay, 6% silt, 82% sand, 2% gravel.

CAP – Special nutrient requirements of *S. capitata*.

Phosphorus trials

On-farm trials with *Stylosanthes* intercropped with cereals and sown on fallow lands, identified P as the most limiting element. Phosphorus response trials were therefore carried out in 1981 and 1982. A factorial design with three legumes (*S. guianensis* cv Cook and cv Schofield and *S. hamata* cv Verano) and four levels of phosphorus (0, 40, 80 and 120 kg P_2O_5/ha) were established. Basal K, Zn, Mg and Ca were applied to all plots in the first year at 80, 5, 20 and 20 kg/ha (as muriate of potash, $ZnSO_4$, $MgSO_4$ and $CaSO_4$, respectively). Scarified seeds of stylo cultivars (12 kg/ha) were broadcast. Plots were kept weed-free during the first two months of growth to encourage adequate stylo cover. Yields were recorded each year by cutting at ground level in November and, to reduce termite attack, all standing herbage (thus excluding fallen leaves, seeds and other litter) was removed. Composite soil samples at 0-15 cm depth were taken from each plot at harvest and analysed for pH, total N, organic carbon, P and K (Table 1). Dry plant samples, composited by treatment, were analysed for crude protein and P content. Starting from 1990, further work on the response of Verano stylo and, a companion legume, *Centrosema pascuorum* to P application (0, 20, 40, 60 and 80 kg P/ha) was carried out on a Ferric Luvisol at the same site (A. A. Tenning, unpublished).

Other soil nutrients

Stunted growth and foliar symptoms of Verano stylo were suspected to result from macro- and micro-nutrient deficiencies. Thus, field experiments were carried in 1983 to evaluate the performance of this cultivar in response to nutrient application. In the first set of experiments, responses were measured to the omission of all or one specific nutrient at a time from the mixture made up of all nutrients (P, K, S, Ca, Mg, boron (B), Cu, molybdenum (Mo), Zn and cobalt (Co); see Table 2). Scarified seeds were broadcast at the rate of 15 kg/ha. The experimental design was a randomised complete block.

The second experiment determined P and Cu requirements of Verano stylo, identified as the most deficient nutrients in the first experiment. Four levels of P_2O_5 (0, 30, 60 and 90 kg/ha) and three levels of Cu (0, 3.0 and 6.0 kg/ha) were laid out in a factorial design. Except for P and Cu, all plots received a uniform basal dressing of the complete nutrient mixture at rates given in Table 2. Composite soil samples were taken after harvest and analysed for N content, while composite plant samples were analysed for chemical composition.

Table 2. *Rates of application and compounds used to achieve desired nutrient combinations by nutrient subtraction.*

Treatment	Nutrients (kg/ha)	Chemical compounds	Treatment	Nutrients (kg/ha)	Chemical compounds
1: All nutrients		All compounds	7: Minus B	6	$Na_2B_4O_7.10H_2O$
2: Minus P_2O_5	135	$NaH_2PO_4.H_2O$	8: Minus Cu	6	$CuSO_4.2H_2O$[1]
3: Minus K	50	KCl	9: Minus ZN	6	$ZnCl_2$
4: Minus S	60	Na_2SO_4	10: Minus Mo	0.5	$Na2MoO_4.2H_2O$
5: Minus Ca	200	$CaCO_3$,	11: Minus Co	0.5	$CoC1_4.6H_2O$
6: Minus Mg	25	$MgCl_2.6H_2O$	12: No nutrients		

1. $CuCl_2.2H_2O$ provided Cu in treatments where S was eliminated from applied nutrients.

Source: Mohamed-Saleem et al (1986).

Kanwa trials

Analysis of a local salt (*kanwa*) — used by pastoralists for supplementing cattle — showed that it contained several essential nutrients (21.5, 4.7, 23.7 and 0.6% of Na, K, Ca and P, respectively; 849, 75, 407, 44, 24 and 176 mg/kg of Mg, Fe, Mn, Cu, Co and Zn, respectively). It was therefore tested as a fertiliser on legume fodder banks in three trials during 1985.

In all trials a complete randomised block design was used with five levels of *kanwa* (0, 30, 60, 90 and 120 kg/ha) together with a uniform dressing of 18 kg of P (as single superphosphate) and 30 kg of K/ha (as muriate of potash). These treatments were superimposed on i) a 5-year old Verano stylo pasture and ii) on plots cleared of their natural plant cover and sown with scarified Verano seed at 10 kg/ha. Both trials were carried out in Kurmin Biri and the second trial was repeated in Ganawuri.

Nutrient requirements of *Stylosanthes capitata*

This species generally has performed poorly and failed to nodulate well in both tropical Africa and northern Australia. In trials in the subhumid zone in 1985 and 1986, efforts to induce nodulation using several Rhizobium strains and mineral nutrients failed. However, five years later many plants surviving at the experimental sites looked healthy, were high-yielding and nodulated well whereas others grew poorly. This prompted a study of the soil factors contributing to this variable performance. At Abet, 10 soil samples were collected at two depths (0–15 cm and 15–30 cm) from areas where plants were growing poorly (usually at the bottom of the slope), moderately well (on mid-slope) and vigorously (at the top of the slope). At Kurmin Biri, the position on the catena had no effect on growth. Several areas of moderate and poor growth were identified and soil core samples were collected; soil samples were bulked separately for each treatment area by depth before analysing physical and chemical properties.

Management trials

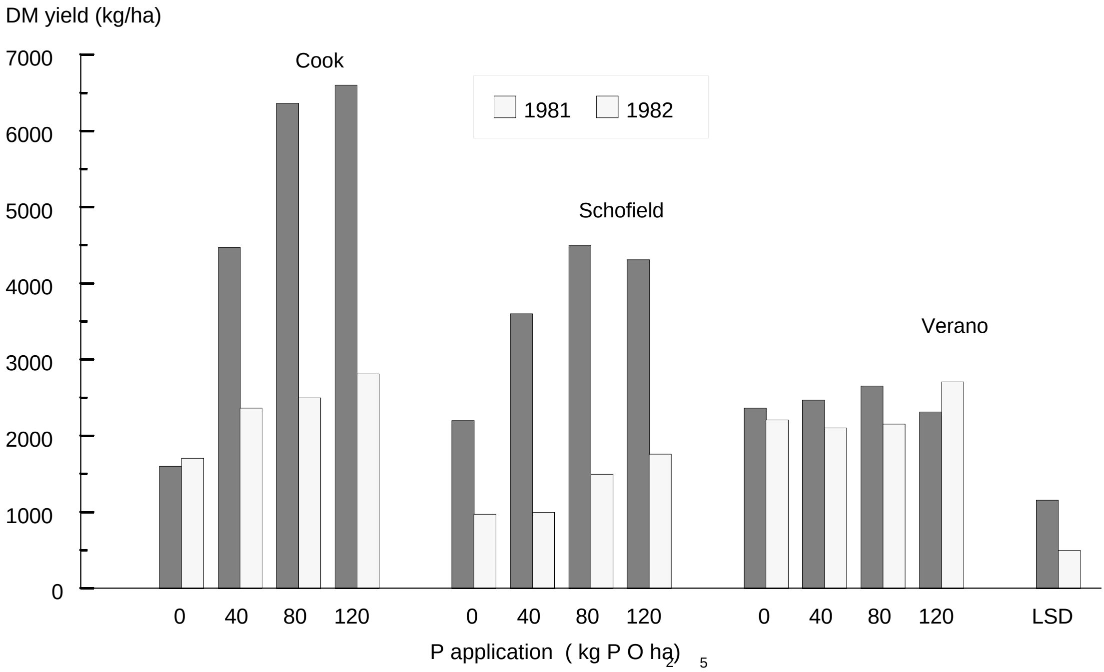
Sites with hardpans that impede plant growth are unsuitable for crop production but could be used for growing forage. Trials to test the effects of tillage methods on physical properties and yield of stylo were established in 1987. Three treatments (disc-harrowing to a depth of 10–15 cm, disc-harrowing followed by subsoiling or by ridging) were tested in a randomised complete block design. Verano stylo was sown (15 kg of scarified seeds) as a test crop with 35 kg of P/ha as SSP applied at planting. Soil cores were collected periodically during the growing season in metal rings at soil depths of 0–10, 10–20, 20–30 and 30–40 cm to determine bulk density and moisture content.

Results and discussion

Responses to phosphorus

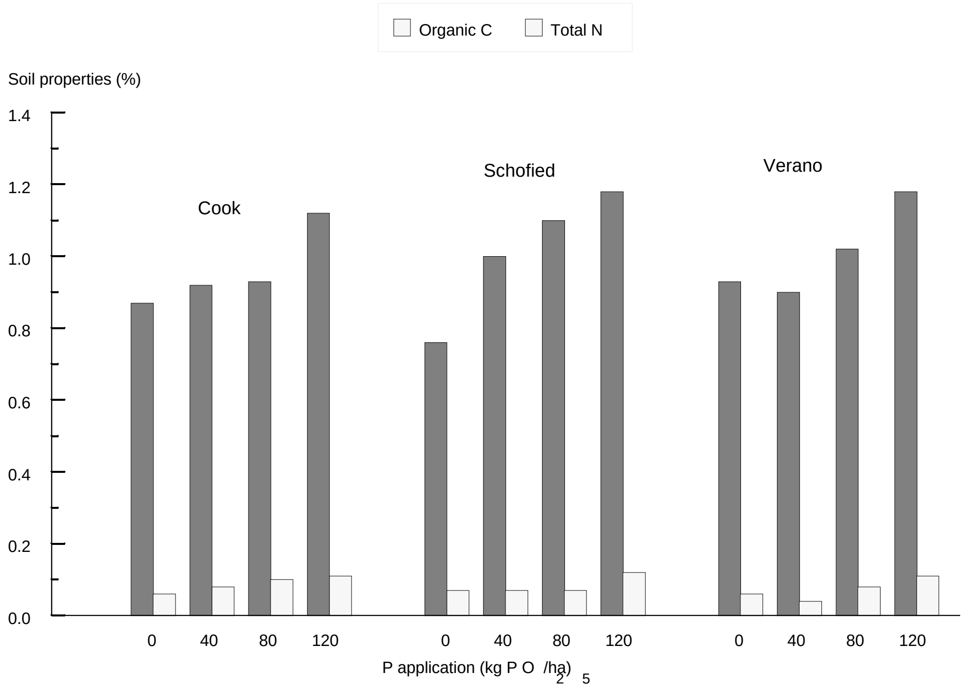
The results suggest that Verano stylo, in contrast to the two *S. guianensis* (stylo) cultivars, showed a low response to P application in the year of sowing (Figure 1). However, harvest of only standing herbage in November may have disadvantaged Verano stylo, as leaf and seed fall occurs much earlier than in the stylo cultivars (Peters, 1992). Also, the removal of herbage in November may have influenced recovery of the stylo cultivars in the second season, since, being late-maturing cultivars, little seed drop was likely and all regrowth was produced from perennating plants rather than from newly grown seedlings. This may explain why stylo yields were less than half (1–3 t DM/ha) those attained in the first year, whereas Verano stylo — being an early seeder — produced similar yields in both seasons. However, in more recent work in Kurmin Biri, Peters (1992) showed similar differential responses to P application between two newly acquired stylo cultivars and Verano stylo (see Tarawali et al, Table 8, p. 94). Soil analysis showed an increase in total N and organic carbon (C) with increasing amounts of applied P for all three stylo cultivars (Figure 2).

Figure 1. *Effect of P application on dry-matter productivity of stylo cultivars.*



Source: Mohamed-Saleem and von Kaufmann (1986).

Figure 2. *Effect of P application on some soil properties.*



Source: Mohamed-Saleem and von Kaufmann (1986).

The response to applied P on a Ferric Luvisol depended on the legume used. Verano stylo showed a strong response only up to 20 kg of P, in contrast to the linear effect ($P< 0.05$) of up to 80 kg of P/ha on *Centrosema pascuorum* (Figure 3). It is likely that the low responses to P can be attributed to the high sorption capacities and the high level of non-active forms of P in the soils found in Kurmin Biri.

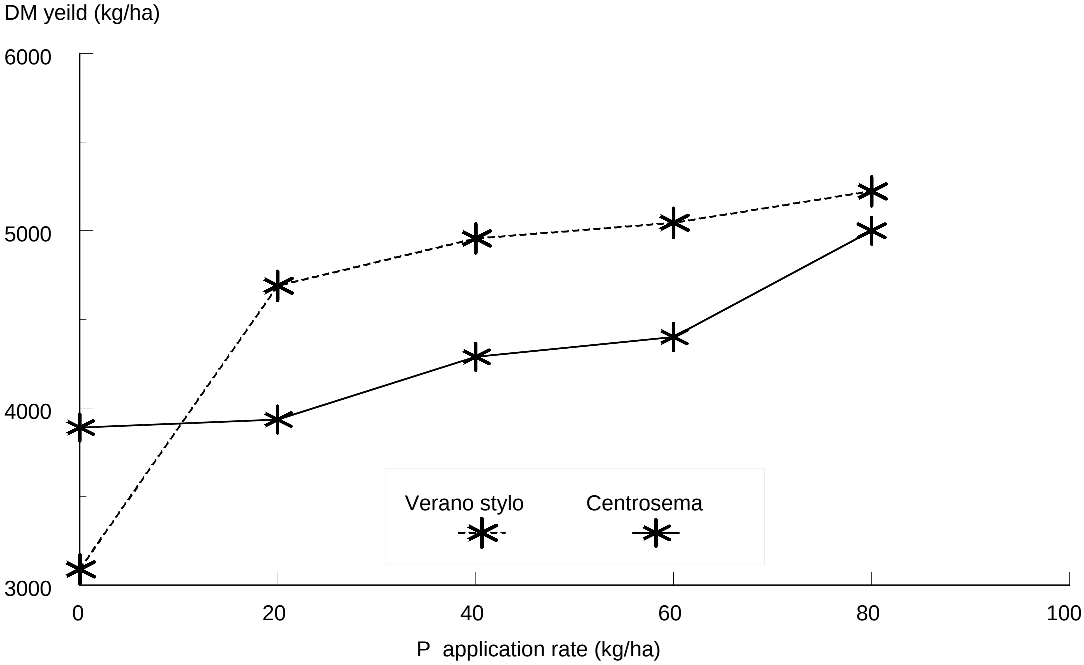
Response to other nutrients

In these trials, dry-matter yield of Verano stylo approached 5 t/ha when all nutrients, as listed in Table 2, were supplied (Figure 4). DM yields resulting from the omission of B, Mo, Zn, Mg, Ca and K were only 10–20% below the potential yield obtained when all nutrients were applied (Mohamed-Saleem et al, 1986). Eliminating Co or S resulted in a 30–40% drop in DM yield and removal of P or Cu caused a reduction of 64%. Omission of S, Zn and Mo resulted in larger yield reductions in the second year than in the first, confirming that soils in the experimental area were deficient in several essential nutrients. Actually, production declined in all treatments in the second year despite a better rainfall distribution. Because of the low cation exchange capacity (CEC) of the experimental site (2.94 meq/100 g) nutrients applied as cations are weakly held and may be lost through leaching (Jones and Wild, 1975). In the second trial, significant interactions were noted between Cu and P nutrients; application of 3 and 6 kg/ha of Cu in the absence of P increased yields by 0.4 and 0.8 t DM/ha, respectively.

Response to *kanwa*

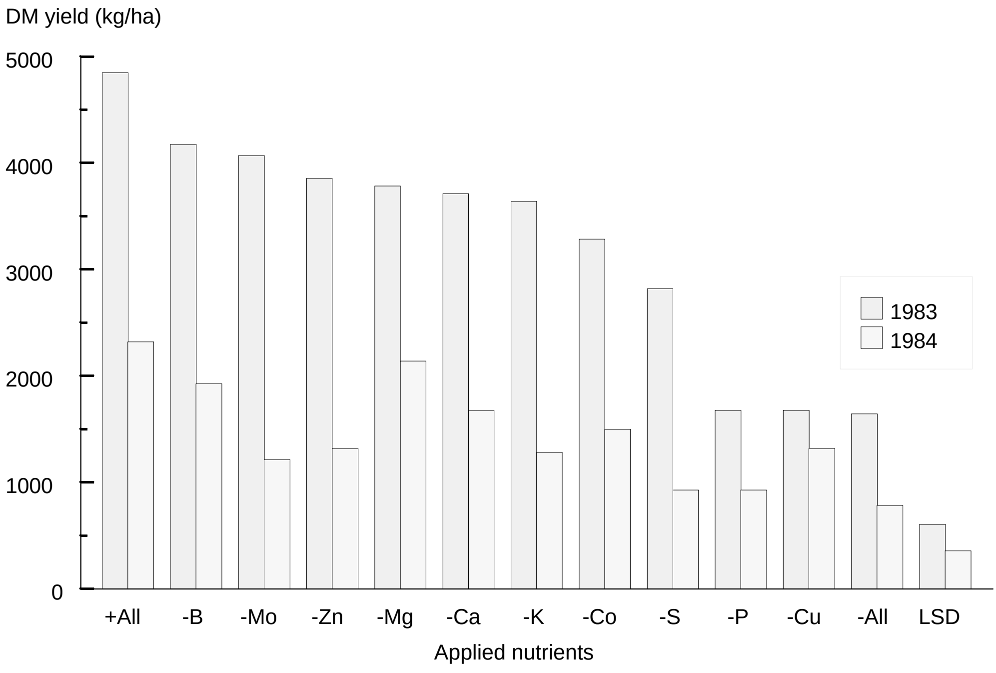
Kanwa application of up to 90–100 kg/ha on old and newly established Verano stylo increased DM yield significantly (Figure 5), but responses varied between sites, stylo species and the amount of rainfall during the growing season. In the season of application, one kilogram of *kanwa* up to the optimum level increased yield in the old Verano stylo pasture by 19 kg DM compared with 60 kg in first-year stands. This indicated that *kanwa* could be recommended as a source of cheap and locally available fertiliser.

Figure 3. *Effect of P application on dry-matter yield of Verano stylo and* Centrosema pascuorum *on Ferric Luvisol.*



Source: ILCA (1988).

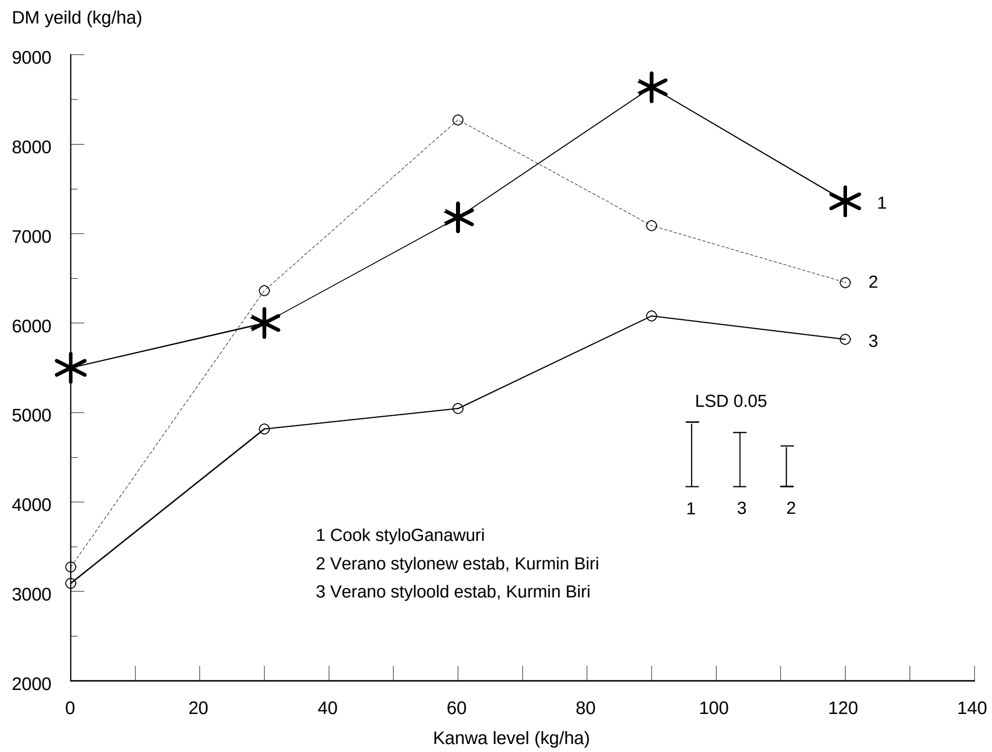
Figure 4. *Dry-matter yields of Verano stylo as influenced by varying nutrient additions.*



Source: Mohamed-Saleem et al (1986).

As all plots received a basal dressing of P and K, it is likely that the micro-nutrients in *kanwa* produced the positive response, especially of Cu and Co, the deficiency of which caused substantial yield reductions in the omission trials (Figure 3). Higher stylo yields were found in Ganawuri; although stylo is generally more productive than Verano stylo, the steep response to *kanwa* may have been due to soils which, being derived from basalt (and

Figure 5. *Effects of different levels of* kanwa *on stylo dry-matter production.*



Source: Mohamed-Saleem and Otsyina (1987).

therefore more fertile than the soils over granite in Kurmin Biri), are often found to be copper-deficient.

Nutrient requirements of *S. capitata*

The soil properties in areas showing different performances of *S. capitata* for two locations are given in Table 3. At Abet, poor, moderate and good stands of *S. capitata* produced the equivalent of 5.5± 2.7, 11.9± 1.1 and 15.7± 1.8 t DM/ha, respectively. At Kurmin Biri, plots with poor and moderate growth yielded 2.0± 0.9 and 5.4± 0.8 t DM/ha, respectively. Excellent *S. capitata* growth appears to be associated with low pH, high organic carbon and total N, and low calcium levels in the top soil. Generally, plant growth was also better on sites where the micro-nutrients were high, in particular Zn. This outcome suggests that *S. capitata* performance probably depends largely on successful nodulation, which requires a specific combination of soil pH and levels of Ca, Zn and available P. The high yields in Abet, where available Ca was lower, are consistent with those of Grof et al (1979), who observed that *S. capitata* did not nodulate effectively when soils were limed. However, nodulation occurred normally in soils with a pH of 4.3 and a corresponding high aluminum level of 3 meq/100 g.

Tillage trials

Tillage methods significantly influenced bulk density; the lowest values (1.24–1.27 g/cm^3) were encountered on ridges made of heaped top soil (0–10 cm) compared with 1.37–1.48 g/cm^3 when the surface was only disc-harrowed. Shallow disc-harrowing did not reach the subsoil (20–30 cm) and consequently higher bulk densities (1.70 g/cm^3) were found. Subsoiling reduced density to 1.39 at three weeks after tillage, increasing to 1.45 g/cm^3 at

Table 3. *DM yield (t DM/ha) of* S. capitata *growth classes and associated soil characteristics at two depths (cm) in two locations.*

Location	Abet						Kurmin Biri			
Yield class	Poor		Moderate		Good		Poor		Moderate	
Parameter (cm)	0–15	15–20	0–15	15–30	0–15	15–30	0–15	15–30	0–15	15–30
DM yield (t/ha)	5.5		–		15.7		2.0		5.4	
pH ($H_2 0$)	4.9	4.8	4.8	4.9	4.6	4.7	4.7	4.6	4.6	4.7
Organic C (%)	0.16	0.38	0.36	0.36	0.44	0.22	0.56	0.60	0.90	0.52
Total N (%)	0.028	0.042	0.056	0.042	0.056	0.042	0.056	0.056	0.070	0.070
Available P (ppm)	5.4	–	5.4	2.3	3.6	2.7	0.9	0.9	1.8	0.9
Ca (meq/100 g)	0.60	0.88	0.59	0.88	0.62	0.70	1.11	0.93	0.71	0.70
Zn (ppm)	0.8	0.5	0.6	0.5	1.8	0.6	0.6	0.6	0.9	0.5

seven weeks; the subsoil below ridges showed bulk densities of 1.48 and 1.58 g/cm^3, respectively. Due to higher rainfall infiltration or to lower runoff, stored soil moisture was significantly higher in the subsoiled plots than in either the ridged or the disc-harrowed plots (Table 4). Subsoiling significantly increased yield of Verano stylo to 6.9 t DM/ha as compared to 5.5 t on disc-harrowed and 5.0 t on ridged land. This trend showed that there is a minimum rooting depth below which Verano stylo cannot attain its yield potential.

Table 4. *Moisture storage (mm in 0–45 cm top soil) as affected by tillage method.*

Tillage method	Time after planting (weeks)		
	3	7	13
Disc-harrowing only	74	79	88
+ ridging	78	78	82
+ subsoiling	85	98	106

Source: Adeoye and Mohamed-Saleem (1990).

Conclusions

Responses to P-application vary widely between *Stylosanthes* species and soil types. Although other factors such as rainfall distribution, poor germination and seedling mortality may account for differences in yields, deficiencies of micro-nutrients contribute substantially to explain suboptimal yields. The requirements for P, S, Cu, B and Co for optimum stylo production in the subhumid zone of Nigeria has been demonstrated. Low applications of the local mineral salt *kanwa* can redress some of the nutrient deficiencies effectively. The high yields of *S. capitata* showed that it can grow well on soils with low pH, and adequate levels of P and micro-nutrients. Considering that soils with hardpan are common, subsoiling would increase pasture and crop yields on soils with poorly drained or impermeable horizons close to the surface.

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Development of management strategies for stylo with emphasis on pests and diseases

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Abstract

Stylosanthes has been cultivated in Nigeria for over two decades to supplement animal feed protein. Efforts have been directed at increasing yield with minimum attention being paid to pests and diseases of the crop. However, *Stylosanthes* species are notably susceptible to anthracnose disease all over the world. Screening many accessions of *Stylosanthes* at ILCA's subhumid research site in Kaduna showed that although anthracnose is the major disease, the genus is susceptible to other foliar diseases and basal and stem rots but there were no signs of nematode attack. The most significant pest problem was termite attack in the dry season.

Management strategies for pest and disease control in *Stylosanthes* production, including different cultural practices and the use of chemicals and resistant varieties are discussed. Cultural practices can be partially successful, whereas the use of chemicals is less feasible due to costs and technical limitations. The use of resistant accessions offers the best option; the research for such germplasm should be a continuous process that involves the interaction of pathologists, entomologists, agronomists and plant breeders.

During the evaluation programme at ILCA, Kaduna, *Stylosanthes* accessions that are resistant or tolerant to anthracnose have been identified. These are *S. guianensis* ILCA 163, 164 and 15557 and *S. hamata* ILCA 15876.

Mise au point de stratégies de gestion du *Stylosanthes* axées sur la lutte contre les maladies de la plante

Résumé

Stylosanthes *est cultivé au Nigéria depuis plus de vingt ans pour complémenter l'alimentation des animaux. Essentiellement axées sur l'accroissement de la production, les actions entreprises s'intéressent peu aux maladies de la plante. Et pourtant, les espèces de* Stylosanthes *sont extrêmement sensibles à une maladie comme l'anthracnose partout dans le monde. Les études de dépistage de maladies effectuées sur* Stylosanthes *à Kaduna au site de recherche du CIPEA pour la zone subhumide montrent que l'anthracnose était bien la principale maladie de* Stylosanthes*; celui-ci était en outre sensible à d'autres maladies des feuilles, aux pourritures du collet et de la tige mais aucun signe d'attaque de nématodes n'avait été observé. Les termites constituaient le problème le plus sérieux pendant la saison sèche.*

Cet article examine les stratégies de gestion appropriées pour combattre et prévenir les maladies de Stylosanthes, *y compris les techniques culturales ainsi que l'utilisation de produits phytosanitaires et de variétés résistantes. Les méthodes culturales constituent une solution plus facile que l'utilisation des produits phytosanitaires, laquelle est limitée par des contraintes financières et techniques. Les variétés résistantes représentent la meilleure option possible, mais la recherche sur leur matériel génétique devrait réunir en permanence des pathologistes, des entomologistes et des phytogénéticiens. Enfin, le programme d'évaluation exécuté au site de recherche du CIPEA à Kaduna a permis d'identifier deux acquisitions de* Stylosanthes *résistantes à l'anthracnose, à savoir ILCA 163 de* S. guianensis *et ILCA 15876 de* S. hamata.

Introduction

Introduced into Nigeria in 1947 from Queensland, Australia, *Stylosanthes* species were not fully utilised as fodder crops until the last two decades (Nwosu, 1960). Three species are currently recommended for commercial cultivation in Nigeria, namely *S. guianensis* cv Cook, *S. hamata* cv Verano and *S. humilis* cv Townsville. Most research work has concentrated on identifying agronomic practices that will increase dry-matter yield and little attention has been paid to pests and diseases affecting stylo.

The most important disease of *Stylosanthes* is anthracnose which is caused by *Colletotrichum* spp. First recorded on *Stylosanthes* in Brazil in 1937 (Anon, 1937), it has attacked the plant in tropical regions of America, Australia, Asia and Africa (Lenne and Sonoda, 1982). The commercial cultivars of *S. guianensis,* namely cvs Schofield, Cook and Endeavour, were particularly susceptible to anthracnose in Colombia (Irvin and Cameron, 1978). Forage yield losses of 26–58 % have been reported on several species of *Stylosanthes* in Florida (Lenne and Sonoda, 1982).

No literature is available on the diseases and pests of *Stylosanthes* in Nigeria. However, the International Livestock Centre for Africa (ILCA), working in Nigeria's subhumid zone, has included screening for anthracnose resistance and tolerance in its evaluation programme since 1981. In addition to this general screening of all material, more detailed pathological experiments commenced in 1987.

This paper presents a summary of the pests and diseases that attack *Stylosanthes* species in the subhumid zone of Nigeria, and, as a result of pathological experiments, suggests methods for controlling the pathogens and pests.

Pests and diseases of *Stylosanthes* in Nigeria

Pests of *Stylosanthes*

Few pests have been recorded on the *Stylosanthes* accessions being evaluated by ILCA in the subhumid zone. Among these are leaf-eating beetles (Chrysomelidae) that feed on the leaves at the early stage of growth; leaf hoppers (Cicadellidae) found on the plants before flowering; and the blister beetle, *Mylabris* sp, that feeds on stylo flowers. The most important pests are the termites (mostly *Macrotermites subhyalimus*), which become common after the end of the rains.

Soil analysis has shown that many organisms are associated with root and stem rots of *Stylosanthes* depending on the time of the year and the cultural practices through which the plants were established. Although nematodes (species of *Pratyleuchus* and *Meloidogyne*) have been isolated from fields of *Stylosanthes* they did not attack this species.

Diseases of *Stylosanthes*

Anthracnose is by far the most significant disease of *Stylosanthes* in Nigeria. However, field observations of 17 accessions of *S. guianensis* obtained from Colombia showed that apart from *Colletotrichum*, *Stylosanthes* is susceptible to some other virulent pathogens (Mohamed-Saleem and Adeoti, 1989). The accessions were very susceptible to other leaf spot diseases including leaf spot and leaf blights induced by *Phoma sorghina* (Sacc. Boerema et al) and *Curvularia eragrostidis* (Henn.) J. A. Meyer and leaf blight caused by *Cochliobolus eragrostidis* (Tsuda and Ueyama) Sivan. The combined effects of these other leaf spots causes a reduction in the forage and seed yields.

Soil-borne pathogens of *Stylosanthes* were also identified and these included *Pythium* spp, *Fusarium solani* (Mart.) Saac., *F. acuminatum* Ell and Eveth, *F. oxysporium* Schlecht and *F. moniliforme* Sheldon (ILCA, 1988).

Pest- and disease-management control in *Stylosanthes*

Pests and diseases may be controlled by adopting cultural or chemical methods or by using resistant varieties. In Nigeria, the choice of method must be appropriate to the level of technology available to the target group which includes settled agropastoralists, small-scale farmers and peri-urban dairy farmers.

Cultural methods

This approach shows good potential for the management of pests and diseases of *Stylosanthes* in Nigeria since the usual cultural practices of the farmer are not changed but only modified to obtain maximum effect.

Field sanitation

Burning at the end of the dry season removes leaf litter and trash from the previous year. At the same time it destroys many diseased leaves and stems which could serve as a source of primary inoculum for the pathogens on seedlings and regrowth in the following season. Burning also removes diapausing insect pests (Adesiyum and Ajayi, 1980). One disadvantage of burning is that old stands of perennial *Stylo* species are often destroyed. Since farmers often burn their crop fields at the onset of the wet season late burning would not be an unusual practice to recommend.

Grazing

Strategic grazing in the wet season may help to reduce the vegetative cover, to prevent the dense, humid conditions that would favour pathogen development (Mohamed-Saleem and Adeoti, 1989). Light grazing of *Stylosanthes* fodder banks in the wet season is a recommended management practice to control fast-growing grasses (Otsyina et al, 1987). In the dry season, stopping grazing early in the dry season would still leave some diseased leaves in the field; continuing grazing until at least February leaves the regrowth free from foliar diseases and causes a general reduction in the insect population.

Tillage

Routine land preparation which includes hoe tillage, ploughing and harrowing before sowing is very effective in exposing termites, such as *Macrotermes* spp, particularly *M. bellicosus* which have shallow surface nests. If properly ploughed, residual plant trash will be buried thus reducing the primary inoculum from the previous years' plants. Tillage also enhances the growth of *Stylosanthes* seedlings. However, land preparation may have limited use in management because some of the cultivars are perennial and the field would not be prepared every year.

Rotational cropping

Growing stylo in rotation is better than keeping it as a permanent pasture since this leads to a build up of soil-borne pathogens of *Fusarium*, *Pythium* and *Sclerotium* (S. A. Tarawali and A. A. Adeoti, unpublished data).

Crop mixtures

Since pastoralists normally settle around farming communities to market their milk and to have access to crop residues for grazing, crop mixtures that include *Stylosanthes* are likely to be readily accepted.

Mohamed-Saleem (1984) reported that undersowing sorghum with *Stylosanthes* at the right time increased both *Stylosanthes* and sorghum yields. However, some caution should be exercised in developing crop mixtures. For example, recent work (ILCA, 1988) has shown that Cook and Verano Stylo are highly susceptible to *Phoma sorghina* and *Helminthosporium* spp which are pathogens of sorghum. If mixed with maize *Mylabris* spp, which is attracted to maize pollen, may feed on stylo flowers causing reduction in seed yield.

Irrigation

Irrigating *Stylosanthes* at the end of the rains in October as a means of sustaining green yield has been tested in Kaduna (Mohamed-Saleem and Adeoti, 1989). The results showed that there was a build up of soil-borne pathogens, particularly of *Fusarium* species. This eventually led to the yellowing of leaves, retarded growth and even death of some old plants; there was also poor seedling establishment in the subsequent wet season.

During the wet season, foliar diseases such as anthracnose, *Phoma* leaf spot, *Curvularia* leaf spot, *Cochliobolus* leaf blight and the root and basal rots induced by *Pythium* and *Sclerotium* species were the most important diseases. During the dry season when the soil was periodically irrigated *Fusarium* species increased. Therefore, supplementary irrigation for *Stylosanthes* production in the dry season is not recommended.

Chemical control of pests and diseases in *Stylosanthes*

Control of pests and diseases using pesticides and fungicides has been successfully demonstrated in *Stylosanthes* fields. Lenne and Sonoda (1982) showed that plots of *Stylosanthes* sprayed with fungicides (benomyl and maucozeb) gave significantly higher dry-matter yields than unsprayed plots. They also showed that the strategic use of fungicides at flowering produced anthracnose-free seeds. Alafiatayo (1982) reported that the use of companion fungicides such as Delsene M (Carbendazin and Maneb) gave the best control of *Colletotrichum* in the field.

Dressing *Stylosanthes* seeds with benomyl and Dithane M 45 before sowing effectively controlled anthracnose since *Colletotrichum* is seed-borne (Lenne and Sonoda, 1982). Because of the high labour, expertise, financial cost and technology required in field spraying, seed dressing before sowing appears to be more feasible and could easily be adopted by farmers who are already used to treating crop seeds. Foliar application of insecticides at flowering will maximise seed production; except where seed is the ultimate aim there may be no need to spray for insect control.

The use of resistant varieties

The use of resistant cultivars is the most economic method of controlling stylo diseases since it requires no additional cost after establishment of the crop. Earlier screening of stylo cultivars by ILCA showed that *S. hamata* cv Verano was fairly resistant to anthracnose (ILCA, 1987). Further screening of 17 accessions of *S. guianensis* from CIAT (Centro

Internacional de Agricultura Tropical) identified two accessions, namely CIAT 184 and 136 (ILCA 163 and 164, respectively) as the most resistant to anthracnose (Mohamed-Saleem and Adeoti, 1989). Subsequent observations of these accessions in other trials have shown that both show some anthracnose symptoms (black spots), but that they tolerate the disease (Tarawali et al, pp. 81–95).

All ILCA's evaluation trials include screening for anthracnose and led to the identification of other tolerant accessions, *S. guianensis* ILCA 15557 and *S. hamata* ILCA 15876, (Tarawali et al, pp. 81–95). During the trials, accessions that were selected at other sites (e.g. Ethiopia, Florida, Australia, Colombia) for anthracnose resistance often succumbed to the disease when grown in subhumid conditions in Nigeria, often in the second season of growth.

Pathological examination of samples of *Stylosanthes* accessions from the evaluation plots revealed that a number of different species of *Colletotrichum* were present. These included *C. "capsici"*, *C. destructivum* and *C. gloeosporiodes*. The presence of *C. "capsici"* is noteworthy because this species tends to be less host-specific and therefore potentially more dangerous (AFRC, 1989).

Resistance to insect pests is determined by those characters of the plant which influence the amount of damage caused by insects and its ability to tolerate this damage. According to Painter (1951) the mechanisms involved include avoidance, where the insect behaviour is adversely affected by plant; antibiosis, where the insect growth and survival is adversely influenced by the plant, and tolerance where the plant can support higher insect populations than more susceptible cultivars without loss in yield. Obviously, insect damage and pathogen attack could be inter-related and Lenne et al (1980) suggested that work on pests and disease resistance in *Stylosanthes* should involve the collaboration of plant pathologists, entomologists, agronomists, plant collectors and breeders.

The identification of resistant cultivars is a continuous process since the long-term use of a limited number of accessions may lead to the development of new pathogenic races and insect biotypes.

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Management options for increasing productivity of *S. hamata* in fodder banks and in smallholder leys in West Africa

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Abstract

Due to its tolerance to anthracnose Verano stylo has become the most widespread species in West Africa and remains the mainstay of fodder-bank development in Nigeria, Mali and Côte d'Ivoire, while in semi-arid Niger it proved most promising for intercropping with millet on deep Arenosols.

Management of large-scale Verano-based pastures has relied foremost on intensive research in the monsoonal rangelands in Australia, originally developed for *Stylosanthes humilis*. Similarly in Nigeria low input oversowing of Townsville stylo was seen as a panacea to improve rangelands in the semi-arid and subhumid zones, adapting Australian technology to West African circumstances. Following the introduction of *S. hamata* in the early 1970s, it proved superior to Townsville stylo when used for rangeland improvement.

Although the adoption rate of fodder banks in Nigeria has been encouraging, the concept is more adapted to medium-scale agropastoralists with up to 50 head of cattle than to smallholders for whom cropping is more important than livestock production. This paper briefly reviews the current management options of Verano-based pastures and explores the changes required to manage small-scale leys or fallows that can serve as feed for livestock and function as improved fallows to raise soil fertility in smallholder crop–livestock systems.

Options de gestion en vue d'accroître la productivité de *S. hamata* dans les banques fourragères et les petites soles en Afrique de l'Ouest

Résumé

En raison de sa résistance à l'anthracnose, le Verano est devenu le stylosanthes le plus cultivé en Afrique de l'Ouest. Il demeure un élément de base des banques fourragères au Nigéria, au Mali et en Côte d'Ivoire et, sur arénosol profond dans la zone semi-aride du Niger, donne des résultats extrêmement encourageants dans les associations avec le mil.

Les techniques actuelles de gestion des grands parcours à base de Verano ont été mises au point essentiellement à partir de recherches intensives effectuées principalement sur Stylosanthes humilis *en Australie, sur des parcours de la région des moussons. Egalement importé d'Australie et adapté aux conditions prévalant en Afrique de l'Ouest, le sursemis extensif de* Stylosanthes *Townsville était considéré comme approprié pour améliorer les parcours dans les zones semi-arides et subhumides du Nigéria. Cependant,* S. hamata, *introduit au début des années 70, s'est révélé supérieur à* Stylosanthes *Townsville dans l'amélioration des parcours.*

Le rythme d'adoption des banques fourragères est encourageant au Nigéria.Cependant, cette technologie semble plus adaptée aux exploitations agropastorales de taille moyenne ayant jusqu'à 50 têtes de bovins qu'aux petites exploitations pour lesquelles la production végétale est plus importante que l'élevage.

Cet article passe brièvement en revue les options actuelles en matière de gestion des parcours à base de Verano. Il examine en outre les transformations à y apporter en vue d'une gestion rationnelle de petites soles destinées à améliorer l'alimentation des animaux ou la fertilité des sols dans les systèmes de la petite exploitation mixte.

Introduction

Brief history of research efforts

Until the mid-1970s species selection of stylos fell into two major groups: for intensive forage production in higher potential areas reliance was mostly on the *S. guianensis* group whereas for large-scale semi-arid rangeland improvement, oversowing with *S. humilis* was widely investigated both in Australia and in Nigeria. It was believed that large tracts of rangelands in northern Nigeria could be improved by aerial oversowing and research focused on low-input establishment (de Leeuw, 1974). *S. guianensis* was emphasised for small-scale ley farming with higher inputs and multi-purpose utilisation such as hay-making, stall-feeding and undersowing in crops (de Leeuw and Brinckman, 1974; Brinckman, 1975).

In the mid-1970s the rapid spread of anthracnose affecting both *S. guianensis* and *S. humilis* germplasm prompted an intensive search for alternative disease-tolerant material. To replace *S. guianensis*, other perennial stylos were evaluated and accessions from the *S. viscosa*, *S. scabra* and *S. capitata* groups were selected (Mott et al, 1989; ILCA, 1987–90). To find substitutes for *S. humilis, S. hamata* (cv Verano) became the most promising candidate. This species not only possesses the same attributes of *S. humilis*, but is also more anthracnose-tolerant, day-length neutral and perennates when growing conditions are favourable (Roeleveld, 1978; de Leeuw et al, pp. 105–111); (listing of attributes in Annex).

This shift towards new germplasm was also apparent in ILCA's research related to fodder-bank development. While initially *S. guianensis* (cv Cook) was selected as the most promising cultivar for semi-intensive sowing in higher rainfall areas of the subhumid zone, *S. hamata* was included in the seed mixture. Within a few years (1979–82), cv Cook was ousted by recurrent anthracnose attacks and gradually replaced by cv Verano which has remained the major legume in most Nigerian fodder banks (Mohamed-Saleem, 1986).

Similar developments occurred in Côte d'Ivoire where intensively managed perennial stylo-grass pastures were established to fatten immature steers (Ruthenberg, 1976). These efforts were nullified by anthracnose outbreaks and Panicum–Verano mixtures were tried as an alternative (Ruthenberg, 1976; Lazier 1984). While Verano was used as a substitute, the search for anthracnose-tolerant perennial stylos continued. In Nigeria, several tolerant accessions were found productive but they rarely outgrew *S. hamata* especially in the drier areas (ILCA 1988; 1989). In Katherine (Australia), long-term research compared *S. hamata* pastures with those sown to *S. scabra* (cv Seca, Fitzroy) and *S. viscosa;* it was found that in the long-term, Verano was difficult to "beat" (Mott et al, 1989; Winter et al, 1989).

Management of fodder banks

The persistence and yield stability of Verano have been impressive. Several fodder banks consistently produced 4–6 t DM/ha over several years with a 50–70% legume content. Apparently, this persistence was generated by large seed pools varying from 300–3000 seeds/m^2 (Mohamed-Saleem and Suleiman, 1986).

In well-managed fodder banks there was little evidence of yield decline over time. Yields in the first year were similar to those four years later indicating that the methods of establishment were efficient. (Mohamed-Saleem, 1986; Otsyina et al, 1987). However, only a few banks (up to six) were regularly sampled, out of a total of 70 that were established by 1986 and of which 50 were under complete farmer-management. In 1990, 30 fodder banks were sampled in four states showing an average yield of 5.6 t DM/ha, but with a wide range of 1.9 to 9.5 t/ha. Variation in yields was linked with grazing pressure. Fodder banks that were grazed year-round yielded 2.3 t/ha compared with 6.7 t/ha for areas that were only used for 3–5 hours during the dry season (ILCA, 1990:55). This may indicate that utilisation by stock was often below optimum and probably could be improved.

Although the long-term sustainability of Verano pastures is dependent on many factors, wet season grazing management and phosphorus fertilisation are essential. Response to defoliation during the growing season was marked indicating that by cutting swards every 6–9 weeks 5.1–5.8 t/ha was produced in the first year increasing to 6.8–7.2 t/ha in the second year, or 105–115% and 60–70% above the end-of-season yields, respectively, from single harvests (ILCA 1988; 1989).

The effect of grazing was also demonstrated in Shika at the National Animal Production Research Institute (NAPRI). Initially, in the first year, Verano–*Cenchrus ciliaris* pastures were low in legume content (10–16%). However, after four years of grazing by heifers at three stocking rates (1.1, 1.7 and 3.3 head/ha) during the rainy season for seven months from April to October, Verano content increased from 28% at the lowest stocking rate to 60% at the highest (Agishi, 1982). This favourable impact of grazing was also reported in Australia. In Katherine, a comparison of grazed and ungrazed patches showed a five-fold increase in stylo yields, a 15-fold higher seedling density and an almost complete absence of competing grass cover when grazed (Mott et al, 1989: 1236). While it is recognised that P-fertilisation is essential to maintain stylo dominance in swards, the long-term optima for stable yields are difficult to determine and responses are often conflicting (see Haque et al, 1986). In Kurmin Biri (Nigeria) application of 50 kg of P doubled yields of *S. guianensis* cv Cook (2.3 to 4.8 t DM/ha) but gave much lower responses in cv Schofield (+ 40%) and Verano stylo (+ 20%) (Mohamed-Saleem, 1986: 339). In contrast, providing all soil nutrients except P to Verano produced 1.6 t DM/ha as compared to 5 t when all nutrients were applied (Mohamed-Saleem, 1986: 342).

A high response of Verano to P was confirmed in Shika. At 0 and 30 kg $P_2 0_5$ per hectare, yield increased from 2.8 t to 6.0 t DM/ha. This increased further to 8.7 t DM/ha at 120 kg/ha of P_2O_5; thus a level of 30 kg P_20_5 per hectare was close to the economic optimum for yield. However, for seed yield the optimum was higher. Over the same range of P, seed yield increased from 480 to 1280 kg/ha; the highest returns were reached at 90 kg P_20_5 per hectare yielding 1266 kg/ha or 8.7 kg of seed per kg $P_2 0_5$ applied (Agishi, 1982). Lower responses may be due to weed competition since in Shika with increasing P-application (0–60 kg) the stylo component in the establishment year fell from 50 to 30% in cv Cook and from 90 to 50% in Townsville stylo (Agishi and de Leeuw, 1986: 474).

Although small-plot experiments are an essential step to find optimum fertiliser management, long-term trials are needed to explore effects on pasture dynamics, grass-legume balance and on secondary productivity. From 10 years of monitoring research in large-scale Verano pastures in Katherine, Winter et al (1989b) concluded that the productivity of legume and growth rates of cattle can be improved by rather small inputs of superphosphate . They recommended 100 kg/ha at establishment and 25 kg/ha annually for maintenance. Similarly, Edye and Gillard (1985) working in commercial properties in north Queensland, reduced establishment and maintenance cost by lowering total superphosphate inputs from 220 kg/ha to 60–110 kg/ha and stated that despite these low inputs Verano pastures remained stylo-dominant over periods of up to 15 years.

Management systems for *S. hamata* leys

Seed production gardens

- Establish fenced gardens of 100–200 m^2 in protected compounds.
- Provide maximum inputs (high seed rate at 2 g/m^2, P-fertiliser, weeding, efficient seed harvesting) so that a seed yield of 10–20 kg per annum over several years can be expected.
- Retain seed garden as back-up for sustained long-term fallow improvement.

Establishment and management of fallow areas

- Use high seed rates (10 kg of pods/ha or more).
- Graze intensively before seeding and 10–30 days after legume emergence depending on seedling growth and weed competition.
- Apply selective heavy grazing (by tethering) during the following periods:
  - immediately before flowering and seed setting of the main competing volunteer grasses
  - during the expected seed-fall of stylo
  - during early dry season to harvest seeds and fallen leaves and prevent early fires through reducing fuel load and promoting patchiness.

Selective tethering will become particularly essential during the end of the fallow cycle when soil nitrogen is building up and nitrophilous grasses such as *Pennisetum pedicellatum* tend to increase. These grasses are highly palatable before flowering making control by tethering will be effective.

Other interventions

- Collect faeces of stock tethered on stylo in the early dry season both from the fallow and the night holding-areas and arrange for manure storage.
- Spread stored manure at the beginning of the following growing season in old fields (in particular on patches where regenerating stylo density is low) or in new fields entering the fallow cycle.
- To prevent late fires and to retain some forage for late dry-season grazing, control grazing pressure through spot grazing or by harvesting the standing crop for hay during the dry season, thereby creating patchworks of low plant cover ground surrounded by tall herbage stands.

Although year-round protection of improved fallows can be ensured by adequate fencing, in practice this may not be feasible due to high costs. However, on-farm cropping patterns could be so arranged, that these small improved fallows are surrounded by long-cycle crops such as sorghum or cotton. Sorghum is usually harvested in late November and cotton during December–January and therefore remain protected and ungrazed. This protection would ensure sufficient seed-fall of stylo for regeneration in the following season.

Discussion and conclusions

Fodder banks

Although the success rate of fodder banks has been satisfactory, further improvements in management are possible particularly in respect of grazing and phosphorus application for maintenance. From early work (Taylor-Powell and Ingawa, 1986; Taylor-Powell and Suleiman, 1986) and more recent surveys of 30 fodder banks (ILCA, 1990), it is clear that the grazing management of fodder banks by agropastoralists varies according to their perception of fodder banks as a feed source and to their immediate and longer term production goals. Hence, the number and types of animals used, the periods, frequency of grazing and therefore the overall utilisation rates have varied enormously. Although no single system can be ideal, certain guidelines may be necessary to match management that is optimal biologically with the producers' goals. In the dry season the nutritional value of feed for livestock at risk and the hazards of accidental fires are likely to determine use patterns. However, wet- season use should be mostly geared to guarantee maximum legume yield with a high leaf and seed content. A re-assessment of the current evidence to formulate detailed user guidelines should be attempted.

Similarly, fertiliser rates need careful scrutiny. Given the general satisfaction with current establishment practices, 150 kg/ha of single superphosphate at initial seeding may still be optimal although on more fertile soils rates may be lower. However, a maintenance application of 100 kg/ha per annum as recommended by Otsyina et al (1987) may be too high and in line with Australian experience could be lowered, in particular when combined with judicious wet season grazing management. Furthermore, time of application may be important while "patch application" to enlarge legume-dominant areas is worth considering.

Fallow leys

The entire management strategy of oversowing fallows should be geared to maintain a high seed output throughout the 3–4 year life of the fallow to ensure stylo yields of 4–6 t DM/ha per annum. Apart from promoting profuse seed-fall, two back-up sources can be developed by retaining the intensively-managed seed garden permanently and by selective tethering of stock on high-seed areas and collecting their faeces for storage and spreading early in the next growing season.

Although labour-intensive, tethering may be worthwhile as it provides stock with good-quality feed during the growing season when herded stock is often poorly fed because of short grazing days in overgrazed communal rangelands far away from cropped land. These grazing areas are often located on non-arable land with shallow soils and poor grass cover. Tethering on fallows could be done with selected stock such as pregnant or lactating cows, work bulls, young calves or small ruminants that are usually kept around the compound.

Sole reliance on Verano may be imprudent. Therefore, the seeding of legume mixtures should be encouraged not only containing perennial stylos but also other legumes (*Centrosema* spp, *Clitoria* etc). It seems unfortunate that while in temperate zones multi-species best-bet mixtures were commonplace in pastures and meadows (before high N-pastures with single species became *en vogue* to increase feed per hectare), mono-cultures are recommended in Africa; rarely are evaluation plots established testing combination of more than one grass and one legume.

Multi-species leys are likely to be less risk-prone and more sustainable due to between-species differences in responses to rainfall distribution, temporal growth rhythms, competitive ability and palatability to grazing stock. Inclusion of perennial grasses may further enhance longer-term yield stability. Mott et al (1989) showed that livestock output was greatest in Verano pastures that contained a perennial grass component of about 40%. Again there is no reason why several grasses — with different growth patterns — could not be grown together with several legumes.

Given the rapid uptake of short-term legume fallows by farmers in West Africa, new management strategies have to be designed and tested that are adapted to variable production goals. In subhumid Nigeria, small-scale farmers are mostly concerned with soil fertility maintenance rather than using their fallows as a source of feed, even though tethering goats during the cropping season on fallow seems to be catching on (see Mani et al, pp. 155–165). In Mali and other countries with cotton cash-cropping using animal traction, the emphasis will be — like Fulani agropastoralists — on improving feed supplies for livestock.

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Annex

Major attributes of *S. hamata*

The success of *S. hamata* as a pasture legume can be attributed to the following characteristics:

Germination and seed biology

- Rapid germination of seeds (50–80% within two days) due to fast water uptake.
- Requires high temperatures (> 50°C) to break hard-seededness, thus providing protection against out-of-season rainfall and fire hazards.

Seedlings

- Rapid root growth (4–13 mm/d) leading to deep penetration and high soil-moisture extraction at an early age.
- During periods of high soil-moisture content and high temperatures (> 25°C) fast above-ground growth rates (vertical growth 4–10 mm/d).

Low sensitivity to moisture stress and dessication due to efficient stomatal control, osmotic adjustment and parahelionasty.

Flowering and seed-production

- Because flowering is controlled by age and/or plant size rather than by day length, flowering and seed setting are extended over time ensuring a high probability of adequate seed production (up to 1.8 t/ha).
- Being a facultative perennial, some plants survive into the next growing season, further assuring sustained seed production in most growing seasons.
- Being an indeterminate species, non-selective defoliations during flowering and seed-setting have little effect on subsequent seed yield.
- Efficient seed dispersal mechanisms (seed intake by herbivores, spread in faeces, transport by ants and termites).

Other characteristics

- High anthracnose tolerance.
- Low palatability early in the growing season and high levels in the late rainy and early dry season.

Section 4

Stylosanthes-based pastures for livestock production

Stylo-based pasture development for agropastoral production systems

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Abstract

Countries in sub-Saharan Africa are in urgent need of simple and self-reliant innovations to raise food and fodder productivity. Livestock suffer from protein deficiencies, particularly during the dry season. Continued cropping seems impractical in tropical Africa without adequate nutrient and organic-matter replenishment in soils.

The genus *Stylosanthes* has provided ample germplasm for a wide variety of agro-ecological situations in the tropics. *Stylosanthes hamata* cv Verano, was found to be particularly adaptable and resilient in agropastoral farming in the subhumid zone of West Africa. In on-station and on-farm trials, stylo has contributed significantly to livestock productivity and soil fertility. It is easily integrated into cropping systems and has improved food and fodder productivity on a sustainable basis. Nonetheless, farmer adoption of forage legumes (e.g. *Stylosanthes*) into the land-use systems has been slow. Whether this is because of an “adoption lag” or due to a negative farmer evaluation of the benefits is a topic for future research.

Mise en valeur des parcours à base de *Stylosanthes* pour les systémes de production agropastorale

Résumé

Les paysans africains ont de toute urgence besoin d’innovations simples et efficaces pour pouvoir produire davantage de denrées vivrières et d’aliments du bétail. Les animaux manquent de protéines, notamment pendant la saison sèche. En Afrique tropicale, les terres ne peuvent être cultivées longtemps sans un apport d’éléments nutritifs et de matière organique en quantités suffisantes.

Le genre Stylosanthes *fournit du matériel génétique adapté à un nombre extrêmement varié de conditions agro-écologiques dans les régions tropicales. On s’est aperçu que* Stylosanthes hamata *cv. Verano était particulièrement bien adapté aux systèmes de production agropastorale de la zone subhumide de l’Afrique de l’Ouest. Dans des essais en station comme en milieu réel,* Stylosanthes *a contribué à améliorer de manière significative la productivité du cheptel et la fertilité des sols. Facile à intégrer dans les systèmes agraires, il a permis d’améliorer durablement la production alimentaire et fourragère. Cependant, les paysans ne semblent guère pressés d’introduire les légumineuses fourragères (ex.* Stylosanthes) *dans les systèmes d’utilisation du sol. Des études supplémentaires doivent donc être entreprises pour savoir s’ils observent d’abord un “temps de réflexion” ou s’ils doutent carrément de cette innovation.*

Introduction

The Government of Nigeria has employed several strategies to improve livestock productivity in the country. For many years, most of the budget for the livestock sector was allocated to combat major epidemic diseases, particularly rinderpest and contagious bovine pleuropneumonia. State governments set aside vast areas of land as “grazing reserves”, believing that nomadic and transhumant pastoralists would settle, if they had secure access to pasture and water. Much effort went into developing infrastructure such as roads, fire traces, dams and milk collection centres. Despite these developments there was little response from the pastoral herd owners.

During the same period, the national agricultural research system (NARS) introduced and screened new varieties of forages to enrich natural pastures. As there was no tradition of pasture seed production seeds were imported until the late 1970s when the government established a few multiplication units. Large tracts of land were oversown with exotic legumes without much success as establishment was generally poor. Even if seedling growth was satisfactory, forage growth was grazed before seed setting or burnt during the dry season.

Milk-collection centres associated with grazing reserves failed to convince pastoralists to move into the reserves. Milk prices offered were too low and not adjusted upward when supplies declined as the traditional markets do (Waters-Bayer and Bayer, 1984). Agropastoralists were not allowed to grow crops as this was forbidden by the early legislation governing the creation of grazing reserves.

Outside grazing reserves, most land is still owned by communities of cultivators where land tenure and usufruct rights are governed by complex traditions. FulBe pastoralists frequently have difficulty obtaining land, especially where areas are intensively cultivated. Yet agropastoralists prefer to settle close to villages and small towns with amenities, markets to sell livestock products and to buy food and goods from, and with access to ample crop residues in the hinterland.

Even if grazing reserves had been successful they could never contain more than a small fraction of the pastoral livestock in Nigeria. The national cattle herd is estimated at 13 million head, owned by about 200 000 pastoralists. This population would require 30–40 million hectares of grazing or over a third of the country. Thus, the earlier livestock improvement strategies fell short of responding to the needs and aspirations of the livestock producers.

Fodder banks

To develop feed resources the following criteria for appropriate innovations were listed (Kaufmann and Blench, 1988, unpublished):

- The innovation must be a low-cost, low-input technology that can be readily transferred
- The benefits must be apparent to both agropastoralists (livestock owners) and cultivators (land owners) so that it can be fully integrated into the prevailing land-use systems
- The principle and merits of the innovations must be accepted by, and be appropriate to the means, of the extension services.

ILCA pursued a farming- systems approach and established the necessary rapport with the principal participants so as to understand their livestock-production systems, production goals and aspirations. Thereafter, technologies that suited the producer’s resources were designed. In the early 1980s, ILCA concentrated its on-farm research at

Table 1. *Grain yield (kg/ha) at zero N application to soils with different histories and the amount of N required to raise grain yields of cropped soil to the level of other land-use types, Kurmin Biri, 1983.*

Soil type	Grain yield at	
	0 kg/ha of N	N kg ha[1]
Cropped for three years	461	0
Uncroped for many years	1275	30
S. hamata for two years	1329	32
S. hamata for three years	2508	90
S. quianensis for one year	1643	44
S. guianensis for two years	2696	110

1. Amount of applied N (kg/ha) required by cropped soil for equivalent yields of other soil types at zero N.

three sites: a government-assisted settlement of agropastoralist farmers in Kurmin Biri, small-stock owning in Abet and cattle-owning arable farming communities in Ganawuri.

The following constraints to forage production were identified by Mohamed-Saleem and Suleiman (1986):

a) Acute shortage of labour as all available labour was required for subsistence cropping.

b) Lack of agricultural mechanisation, including animal traction.

c) Little security over land rights precluding long-term commitments to land development.

d) Communal grazing by nomadic and transhumant herds and herders who enter and graze sown pastures unless they are fenced.[1]

e) Indiscriminate fires destroying standing herbage reserves.

In response to these constraints ILCA formulated the "fodder-bank" package. The forage legume fodder bank is defined as an "enclosed area of concentrated forage legumes reserved for dry season supplementary grazing".

Recommendations for establishing fodder banks can be summarised as follows:

a) Fence an area of about 4 ha and prepare the seedbed by confining cattle overnight in the target area, or by grazing it for one to two weeks after seed broadcasting or by harrowing where possible.

b) Broadcast scarified seed of *Stylosanthes hamata* cv Verano which was the only forage legume of which seed was available in commercial quantities.

c) Control fast-growing grasses and other weeds by grazing early in the growing season (two to five weeks after sowing) and defer further grazing until the dry season to allow the forage to bulk-up.

d) Graze pregnant and lactating cows at a stocking rate of about five head per hectare, depending on the forage supply, for 2.5 hours per day preferably after the cattle return from grazing natural pastures. Ensure that sufficient seed drop and enough stubble remains for regeneration in the next season.

1. The fodder-bank concept originated from participant observation and feedback from one pastoralist who was settled in Kachia grazing reserve, Kurmin Biri. He started to cooperate with ILCA and national scientists in sowing stylo as a relay crop with his sorghum. It appeared that the pastoralist simply enjoyed watching ILCA and government staff working on his plot thereby raising his status in his community. But at the onset of the next growing season he fenced off the previous year's cropped area, to allow the stylo to regenerate, and shifted his cropping to another site. This action broke an old and firmly held myth that cattle owners would not be permitted to erect or maintain fences to protect pasture. Once the possibility of fencing was established guidelines were formulated for establishing and managing fodder banks.

Table 2. *Costs of fodder banks compared with purchased cottonseed cake.*

Fodder bank (kg/ha)		Total
Total dry matter	4 t/ha	16 t
Grazable dry matter	50%	8 t
Protein	9%	720 kg
	1985	1989[1]
Capital cost (₦)	2502	6044
Recurrent cost (₦)	498	1466
Cottonseed cake		
Protein		720 kg
Required dry matter	30%	2400 kg
	1985	1989[2]
Capital cost (₦)	0	0
Recurrent cost (₦)	840	2064

1. Open-market price.

2. Inputs supplied by extension agency.

Source: ILCA records.

In 1980 the first two trial fodder banks were established; one near an arable farming community at Abet and the other in the Kachia grazing reserve near Kurmin Biri. The fodder banks were sited near the cattle owners' homesteads for better supervision and protection. Bush poles and branches cut from the vicinity were used to make boundary fences. As the major objective of the fodder bank was to provide protein supplementation the management practices were aimed at enhancing the legume component in the pastures. This called for close monitoring of seedling growth and frequent visits by ILCA staff to interact with the owners. Daily milk offtake was recorded for each herd together with deaths, sales, purchases and births. During the cropping season all farming operations, other inputs and resulting crop yields were monitored.

Initially, ILCA ensured strict compliance with the guidelines it had set out for managing fodder banks. At the end of the growing season the biomass production and forage quality were determined to set permissible stocking rates for the coming dry season. ILCA enumerators made sure that only lactating and pregnant cows were selected and put into the fodder bank when they returned from daily grazing.

When the farmers undertook to pay the fodder bank costs themselves they included their own ideas and preferences. Some of their decisions were at variance with the guidelines:

a) Grazing fodder banks early in the growing season was unacceptable to the owners who feared worms would infest their animals from the dung that was deposited during to prepare the seed-beds.

b) Some animals died or had to be sold prematurely at reduced prices during the dry season. The fodder-bank owners chose to counter this by grazing all their animals on the fodder banks instead of just the selected cows even though this reduced feed per head. This practice was less labour demanding since the tedious daily separation for grazing on fodder banks was avoided. The grazing frequency and duration was also changed; some owners preferred to use the fodder banks early in the dry season when the feed quality was high, while others preserved the bank as a last resort until the latter part of the dry season. Some owners believed that by grazing fodder banks early in the dry season, when the feed quality was best, the animals would be in better condition to withstand the stress of the dry season. The *ex-ante* analysis did not anticipate forced sales but *ex-post* financial analysis confirmed that this was a wise policy especially in view of the owners short time horizons and high risk aversion.

c) Some large herd owners wanting fodder banks were discouraged because of the prevailing common land tenure laws which made it difficult to acquire enough land. Furthermore, the insecurity of land-use rights made them reluctant to invest in land except for short-term benefits such as cropping.

d) The inability to sustain legume dominance over several years frustrated some of the owners as the benefit of the fodder bank to their cattle began to decline.

Feed-back from adopters stimulated remedial research. Alternative land preparation methods were substituted for kraaling so that the owners would agree to graze the fodder banks early in the wet season without fear of worm infestations. The owners also wished to keep all the manure for their crop fields rather than for forage production. New disease-tolerant and more competitive legume species were selected to suit different ecological niches within the subhumid zone. Nitrogen-demanding cereal crops were introduced in rotation with legume pastures to exploit and thereby reduce soil-nitrogen levels, resulting in compatible opportunities for ley farming. Grain and fodder yields of maize planted after one to three years of stylo growth increased significantly compared with maize grown after bush fallow or cropped continuously (Table 1). This was attributed to increased soil nitrogen and better physical properties in the stylo pasture (Mohamed-Saleem and Otsyina, 1986).

Impact analysis

Field situation

Twelve years ago the first fodder-bank trial was established in Nigeria. Therefore, it is time to start asking how far the innovation has spread and what its impact has been on the livestock enterprises of the target farmers. At least two major phases can be distinguished in the development and extension of the fodder-bank innovation — up to 1986 when the Naira was at par with the US dollar and thereafter when its value rapidly declined.

As pressure for arable land increases, forage legumes can play a greater role in low external input cropping systems by conserving soil fertility and sustaining grain production. Yet, in Nigeria the number of fodder banks has increased less than expected and the prospects for adoption in other countries remains largely unexplored. There are several reasons for this slow adoption rate. Interviews with fodder-bank owners showed that lack of extension was the most important reason, followed by inappropriate land tenure. FulBe agropastoralists who have large herds found the standard 4-ha fodder banks too small to feed their whole herd making it a poor investment.

Researchers' view

The adoption rate of fodder banks will ultimately depend on how it matches adopter objectives. Some of these objectives are increased cow productivity and calf survival; increased total herd output and avoidance of distress sales; increased crop yields; and increased security of land tenure.

Recent developments in the Nigerian economy have had a significant impact on both the costs and supply of inputs and on livestock prices, affecting the profitability of fodder banks. Up to 1985, the exchange rate of the Naira made imported inputs cheap and readily available. After the introduction of the structural adjustment programme (SAP) in 1986, the Naira was devalued manyfold to reach a level of ₦ 20 per US$ in November 1992. Imported steel posts and galvanised sheep-proof fencing therefore became expensive and short in supply.

In 1985 a fodder bank was costing ₦ 2500 to establish and ₦ 500 annually to maintain (Table 2). By 1989 these costs had risen to ₦ 6000 and ₦ 1500, respectively, if inputs were purchased in the "open market". The return on investment depends on whether protein feed supplement is cheaper than the alternative of feeding cottonseed cake. However, SAP favoured cattle producers because prices of imported animals, meat and dairy products have risen as the exchange rate fell. This suggests that fodder banks are reasonable investments, even when only the impact of improved cattle productivity is taken into account. There are significant add-on benefits such as avoidance of distress sales; owners without fodder banks usually have up to two salvage sales per year, while sales among fodder-bank owners were negligible.

Future prospects

To a region facing livestock feed deficits, the fodder-bank concept offers a self-help option for producing good quality supplementary feed on a sustainable basis. Because previous feed-improvement strategies were largely ineffective great care was taken to tailor fodder banks to producer circumstances. Inputs and management requirements for fodder banks are simple and within the reach of the target group, while the potential benefits to livestock production and to household income, can be substantial.

In Nigeria Verano stylo and *Stylosanthes guianensis* cv Cook were the primary species used in fodder banks. Land suitability assessments using the FAO agro-ecological zones model (Kassam et al, 1988) were carried out for Verano stylo-based fodder banks in 10 West African countries, revealing a large potential for fodder banks. Even if a small proportion of the suitable land were sown to stylo (e.g. 10%) large amounts of good-quality fodder would be added to the national feed budgets of these countries(Mohamed-Saleem and de Leeuw, pp. 317–323).

There is ample scope for fodder banks in the Nigerian subhumid zone. Assuming that 4 ha is sufficient to provide supplemental forage for a typical 50-head herd, a total of 360 000 hectares is needed to cater for the estimated 4.5 million head of cattle resident in the subhumid zone of Nigeria.

Since the proportion of cropped land in the zone is still relatively low, there are sufficient fallows and natural pastures for grazing. It is argued that even with the threat of seasonal feed deficits livestock owners lack adequate incentives to grow forages (Mohamed-Saleem and de Leeuw, pp. 317–323). It is further argued that the converse is not necessarily true, because even when cropping density is high there are plenty of crop residues available in the dry season, reducing the need for legume pastures.

The scientists, who have longer time-horizons, see the prospects for fodder banks in the subhumid zone in a different light. Given the rate at which cropping is increasing, livestock mobility will be severely hampered forcing agropastoralists to settle. Farmers in the zone are also investing in cattle and they are unlikely to move their livestock to distant areas in search of feed. These trends will create greater incentives for finding other renewable feed sources. Equally important is the linkage between cropping intensity and land degradation and the need for crop-free rest periods. Even at the highest levels of fertilisers, soils in the subhumid zones are fragile and rest periods are deemed essential for monitoring organic-matter content to sustain current productivity levels (Young and Wright, 1984). It is in this context that competitive and deep-rooting forage legumes will become more important in the future for use in well-balanced forage-crop rotational systems. This trend may improve farmer-agropastoral relations because this potential for land improvement may encourage farmers — as the traditional "owners" — to allow agropastoralists access to land for fodder banks. Cultivation of part of the fodder bank by the farmer each year will raise crop yields enough to compensate for leasing the land. There are opportunities for good compromises that could meet the aspirations of both parties.

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An assessment of stylo as a source of supplementary feeding

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Abstract

The potential of species of the genus *Stylosanthes* as a source of livestock feed is known. Stylos are adapted to growth on soils low in available phosphorus (P) and their introduction has widely been shown to improve pasture and animal productivity in the seasonally dry tropics.

Stylos have the capacity, unusual among pasture species, to produce herbage with a concentration of nitrogen (N) adequate for animal production while simultaneously being inadequate in P. Increases in nutrient content and productivity normally occur in response to phosphatic fertiliser application. While herbage of 2% N or more can be produced under these circumstances, the field experience is that lower concentrations are more usually obtained, especially marked in more mature and senescent material. This occurs frequently with deficient levels of P, and very low concentrations of sodium (Na) are the norm. This situation, combined with the overall observations of digestibility averaging between 50 and 60%, with many being substantially lower, shows that the quality of stylo frequently can be marginal for animal production.

Attention to management is required to maximise utilisation of the leaf fraction, of higher quality and digestibility than stem, along with recognition of the potential deficiencies of essential mineral nutrients. Clear benefits can accrue from incorporation of stylo in fodder banks or cropping systems for both grazing and cut and carry husbandry procedures.

Evaluation du *Stylosanthes* comme source d'aliment complémentaire

Résumé

Les potentialités des espèces du genre Stylosanthes *en tant que source d'aliment du bétail sont bien connues. Elles sont adaptées aux sols pauvres en phosphore (P) assimilable et contribuent à améliorer les parcours et la productivité animale dans les régions tropicales, notamment en saison sèche.*

Les espèces du genre Stylosanthes *ont la faculté, rare parmi les plantes fourragères, de produire pour le bétail du foin riche en azote (N) mais pauvre en phosphore (P). Un apport d'engrais phosphatés améliore généralement la teneur en éléments nutritifs et la productivité. Certes, on peut espérer produire dans ces circonstances du fourrage contenant jusqu'à 2% ou plus d'azote; dans la pratique cependant, le taux d'azote est plus faible, notamment lorsque la plante est en phase de maturité ou de sénescence. Cela arrive généralement avec les carences en phosphore étant entendu que les carences en sodium (Na) sont habituelles. Tout cela, ajouté à une digestibilité moyenne de 50 à 60%, souvent plus faible, montre bien que la qualité*

du fourrage de Stylosanthes *est généralement trop juste pour les besoins de la production animale.*

La méthode de gestion doit permettre d'utiliser de préférence les feuilles, plus riches et plus digestibles que les tiges, sans perdre de vue les possibles carences en éléments nutritifs essentiels. Cela dit, l'introduction de Stylosanthes *dans les banques fourragères ou les systèmes agraires permettra d'améliorer de manière substantielle l'alimentation du bétail, que les animaux se nourrissent directement au pâturage ou soient alimentés à l'auge.*

Introduction

The potential for increasing the productivity of grazing cattle by introducing *Stylosanthes* species in pastures of the seasonally dry tropics has been thoroughly established in Australia (Shaw, 1961) and South America (Alkämper and Schultze-Kraft, 1979). Likewise, using *Stylosanthes* to improve the productivities of pastures, animals and crops has been documented over a number of years in Nigeria (e.g. Agishi, 1971; Otchere, 1986; Mohamed-Saleem and Suleiman, 1986). Dry-season access of Bunaji cattle to *Stylosanthes*-based fodder banks was shown by Otchere (1986) to produce significant increases in milk offtake (70%), calf growth (40%) and viability (30%), and by Bayer (1986) to reduce cow liveweight loss by 50%. That the basis of these improvements lies in the capacity of the legume to fix atmospheric nitrogen, and that the improved animal productivity stems from the increased availability of higher quality feed, especially in terms of protein and digestible energy, require no further expansion here.

An assessment of the feeding value of stylo requires a clear understanding of the ways in which the various attributes of the plant contribute to improved animal productivity over and above that realised from the normally available herbage in the absence of the legume. This will provide for a more critical focus of research programmes designed to optimise production from systems in which legumes are incorporated.

Animal productivity depends on the dietary supply of adequate quantities of essential nutrients, and those recognised most widely in the tropics as potentially limiting are energy, nitrogen, phosphorus and sodium. Feed composition, voluntary intake, digestibility and dietary selectivity all influence nutrient supply, and need to be considered to ensure that the most effective nutritional contribution from the legume can be obtained in whichever feeding system it is to be employed.

Plant composition

Impaired animal production occurs when the diet contains less than 1% N (Milford and Minson, 1966), 0.12% P (Little, 1980) and 0.05% Na (Morris and Gartner, 1971). The ARC (1980) recommended that dietary nitrogen:sulphur ratio should not exceed 14:1, so the dietary S concentration should exceed 0.07%. These criteria very frequently are not met by natural pastures in the tropics, especially during the dry season. N is usually the primary limiting nutrient while dietary deficiencies of N and P normally occur together (Little, 1970). In this regard, Little (1968) showed unfertilised *S. humilis* to be a most unusual pasture species, containing a concentration of N adequate for animal nutrition and a very inadequate level of P. This seems to be characteristic of many species of stylo (Little et al, 1984), a feature probably related to the tolerance of this genus to low levels of available soil P that confers its advantage over many other legumes for such environments.

Several reports of the composition of various mature stylo species from pot and field experiments (reviewed by Little et al, 1984) showed mean concentrations of 1.9% N (range 1.3–2.5) and 0.09% P (0.04–0.16) in untreated herbage. Material that had received superphosphate at < 300 kg/ha revealed 2.1% N (1.3–3.0) and 0.12% P (0.07–0.20). Hall (1974) studied several accessions each of *S. humilis, S. hamata, S. guianensis, S. scabra, S.*

subsericea and *S. viscosa* by sampling whole plants at flowering in north-west Queensland, Australia, and found N content to average 1.7% (1.1–2.2), while P contents lay mainly in the range 0.07–0.10%. However, *S. hamata* cv Verano and *S. scabra* cv Seca "had consistently low phosphorus levels, from 0.03 to 0.09%". These figures are all from mature herbage; nutrient concentrations are generally highest in young material, but the decline with advancing maturity can be both substantial and very rapid. Thus Fisher (1969) showed the N content of both leaves and stems of *S. humilis* to have virtually halved within four months, while the same proportional reduction in P content, to 0.07%, occurred in two weeks. These data confirm the observation that stylo species frequently can contain sufficient N to meet animal requirements, but P very often will be deficient.

The application of superphosphate to stylo usually increases plant concentrations of N, P and sulphur (Shaw et al, 1966; Jones, 1968; Ritson et al, 1971). However, Fisher (1970) observed lower nutrient concentrations following fertiliser application, due possibly to dilution effects consequent upon increased growth. Jones (1974) presented detailed analyses of herbage, including trace minerals, following very high rates of P fertiliser and multi-nutrient basal dressing, which showed Na to be the only nutrient not present in adequate concentration for cattle nutrition.

Peters (1992) conducted a detailed study including two strains of *S. guianensis* and *S. hamata* cv Verano in the subhumid zone of Nigeria. He found that nitrogen contents, averaging 1.6–1.7% in the early dry season, rapidly decreased to around 1 through the rest of the dry season; P concentrations were always below 0.10% and Na concentrations were always substantially less than 0.01%. On fodder banks in the same region, Mani (1992) obtained figures of 1–1.5% N and around 0.10% P during the dry season. Thus the experience of stylo in this region is one of marginal N supply and deficient levels of P, which is consistent with Australian results.

On the other hand, Harricharan and Morris (1988) examined two cultivars of *S. hamata* in the Caribbean, and found CIAT 122 to contain 2.84% N and 0.13% P, and CIAT 118 to have 1.63% N and 0.29% P. These cultivars contained, respectively, the lowest P and N levels the researchers recorded in the 44 forage samples examined. It is therefore clear that consideration of the effects of regional differences in soil type and climatic conditions is important in such comparisons. Further, rates of P uptake by stylo have been shown to be much lower when the source was rock phosphate rather than superphosphate (Bryan and Andrew, 1971). It has also been shown that high soil Al can impair uptake of both P and calcium (CIAT, 1980).

Digestibility and intake

These characteristics are prime determinants of nutritive value and are positively correlated, although not sufficiently so for predictive purposes. Plant age and chemical and morphological composition all exert an influence so that lower nutritive values generally are associated with advancing plant maturity, low nutrient concentrations and lower proportions of leaf relative to stem.

A number of reports of digestibility and intake of stylos determined using sheep (reviewed by Little et al, 1984) revealed overall averages for dry-matter digestibility of approximately 50% (range 20–71), and 51 $g/kg^{0.75}$ per day (range 17–73) for dry-matter intake. One of the lower digestibility figures, 35%, was recorded from Nigeria by Brinckman (1974); although the material he examined contained 1.5% N, it was very mature at about nine months. However, if one considers the reports for herbage less than six months old, the mean digestibility figure approximates 59%, and that of intake 60 g $DM/kg^{0.75}$ per day, illustrating the superiority of younger material. On the other hand, in subhumid Nigeria, Peters (1992) found the *in vitro* digestibilities of *S. guianensis* and *S. hamata* to average 50% or less throughout the dry season.

With reference to specific nutrient deficiencies, increases in voluntary intake of P-deficient *S. humilis* have been observed following P supplementation of cattle (Little, 1968; 1985) and sheep (Playne, 1969), but digestibility was unaffected (Playne, 1969). However, marked increases in both digestibility and intake of S-deficient *S. guianensis* accompanied supplementation with S (Hunter et al, 1978).

The above studies involved the whole harvested plant, but grazing animals tend to preferentially select leaf over stem. In Australia, McIvor (1979) and Gardener et al (1982a) reported the *in vitro* digestibilities of separated plant parts and, respectively, found that of leaves to be 64% and 68% while that of stems was 41% and 51%. These compare very closely with similar studies in Malawi, where Lamboll (1982) found the *in vitro* digestibilities of leaf and stem of *S. guianensis* to be 60% and 51%, respectively. In Nigeria, Peters (1992) also found the *in vitro* digestibility of leaf to approximate 60% throughout the dry season, but that of stem averaged less than 40%. The significance of these findings can be gauged from the observation that the proportion of stem in four perennial stylos increased from 20% in the wet season to 75% in the dry (McIvor, 1979), and under grazing, values up to 96% have been recorded (Gardener, 1980). In ungrazed plots in Nigeria, Peters (1992) found that the 40% leaf proportion of *S. hamata* at the start of the dry season decreased very rapidly to 5% by the mid-dry and to 2% by the end of the season, while comparable figures for *S. guianensis* approximated 50, 25 and 10%. Litter of similar composition to the whole plant accumulated to a much greater extent in *S. hamata*; while this would be harvested by grazing animals, it constitutes a serious loss for cut-and-carry systems.

Diet selection

Apart from the preference for leaf already mentioned, it is widely recognised that early in the growing season grazing cattle select grass over legume, moving towards a preference for legume in the late wet and early dry seasons (Hunter et al, 1978; CIAT, 1980; Gardener, 1980; McLean et al, 1981). Mani (1992) observed the diet of Bunaji cattle to contain only 2% stylo during the early wet season on fodder bank, but variation in the botanical composition of selected material can be substantial. Thus Gardener (1980) found diet legume to vary from 2 to 94% during the wet season, and from 6 to 91% during the dry.

Variable effects have also been observed in response to fertiliser application. For example, McLean et al (1981) found an approximately fivefold increase in dietary legume percentage (12 vs 58%) in response to a low level of superphosphate application that was undetectable in terms of forage N and P concentrations; the opposite tendency (30 vs 12%) was observed by Gardener et al (1982b). In the latter work a much higher level of superphosphate input was employed (400 kg/ha/yr), but the reasons for the different degrees of legume selection have not been determined. While these diet selection effects have been observed under grazing, Zemmelink (1980) demonstrated marked increases in quality and quantity of voluntary intake of stylos and other legumes with increasing quantities of material offered in excess of consumption. These findings were obtained in the course of work related to the establishment of nutritive value, but clearly also have important implications in the context of cut-and-carry feeding systems. Of relevance also to cut-and-carry operations is the observation by several workers in various environments that N and P contents of stylos increase in response to cutting during the growing season (Hendy, 1971; Ive, 1974; Mufandaedza, 1976; Robertson et al, 1976; Wilaipon et al, 1981).

Assessment for the subhumid zone

In the fodder bank context, judicious grazing during the wet season, when cattle favour grass, will help to reduce competition for the legume and so produce legume dominance for improved responses to dry-season grazing. It has been established also that improved yields are obtained when these areas are subsequently cropped (Tarawali, 1991), and that stylo intercropping has similar effects with the added advantage of providing better quality material for grazing after harvest (Mohamed-Saleem, 1986).

The evidence reviewed indicates that stylo can play a valuable role as a feed resource of moderately good quality in relation to other material normally available. There is clear potential in the zone for improvement in the nutritive values so far observed. Further, while the provision of salt to livestock is widely practised, the role of phosphatic supplements is worthy of further study, bearing in mind that these are unlikely to be utilised effectively unless herbage N levels substantially exceeding 1% can be achieved (Little, 1970).

It is also apparent that close attention to stylo management is required if its potential is to be realised. The possibilities of conserving stylo hay early in the dry season to minimise leaf loss should be considered for maximising the quality of material available for hand feeding selected stock such as lactating cows, from which substantial returns can be expected. Increased N and P contents in response to cutting during the growing season suggests that the possibility of introducing such a regime into smallholder dairying crop–livestock systems is worth investigating to maximise the benefits of the legume for both animal and crop production. This approach constitutes a significant aspect of ILCA's ongoing research programme in the subhumid zone.

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Development of grazing and utilisation strategies for stylo-based pasture supplies adapted to cattle production systems

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Abstract

The effect of forage legume supplementation on animals maintained on low-quality roughage is mainly due to the high legume intake rather than to increased intake or digestibility of low-quality roughage. Strategies for pasture utilisation entail making changes in stocking rates and pasture size, thereby affecting DM yields and/or their composition. Studies on the impact of such changes are long-term especially when done with cattle. Results of experiments carried out with cattle in simulated farmer-managed grazing systems to investigate several factors including yield and utilisation of *Stylosanthes*-based improved pastures (fodder banks) are discussed in this paper.

Heifers supplemented on fodder banks during the dry season maintained higher ($p < 0.001$) live weights over a three-year period than those on natural savannah. Dry-season supplementation did not affect average-weight changes due to compensatory gains by the non-supplemented groups during the wet season.

A computer modelling approach (GRAZFEED) was adopted to assess possible responses of cattle exposed to improved pastures of different quality. The model indicated that the intake of undegraded dietary protein (UDP) by cattle was limited by the low quality of the pasture even when additional urea–molasses blocks were fed. Intake and liveweight gain could be improved when better grazing was provided.

Stratégies de pâture et de mise en valeur des parcours à base de *Stylosanthes* en vue de la production bovine

Résumé

L'effet de la complémentation d'un fourrage de qualité médiocre avec du foin de légumineuse fourragère est essentiellement dû à la forte consommation de ce dernier plutôt qu'à une ingestion et à une digestibilité accrues dudit fourrage. L'utilisation rationnelle des pâturages passe par l'adoption de stratégies permettant de modifier la charge et la taille des parcours et partant la quantité et/ou la qualité de matière sèche produite. L'effet de ces changements ne peut s'étudier que sur une longue période de temps, notamment lorsqu'on a affaire à des bovins. Cet article présente les résultats d'essais effectués sur des bovins avec simulation de la gestion paysanne, essais dans lesquels plusieurs paramètres ont été étudiés, *y compris la production et l'utilisation de parcours améliorés à base de* Stylosanthes *(banques fourragères).*

Des génisses dont l'alimentation était complémentée en saison sèche pendant trois ans à partir d'une banque fourragère maintenaient des poids vifs plus élevés (P< 0,001) que celles élevées sur des parcours de savane naturelle. Cependant, cette complémentation de saison sèche n'entraînait pas d'augmentations significativement plus élevées du poids dans la mesure où les animaux du lot témoin enregistraient une croissance compensatrice au cours de la saison humide.

Un logiciel de modélisation appelé GRAZFEED a été utilisé pour évaluer le comportement de bovins ayant accès à des parcours améliorés de qualités diverses. Il ressort des résultats enregistrés que les animaux consommaient moins de protéines brutes lorsque le fourrage était de qualité médiocre et ce, même lorsqu'on leur apportait en plus un concentré mélasse-urée. Enfin, un pâturage de meilleure qualité pourrait permettre d'augmenter la consommation et les gains de poids vifs.

Introduction

Previous investigations with sheep have shown that the improved performance from forage legume supplementation could be attributed more to high legume intake than to increased intake or digestibility of low quality roughage (Dixon et al, 1991). Restricting access to the legume supplement was a practical method of rationing supplements.

The effect of forage legume supplement on animals maintained on low quality roughage is partly due to substitution of the low quality roughage with the forage legume, as was noted in sheep supplemented with *Leucaena leucocephala* (Cheva-Isarakul, 1988) or with lucerne (*Medicago sativa*) (Mani, 1992). Similar substitution effects have been reported in cattle fed *Leucaena leucocephala by* Moran et al (1983) and stylo (Mani, 1992).

Developing strategies for pasture utilisation entails making changes in stocking rates, pasture size, yields and/or their composition. Studies on the impact of combining such changes are long-term especially when done with cattle. A modelling approach can be adopted to simulate different management conditions involving changes in pasture yield, composition and the nutritional quality of supplementary feeds.

The studies reported here investigated several factors including yield and utilisation of stylo fodder banks and natural (native) pastures by cattle. The hypothesis tested was that performance of cattle fed fibrous basal feeds and supplemented with forage legumes during the dry season could further be enhanced when additional non-protein nitrogen (NPN) was fed through urea–molasses blocks.

Materials and methods

The study was conducted at the Idon Cattle Breeding Ranch (10°10' N, 7°55' E) which is part of the Kachia Grazing Reserve, 100 km south-east of Kaduna, Nigeria. The area is part of approximately 32 000 ha of rangeland reserved by the government for settling pastoralists. It is approximately 731 m above sea level with an annual rainfall of 1000–1500 mm, most of which falls between April and October.

Herbage yield and botanical composition

Two 20-hectare paddocks of natural tree savannah were sub-divided into four five-hectare paddocks each. One 20-hectare paddock was preserved as natural pasture for use in the dry season and the other was converted into a fodder bank in 1986 by sowing with a mixture (3:1) of *Stylosanthes hamata* cv Verano and *Stylosanthes guianensis* cv Cook and managed according to the guidelines for establishing fodder banks (Otsyina et al, 1987).

Before samples were cut on transects using a 0.5 m^2 quadrat, a visual estimate was made of the herbage cover, and each species identified. The frequency of occurrence of the species was converted to density by the method described by Stoddart et al (1975) and Tothill (1982). All herbage within the quadrat was then cut at five centimetres above ground and separated into stylo; grass and herbs, the fresh weight of each component was recorded. This procedure was followed during the 1988, 1989 and 1990 dry-season trials. The BOTANAL (Tothill et al, 1978) method of pasture evaluation was adopted during the 1991 trial using the same 0.5 m^2 quadrat thrown at random.

Herbage samples

After cutting the forage, samples were air-dried in the field. Samples from each paddock were mixed, sub-sampled, dried at 100°C for dry-matter (DM) determination to calculate dry-herbage yield. Samples for chemical analyses were dried at 60°C for 24 hours, milled through a 1-mm screen and analysed following standard procedures (Goering and Van Soest, 1970; AOAC, 1979).

Treatments and animal management

One hundred (100) open Bunaji heifers (average weight 205 SD 7 kg) were allocated at random to five groups of 20. Each group was allocated at random to one of the following treatments: (1) solely grazed on natural range (G); (2) supplemented by having access to leguminous fodder bank only (GL); (3) preserved natural pasture that remained ungrazed during the rainy season (GNP); (4) preserved natural pasture and urea–molasses blocks (GUM); (5) leguminous fodder bank and urea–molasses blocks (GLM). The trial started in January 1988 and continued for three dry seasons (January to May) up to 1991.

Each treatment group was herded by one herdsmen, who rotated among herds fortnightly. Grazing was carried out for nine hours (0800 to 1700). The preserved natural pasture or fodder bank were grazed at an estimated stocking rate of two tropical livestock units (TLU) per hectare over 14 days by each group of heifers grazing on a five-hectare paddock at a time. Thus, each group was moved to the next paddock in sequence each fortnight. All animals grazed the natural range from morning to noon, when they were watered from a dam. Thereafter, groups 2 and 5 were put onto the fodder bank, groups 3 and 4 to preserved natural pasture and group 1 returned to the natural range. They were watered again at 1700. Mineral salt blocks were made available *ad libitum* at night to all the groups. The urea-molasses blocks were offered *ad libitum* during the night to the two groups GUM and GLM (groups 4 and 5).

At the end of each dry season in May, the animals were regrouped into two herds and grazed only on natural range with mineral salt blocks as supplement. Each animal reverted to its previous treatment group in the second week of December for a two-week adaptation period before being put on its proper treatment in early January.

Whilst on the commonly shared range the heifers were herded with breeding bulls year round throughout the duration of the study. All animals were dipped in acaricide solution weekly during wet seasons and fortnightly during dry seasons. They were dewormed with anthelmintics at the onset, middle and end of each wet season and vaccinated annually against contagious bovine pleuropneumonia (CBPP), anthrax and blackquarter. Animals were weighed fortnightly throughout the year.

Results

Herbage yield and chemical composition

Two paddocks in the preserved natural pasture were completely burnt by accident in 1988 and partially burnt during the 1989 trial period. Table 1 shows the DM yield and botanical

Table 1. *Average dry-matter (DM) yield (t/ha) and composition (%) of fodder bank and preserved natural pasture during the dry season.*

Month	Type of pasture						
	Fodder bank				Natural pasture		
	Yield (t DM/ha)	Composition(%)			Yield t DM/ha)	Composition(%)	
		Stylo	Grass	Herbs		Grass	Forbs
Jan '88	3.1	40	38	22	2.2	90	10
May '88	2.2	15	53	31	1.0	70	30
Jan '89	3.9	55	33	13	1.9	84	16
May '89	1.7	11	66	23	1.2	55	45
Jan '90	7.0	53	34	13	2.2	87	13
May '90	2.9	13	65	22	1.9	79	21
Jan '91	6.4	57	42	1	1.8	96	4
May '91	2.9	30	67	3	1.1	98	2

composition of the fodder bank and the preserved natural pastures. Since the reserved natural pasture was not treated or cultivated in any way the composition and herbage yields were assumed to be comparable to those of the natural range.

At the beginning of each trial the fodder banks were rated as good according to the criteria of Otsyina et al (1987), except in the first year (1988) when stylo content was less than 50% (Table 1). The four-year average DM yield at the onset of the trial was 5 (SD) 2 t/ha for the fodder bank and 2 (SD) 0.6 t/ha for the natural range; yields were reduced to 2 SD 0.6 t/ha and 1 (SD) 0.4 t/ha, respectively, at the end of the grazing in May. The average proportion of the stylo in the fodder bank declined from the 51 (SD) 7% at the start of the trial to 17 (SD) 9% at the end. Conversely, the proportion of the grasses and herbs increased by the late dry season and comprised the bulk of the available feed (Table 1).

It was assumed that only 50% of the herbage (Table 1) was effectively unavailable to stock due to trampling, faecal contamination and other associated grazing effects. The herbage yield during the first year (1988) was estimated to supply 2.0 kg/TLU daily over the 151-day grazing period (January–May) for animals on the fodder bank and preserved natural pasture. In subsequent years, animals on the fodder bank had increased supplies due to declining animal numbers while those on reserved natural pasture had access to about 1–2 kg/day available feed (Table 2).

Table 2. *Stocking rates and estimated feed availability in supplementary fodder banks and reserved pastures, 1988–90.*

Stocking rate	Fodder banks			Pasture		
	1988	1989	1990	1988	1989	1990
Head/ha	1.80	0.95	0.40	1.80	1.10	0.70
(Head/group)	(33)	(10)	(3)	(36)	(22)	(14)
Herbage allowance[1]						
kg/hd	11	14	58	8	12	10
Feed kg/hd per day[2]	1.7	7.7	42.5	2.2	2.1	1.4
Gains/ha/year	20	25	46	2	13	50

The two groups each grazed 20 ha of land for 150 days.

1. Herbage allowance in total herbage in January (see Table 1) divided by the number of grazing days (151 x N of cattle).

2. Feed per day is calculated as the DM disappearance (see Table 1) x 50% divided by the number of grazing days.

The average chemical composition of grass, stylo and herbs in the two pastures is shown in Table 3. Values are given for January, March and May to represent the forage quality at the beginning, middle and end of the dry season grazing period, respectively. The crude-protein (CP) content of the grasses was critically low in both the fodder bank and natural pasture at the end of the dry season grazing period. The stylo and herbs had higher nitrogen (N) content than the grasses throughout the dry season, while the lignin content of stylo was higher than in grass but lower than in herbs.

Table 3. *Chemical composition (g/kg DM) of pasture components.*

Species	Month	CP	NDF	ADF	Lignin	Ash
Fodder bank						
Grass	Jan	38	674	424	62	94
	Mar	37	745	470	75	86
	May	117	741	470	103	136
Stylo	Jan	110	627	537	128	54
	Mar	90	722	614	152	40
	May	147	707	604	161	65
Herbs	Jan	88	486	605	236	95
	Mar	181	580	482	215	69
	May	165	653	614	314	109
Natural pasture						
Grass	Jan	26	727	450	70	86
	Mar	32	720	463	77	98
	May	98	742	461	92	129
Herbs	Jan	91	492	417	161	104
	Mar	178	613	521	262	43
	May	160	633	581	314	94

CP = Crude protein; NDF = Neutral-detergent fibre; ADF = Acid-detergent fibre.

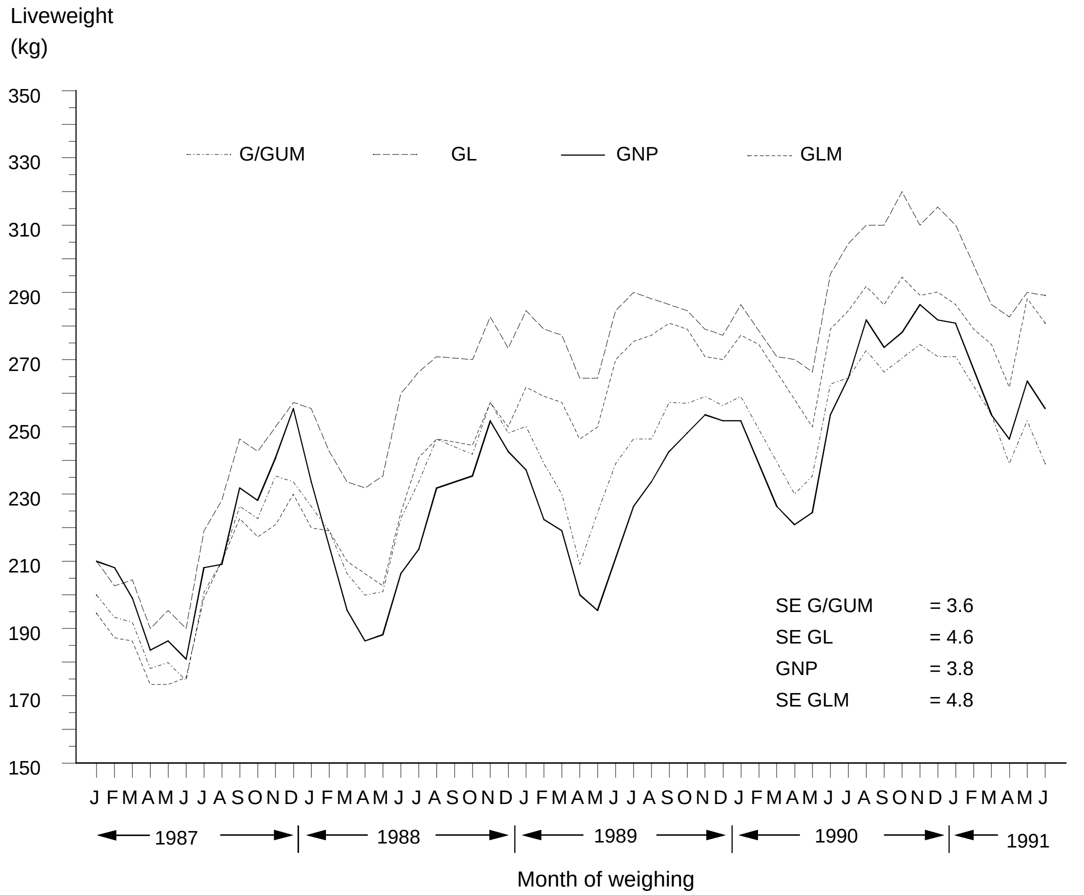
Animal weight changes

Animals supplemented on the fodder banks (GL and GLM) performed best ($P< 0.001$) over the duration of the experiment (Figure 1). However, heifers in all five groups lost weight during each dry season (January to May) and gained weight between May and July. The heifers in the GLM and GL groups were heavier ($P< 0.001$) in each month in 1988 and 1989 after which most of them became pregnant accounting for a declining number of animals over time (Table 2). However, their average animal weight gains in the two years were not significantly different from the other groups (Figure 1). Animals supplemented on the preserved natural pasture (GNP) had a net weight loss of 14 kg during the first year but gained 17 kg during the second year (Table 4).

The GRAZFEED model

Dry, non-pregnant Brahman cows weighing 205 kg at the age of 48 months were selected in the GRAZFEED program as the model class of animals to be supplemented. Four treatment groups were tested. Those grazed on open range only (G); those supplemented with urea–molasses block (GUM); and those supplemented with fodder bank alone (GL); and with additional urea–molasses block (GLM). Since simulations were for the dry-season supplementation only; weather effects on intake or energy expenditure were not considered. Also, the slope was set at one as the multiplier used in GRAZFEED for flat ground.

Figure 1. *Average weight (kg) of Bunaji cows supplemented on fodder bank with or without urea-molasses block (1987–91).*[1]



1. The weights of the G and GUM groups were similar and were therefore averaged to make the graph clearer.

Table 4. *Three-monthly weight changes in the five treatment groups in 1988 and annual changes in 1988 and 1989, kg/head.*

Treatment	Jan–Mar	Apr–Jan	Jul–Sep	Oct–Dec	Year 1988	Year 1989
1) Control(G)	–25	+ 32	+ 7	+ 7	21	27
2) Fodder bank(GL)	–20	+ 36	5	+ 4	15	34
3) Preserved pasture (GNP)	–47	+ 29	+ 9	–5	–14	17
4) GNP + UM block (GUM)	–22	+ 39	+ 8	–7	18	8
5) GL + UM block (GLUM)	–19	+ 32	–5	+ 17	25	15
Mean	–27	34	3	3	13	20
Average daily weight change (g/d)	–30	370	31	35	36	55

The average DM yields obtained from the fodder bank (5.1 t/ha) and natural pasture (2.0 t/ha) were used in the model. The natural pasture was assumed to have 100% dead herbage (DH) with a DM digestibility of 520 g/kg. The fodder bank was assessed with green herbage (GH) fractions of 33 to 50% and a stylo content of 40–60% of the total. The DM digestibility of the GH was assumed to be 660–750 g/kg while that of the dead herbage was 520 g/kg. These were the values for the average DM disappearance from nylon bags of the stylo and *A. gayanus* obtained over 48 hours of incubation in the rumen of heifers grazed in the GL and GLM groups (Mani, 1992). Values for the urea–molasses blocks were 970 g/kg DM, 750 g/kg digestibility, 8.5% N content (with 700 g/kg digestibility) and metabolisable energy content of 11.6 MJ/kg. Six levels (0, 0.2, 0.3 0.6, 1.2 and 2.4 kg/head per day) of intakes of the urea–molasses block were compared, based on the range of intakes of these blocks observed at various times in a complementary study (Mani, 1992). A summary of the results of the runs is shown in Table 5.

Table 5. *Response of cattle to different combinations of natural pasture and fodder-bank grazing with urea–molasses block supplementation using the GRAZFEED program.*

TRT	Pasture DM (t/ha)		Stylo (%)	Estimated DMI (kg/day)		ADG (g)	UDP Def (g/day)
	GH	DH		Pasture	UMB		
Field data							
Native pasture only							
G	–	2.0	0	2.6	0.0	–830	–162
GUM	–	2.0	0	2.5	0.2	–690	–136
GUM	–	2.0	0	2.5	0.3	–620	–124
GUM	–	2.0	0	2.4	0.6	–400	–86
GUM	–	2.0	0	2.1	1.2	20	–
GUM	–	2.0	0	1.7	2.4	180	218 (L)
Fodder bank with 50%stylo							
GL	1.7	3.4	50	3.6	0.0	–190	–91
GLM	1.7	3.4	50	3.5	0.2	–50	–57
GLM	1.7	3.4	50	3.4	0.3	–20	–39
GLM	1.7	3.4	50	3.3	0.6	190	39
Fodder bank projections							
(40% stylo; 75% green)							
GL	3.8	1.3	40	3.8	0.0	50	–71
GLM	3.8	1.3	40	3.8	0.2	90	–62 (L)
(50% stylo; 75% green)							
GL	3.8	1.3	50	3.8	0.0	50	–71
GLM	3.8	1.3	50	3.8	0.2	90	–52 (L)
(60% stylo; 75% green)							
GL	3.8	1.3	60	3.9	0.0	160	–51
GLM	3.8	1.3	60	3.9	0.2	190	–42 (L)

DMI = Dry-matter intake; GH = Green herbage; DH = Dead herbage; UMB = Urea–molasses block; ADG = Average daily gain; Stylo % = Stylo content in pasture; UDP Def = Deficiency of undegraded dietary protein.

(L) = Limit : level of intake urea–molasses block at which pasture intake and weight gain were maximised.

The required daily DM intake of forage by the cows was estimated at 3.9 kg/head by the program. Animals on the open range (G) and those supplemented with urea–molasses block (GUM) were estimated to consume only 1.7 to 2.6 kg daily. High intake was recorded in the non-supplemented animals compared to those supplemented with the urea-molasses block which depressed DM intake from pasture. Animals on the fodder bank (GL) also had slightly higher forage intakes than those fed additional urea–molasses block (GLM). The required daily forage intake was achieved only when the fodder bank contained 75% green herbage with 60% stylo (Table 5). There was no difference in forage intake between the GL and GLM groups at that proportion. When the stylo content of the fodder bank was 40–60%, the benefit of feeding additional urea–molasses block was limited at a daily intake of 200 g/head.

The model showed liveweight losses of 400–830 g/head per day in dry cows on the range and natural pasture up to a level of daily urea–molasses block intake of 600 g/head. This was greater than the range of daily liveweight loss of 210–520 g recorded in the grazing experiment in 1988 (Table 4). The liveweight loss of 190 g/day in the GL changed to a gain of 160 g/day as the green herbage and stylo content of the fodder bank increased. Higher liveweight loss (220 g/d) was recorded in the grazed animals than was predicted by the model for the GL and GLM group (Table 4).

The GRAZFEED program showed that cow performance was limited by the low concentration of protein in the diet such that cows were eating insufficient undegradable protein to meet their estimated needs (Table 5). Because no ration fully met the undegraded dietary protein (UDP) requirements of the animals, an upper limit to further response to supplementation was reached. Thus, the composition of the pasture limited further intake and high levels of urea-molasses block consumption further depressed DM intake of forage from the pasture. At all stages of the runs the program recommended that the animals be moved to better pastures.

Discussion

Herbage yield and botanical composition

The DM yields of the fodder bank were within the range of 5–10 t/ha recorded by Mohamed-Saleem and Suleiman (1986) in other fodder banks, but contained less stylo with a lower CP content. This was because pasture assessment began in January, three months later than in their study.

Stocking rate and grazing intensity are amongst the factors which influence pasture regeneration and botanical composition. Fodder banks grazed by cattle at 2 TLU/ha have been shown to maintain a legume composition from 40 to 57% over a three-year period (Table 1). Cattle are usually allowed to graze the fodder banks for only two to three hours daily (Mohamed-Saleem, 1986; Mani et al, 1987). The rapid decline of stylo during the dry season indicated heavy use because the cattle depended on the stylo as their main source of protein since the grass component was low in N.

Liveweight changes

The pattern of liveweight change was similar to that found on rangelands in monsoonal Australia and southern USA (Norman, 1966; Duvall and Hansard, 1967; Coates and t'Mannetje, 1990) and in West African savannahs (de Leeuw and Agishi, 1978; Diarra and Bosma, 1988). The rapid liveweight loss between March and April in all years (Figure 1) was possibly due to the reduction in gut contents (McLean et al, 1983). The high compensatory liveweight gain during the early part of the rainy season (May–July) when green forage with a higher N content and digestibility became available (Saleem, 1985a) may partially be due to increased gut fill. A similar "flush" effect has been reported in northern Queensland (Winks et al, 1983).

The net weight gain during the first year of supplementation (15–25 kg) in this study was lower than the 30 kg and 66 kg obtained by Haggar (1971) with Bunaji bulls supplemented daily with 0.23 kg of whole cottonseed. Higher net gains of 98 kg by Bunaji cattle on stylo pasture were reported by Agishi (1983); these pastures had higher DM yields, but more importantly, the animals had access day and night instead of the restricted period used in this study.

The poor performance of animals on the preserved natural pasture was attributed to low availability of forage (Table 2) and demonstrated that urea–molasses supplementation alone did not prevent liveweight losses. Because parts of the preserved natural pasture and the adjacent open range were inadvertently burnt, feed shortages were further aggravated in 1988 and 1989.

The GRAZFEED simulation

The GRAZFEED simulation confirmed the nutritional limitations of the natural pasture and showed that there was no advantage to feeding additional urea-molasses blocks to animals with access to good-quality fodder banks containing 75% green herbage. At the same time, it over-estimated losses of stock grazing only natural pastures.

The levels of UDP deficit shown in the model indicate that other forms of supplement need to be fed. This is because, even at 75% green herbage content with 60% stylo, there was still a UDP deficit. However, this program was developed with Australian breeds, while in the Nigerian environment, the basal metabolic rate of the Bunaji cattle might be lower than that for Brahman cattle due to inherent genetic differences (Frisch and Vercoe, 1976; van der Merwe and van Rooyen, 1979), and adaptation to prolonged undernutrition. Thus, the feed requirement of zebu cattle for maintenance and production might be lower.

Conclusion

Although restricted forage legume grazing did not prevent liveweight losses, the losses were lowest in the treatment groups on fodder banks with and without urea–molasses blocks. There was no significant advantage in feeding urea–molasses blocks to animals on fodder banks. The group supplemented on preserved natural pasture had the lowest performance because these animals had access to less feed than both the control animals on free range and those on fodder banks.

An assessment with the GRAZFEED program gave similar results and indicated that higher weight gains can be obtained from the fodder banks that have higher green herbage content even at the current level of DM yield. This implies that it might be possible to derive more benefit from the fodder banks when they are grazed during or towards the end of the wet season. The potential benefit of such a strategy has been demonstrated with goats (Ikwuegbu et al, pp. 167–174). A grazing experiment with Bunaji heifers is currently being conducted to validate the results of the GRAZFEED simulation. The consequences of such a strategy on the persistence of the forage legume, changes in the botanical composition of the fodder bank and input requirements need to be studied.

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Sustaining a crop–livestock farming system in the subhumid zone of Nigeria by matching feed from improved *Stylosanthes*-based pastures and livestock production

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Abstract

Experiments were designed to study the relationships amongst stocking rate, growth of West African Dwarf goats, pasture dry matter (DM) yield and botanical composition and crop yields planted after fallows and legume pastures. Does aged about 18 months were allocated to four stocking rates (SR) of 4, 6, 8 and 10 does/paddock (0.14 ha) in a randomised block design replicated five times. Animals were weighed every two weeks. The grazing trial lasted for 14 weeks.

Grain yields in 1991 from plots sown to *Stylosanthes* in 1990 and longer-term natural pasture were 2245± 606 and 1654± 250, 1533± 444 and 1476± 339, 724± 375 and 475± 194 kg/ha for maize, sorghum and millet, respectively. A similar trend was observed for residues from these crops. At the end of the trial does on SR 4 were significantly heavier ($P < 0.05$) than those on SR 10. Liveweight increases per unit area ranged from 81 to 108 kg/ha and suggested that under on-station conditions SR 8 (57 does/ha) was optimum. Kids from does at SR 4 were significantly heavier ($P < 0.05$) up to 90 days of age and twin kids were significantly ($P < 0.05$) lighter than singles. At SR 10, pasture DM availability lasted for only 14 weeks. There is evidence that crop and livestock production can complement one another in smallholder systems.

Stabilisation d'un système mixte dans la zone subhumide du Nigéria par l'adaptation de la production des parcours améliorés à base de *Stylosanthes* aux besoins des animaux d'élevage

Résumé

Des expériences ont été effectuées pour étudier la relation entre le taux de charge, la croissance de la chèvre naine d'Afrique de l'Ouest, la teneur en matière sèche du fourrage et la composition botanique des parcours et les rendements des cultures mises en place après des jachères et des pâturages à légumineuses. Des chèvres âgées d'environ 18 mois ont été réparties en quatre groupes avec des taux de charge de 4, 6, 8 et 10 animaux par parcelle de 0,14 ha selon un plan à bloc aléatoire complet comprenant cinq répétitions. Les animaux étaient pesés toutes les deux semaines et l'expérience de pâture a duré quatorze semaines.

En 1991, les rendements des céréales semées après Stylosanthes *cultivé en 1990 ou après une prairie naturelle de longue durée étaient respectivement de 2245± 606 et 1654± 250 kg/ha pour le maïs, 1533± 444 et 1476± 339 kg/ha pour le sorgho et 724± 375 et 475± 194 kg/ha pour le mil. La même tendance avait été observée en ce qui concerne les résidus de ces récoltes. A* *la fin de l'essai, les animaux élevés à 4 par parcelle avaient un poids supérieur ($P< 0,05$) à ceux des chèvres élevées à 10 par parcelle. Le poids vif augmentait de 81 à 108 kg/ha, ce qui signifie qu'en station la charge optimum était de 8 animaux par parcelle (57 chèvres/ha). Jusqu'à l'âge de 90 jours, le poids des chevreaux nés de mères élevées à 4 par parcelle était significativement supérieur ($P< 0,05$) à celui des autres petits. Quant au poids des jumeaux, il était significativement inférieur ($P< 0,05$) à celui des petits issus de naissances simples. A la charge de 10 animaux par parcelle, le disponible en matière sèche du parcours n'avait duré que quatorze semaines. Les résultats de cette étude montrent que l'agriculture et l'élevage peuvent se compléter mutuellement dans les petites exploitations.*

Introduction

Crop farmers in the subhumid zone of Nigeria traditionally leave land fallow to allow vegetative material to recycle nutrients and restore soil fertility (Young and Wright, 1984). Increasing pressure on land from a rising human population is reducing the length of the fallow period, therefore with limited fertiliser application, crop yields are decreasing and the environment may be degrading. Nitrogen (N) accruing in the soil after three to four years of fallow enriched by *Stylosanthes* increased grain yields of maize (Mohamed-Saleem and Otsyina, 1986) and acha (*Digitaria exilis*). In addition, the residual N in the soil can be exploited through reduced N requirement for subsequent crops (Tarawali and Pamo, 1992). Improved soil structure made tillage easier thus reducing the amount of farm work. These benefits encouraged the incorporation of forage legume into the farming system and farmers are increasingly adopting legume-enriched fallows.

Small ruminants, pigs, poultry and sometimes cattle are common components in smallholder farming systems. Because malnutrition remains a major constraint to animal production (Kapu, 1975; Mohamed-Saleem, 1986; Mani et al, 1987) a low-input fodder bank package for dry season feeding of livestock has been developed (Mohamed-Saleem and Suleiman, 1986). However, the cost of inputs and securing land rights by agropastorialists have partly contributed to low adoption rate of this package (See Ajileye et al, pp. 311–316).

Small ruminants, (particularly goats), experience feed stress in the wet season (August to October) because they need to be tethered to prevent crop damage. However, when West African Dwarf (WAD) goats grazed *Stylosanthes* or natural pasture in the wet season weight losses were reduced (ILCA, 1988; ILCA, 1991). Performance of goats varied due to differences in the size of farmers' plots and flocks, pasture yield and botanical composition and in management systems. Some farmers grazed fodder banks in one season, natural pasture in the next when the land was cropped, or provided limited supplementation from cut-and-carry feed.

It appeared desirable to investigate the effects of stocking rate, pasture dry matter yield and botanical composition on goat performance. This information may assist resource-poor farmers to produce crop and livestock products more economically.

Materials and methods

Site

This study was carried out at Abet (90°40' N, 8° 0' E) in Kaduna State, 250 km south of Kaduna town. The average rainfall is 1300 mm, 95% of which falls between April and October. The trial area was established on acidic Lithosols, containing 0.36% organic matter, 0.086% nitrogen, 1.8 ppm available phosphorus (P) and 0.13 meq/100 g of potassium (K) (Mohamed-Saleem and Otsyina, 1986).

Pasture establishment and evaluation

Ten hectares of Verano stylo pastures were established in 1990 using procedures described by Otsyina et al (1987). A seed rate of 12 kg/ha was used and 150 kg single superphosphate (SPP)/ha were applied. The pasture was top-dressed in 1991 with 100 kg SSP/ha and was grazed by cattle at the beginning of the wet season to produce a legume- dominant pasture. The pasture was divided into 20 paddocks of 0.42 ha each. Herbage yield was measured by clipping 0.25 m^2 quadrats thrown at random in each paddock in five replicates. These samples were weighed, hand-separated into stylo, grasses and forbs, dried to constant weight in a convection oven at 60^{o}C, milled to pass through a 1-mm sieve in a hammer-mill and stored in airtight containers for chemical analysis. Material in 1-m^2 enclosures protected from grazing was sampled separately at the end of the trial to determine ungrazed DM yields.

Cereal cropping experiments

Each 0.42 ha paddock was divided into three equal sub-paddocks of 0.14 ha. One portion was left as stylo pasture and the other two were cropped with a maize/sorghum inter-crop and sole millet, respectively. The maize/sorghum mixture was planted in May/June 1991 on ridges 30 cm high and spaced 1 m apart. The in-row distance between plants was 20 cm and 60 kg of each of N, P and K were applied. The nitrogen was applied in two split doses. Weeding with a traditional hoe was carried out at planting and six weeks after sowing. The millet was transplanted in August and the crop was fertilised like the other crops. However, since this cereal was planted later in the wet season, it was weeded only once. The spacing between stands of the crop was 30 cm in rows 1 m apart.

Similar paddocks (without stylo) were also constructed in the natural fallow area as controls. One part was stocked at four does/paddock and two paddocks were again cropped with the same cereals as in the legume plots. At the end of the growing season crops were harvested and grain and crop-residue yield determined. The maize was harvested in October and the sorghum and millet in December.

Animal management and experimental design

One hundred and forty West African Dwarf (WAD) does and 20 breeding bucks aged 15 to 18 months were purchased, tagged and quarantined for three months. They were vaccinated against peste de petits ruminants (PPR), routinely treated against ecto- and endoparasites, provided with shelter on their plots and given salt and water *ad libitum*. Animals weighed 16.6 ± 2.58 (mean ± SE) kg at the beginning of the trial. The four stocking rates of 4, 6, 8 and 10 does/paddock (corresponding to 1.90, 2.86, 3.86 and 4.71 TLU/ha) were laid out in a completely randomised block with five replicates. Animals were divided through stratified random allocation to treatments. All animals grazed legume pasture for about one month before being put on trial. Bucks were put into each paddock in August 1991, rotated among paddocks and were removed after six weeks. After 14 weeks (from early August to late November 1991) the plots were destocked to one half of the initial stocking rate and the experiment continued for another 16 weeks until mid-March 1992. Animals were weighed at fortnightly intervals using hanging scales. Birth weights and type, birth dates and deaths were recorded.

Statistical analysis

Data were analysed using the GLM procedure of SAS (1987). The experimental unit was the paddock. The effects in the model were paddock (blocks) and treatment (stocking rates). The other effects (liveweights, sex and type of birth) were factorially combined with treatment without interactions. All other effects were tested against the overall model residual. Pregnant animals were excluded from the analysis. For does that kidded between December 1991 and February 1992, reproductive responses were calculated using a gestation period of 150± 5.0 days. Kids which remained in the paddocks were included for computing growth rates from birth to weaning at 120 days.

Results

Pasture productivity

Before introducing the animals in August yields of stylo pasture averaged 2.9±00.6 t/ha and 2.69± 0.65 t/ha for fallows. At the onset of the dry season in December, yields decreased from 2.9 at four does/plot to 1.6 t/ha for 10 does/plot (Table 1). The fallow with four does/plot produced 2.52 ± 0.11 t/ha. Average productivity of stylo enclosures measured in December was 5.6 t/ha compared with 7.4 t/ha in the fallows.

Table 1. *Effect of stocking rate on pasture DM yield (t/ha) and botanical composition (%) at the beginning (August) and end (November) of the trial.*[1]

Stocking rate (does/paddock)	DM yield		Stylo		Grasses		Forbs	
	Before	After	Before	After	Before	After	Before	After
Fallow	2.69	2.52	–	–	73	87	27	13
4	2.62	2.89	56	67	26	27	18	6
6	2.59	2.28	54	67	27	23	19	10
8	2.86	2.06	66	66	22	24	12	10
10	2.29	1.65	64	71	16	17	20	12
SEM[2]	0.093	0.209	2.9	1.1	22.9	29.0	5.4	2.7

1. The figures refer to pasture composition before and after grazing.
2. Standard error of the mean.

Grain and crop residue yields

Grain yields of millet, maize and sorghum inside the *Stylosanthes* pasture were 50%, 36% and 4% higher, respectively, than those of crops grown in natural fallow. Total feed resources of crop residues and volunteer herbage after the grain harvest varied from 4.5–4.8 t DM/ha for sorghum/maize and 3.1–3.7 t DM/ha for millet. Due to the low canopy cover of millet, volunteer herbage was more prominent. Previous treatments had little effect on total feed in contrast to that on grain (Table 2).

Animal productivity

Mean liveweight changes in the treatment groups at the end of the 14-week grazing trial were different ($P < 0.05$). On the highest SR the available feed was barely sufficient to maintain body weight (Figure 1). The increased weights towards the end of the trial were attributed to foetal growth following conception. Net liveweight increases ranged from 81 to 109 kg/ha across SR (Table 3).

Table 4 shows the live weights of WAD kids from birth to 150 days. Stocking rate and birth type significantly affected birth weight and live weight ($P < 0.05$) at these ages. The litter size of does on SR 4 was higher than on SR 10; 64% of kiddings on SR 4 were twins as compared to 41% in SR 10.

Table 2. *Grain, residue and herbage yields of crops grown on previous stylo pasture and old fallow.*

Parameters	Maize		Sorghum		Millet	
	Stylo	Fallow	Stylo	Fallow	Stylo	Fallow
Grain kg/ha	2245	1654	1533	1476	724	475
	(606)[1]	(250)	(444)	(389)	(375)	(194)
Residue t DM/ha	2.42	2.22	3.87	3.67	1.92	1.08
	(1.04)	(0.74)	(1.52)	(1.50)	(1.12)	(0.47)
Weeds t DM/ha	0.91	0.88	0.91	0.88	1.74	2.26
Total fodder t DM/ha	3.33	3.10	4.68	4.55	3.66	3.34

1. Figures in parentheses are standard errors.

Table 3. *Effect of different stocking rates on growth performance of West African Dwarf goats in the wet season.*

Parameters	Stocking rate (does/paddock)				
	4	6	8	10	Mean (SEM)
Initial weight (kg)	16.6	16.7	16.9	16.5	(0.45)
Final weight (kg)	20.3	18.7	18.8	17.9	(0.72)
Weight change (kg)[1]	3.7[a]	1.9[bc]	1.9bc	1.4[c]	(0.52)
ADG g/d[2]	37.8	19.4	19.4	14.3	(5.2)
Gain, kg/ha[2]	106	81	109	100	(61)

1. Means within rows with different superscripts are significantly different ($p < 0.05$).

2. Livestock increases (kg/ha): weight change x number of does/0.14.

SEM = Standard error of the mean.

ADG = Average Daily Gain.

Discussion

Does on stylo-based pastures gained 1 kg more weight than those on fallows when stocked at four does/ha. There was an inverse relationship between stocking rate and pasture DM availability at the end of the trial (Table 1). While in the wet season the stylo pasture or fallows provided the only feed, in the dry season this feed was complemented by crop residues (plus an understorey of stylo and weeds) from the cropped areas. However, stocking rate for the dry season was reduced by 50% across all treatments. In the next wet season (1992) the highest stocking rate of 10 does/plot (4.7 TLU/ha) was omitted because pasture regeneration provided inadequate feed at this rate.

The increase in grain and crop–residue yields in the stylo areas was attributed to improved chemical and physical properties of the soil caused by the one year of legume growth (Table 2). Preliminary analyses of soil samples collected in June 1992 confirmed that level of stocking affected the soil's physical, chemical and biological properties. The effects of stocking rate on stylo regeneration, soil properties and subsequent crop yields will be further studied in subsequent years.

Figure 1. *Wet season weight changes of non-pregnant WAD does grazing forage legumes at different stocking rates (beginning August 1991).*

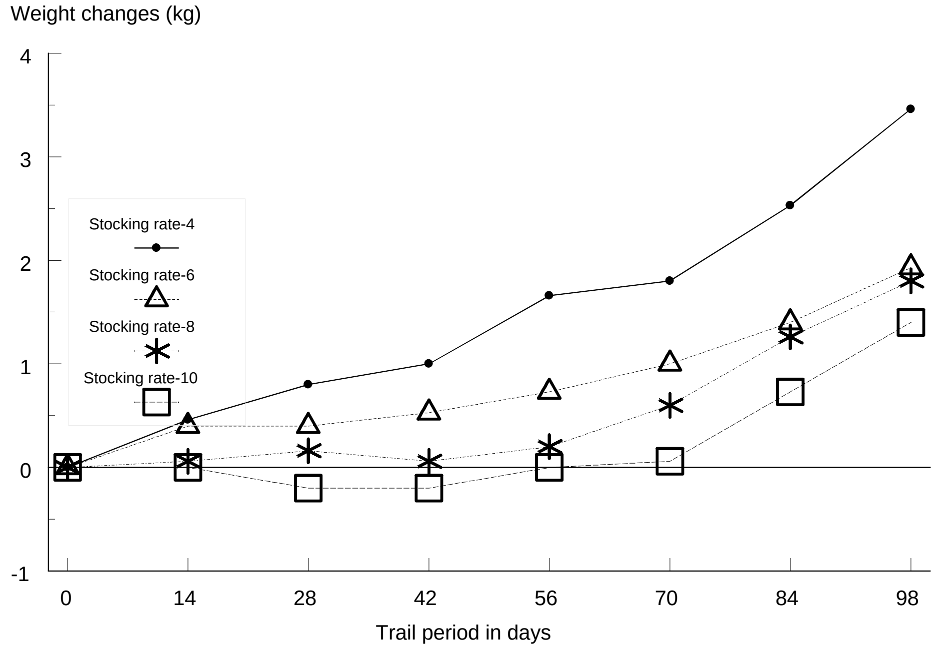

Table 4. *Least squares means (± SE) of live weight (kg) at birth, 30, 90, 120 and 150 days by treatment, sex and type of birth subclasses.*

Effect	Number	Weight (kg)				
		Birth	30 days	90 days	120 days	150 days
Overall	87	1.3± 0.06	3.0± 0.07	5.2± 0.14	5.2± 0.23	6.9± 0.58
Stocking rate		*	***	***	NS	NS
(does/paddock)						
4	15	1.5^{a}± 0.06	3.7^{a}± 0.14	6.6^{a}± 0.31	4.6± 0.17	8.0± 0.56
6	22	1.3^{b}± 0.05	3.2^{b}± 0.12	5.3^{b}± 0.27	5.1± 0.41	6.7± 0.50
8	22	1.2^{b}± 0.05	2.7^{c}± 0.13	4.5^{c}± 0.37	6.3± 0.43	7.2± 0.46
10	28	1.3^{b}± 0.05	2.7^{c}± 0.10	4.2^{c}± 0.20	5.1± 0.40	6.3± 0.61
Birth type		***	***	***	*	*
Single	28	1.5± 0.05	3.6± 0.11	6.1± 0.25	6.0± 0.34	7.6± 0.43
Twin	61	1.2± 0.03	2.5± 0.07	4.3± 0.18	4.5± 0.33	6.5± 0.34
Sex						
Female	42	1.3± 0.04	3.0± 0.09	5.2± 0.19	5.3± 0.32	7.3± 0.35
Male	45	1.4± 0.04	3.1± 0.09	5.1± 0.19	5.2± 0.34	6.8± 0.40

* NS = Not significant; ** P< 0.01; *** P< 0.001.

Means with different superscripts within each column are significantly different (P< 0.05).

Previous studies showed that when goats had access to mini-fodder banks, initially there was a reduction in wet season weight losses compared with animals on fallows, but when feed on offer declined, goats began losing weight in all treatments (ILCA, 1991). At SR 4 in the current trials there was a net increase in pasture DM yield suggesting that pasture growth was greater than the herbage removal by four does. On SR 10, DM yield decreased and after 14 weeks of grazing there was not enough feed to continue the trial at its original SR.

The weight gains in this experiment have important implications for goat feeding in the wet season when malnutrition is severe. This rapid growth will enable WAD goats to reach puberty earlier, while overall productivity will increase directly through better nutrition of the does and indirectly through higher growth and viability of the kids.

In determining an optimum SR, a compromise is required between individual higher weight gains on the lower SR and the increased total kid crop from the higher SR on the one hand and pasture regeneration, persistence and DM yield during the subsequent wet season. It appears that the optimum stocking rate is close to eight does/paddock or 57 does/ha over the initial 14 weeks.

There are several features in the mini-forage bank concept that are attractive to farmers. The plots are small and compatible with average flock sizes. The package is simple and can be adopted also by women, providing them with greater security of land use. Any smallholder farmer can modify the package whether his major interest is in cropping by exploiting the N accruing in the soil from the improved fallows, or in livestock keeping. For livestock, the forage legume bank is used to feed small ruminants both in the wet season and in the dry season together with crop residues.

In the simplified package that is now being tested at farmer level, the cost of inputs has been reduced by introducing live fencing posts like *Ficus* spp instead of the metal posts and wire netting initially recommended for a secure enclosure. Because animals are tethered in the fodder banks as in the traditional system, one strand of barbed wire is sufficient to demarcate the plot; this affords the farmer controlled use and protection of his fodder resource. It is postulated that the mini-fodder bank package appears to be a promising avenue of integrating crop and livestock production in the smallholder farming system.

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An evaluation of stylo–grass mixtures for pasture leys

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Abstract

Mixed pastures of stylo (*Stylosanthes guianensis* cv Cook) and Rhodes grass (*Chloris gayana* cv Callide) were sown between 1979 and 1985 to assess methods of establishment and resulting herbage production from cutting and grazing regimes at Shika (National Animal Production Research Institute (NAPRI)).

Broadcasting stylo seed produced higher dry matter (DM) yields than drilling. The grass: legume seeding ratio of 3:7 gave the highest yield and proportion of stylo in the 1979 (1.64 t/ha, 32%) and in the 1980 (3.21 t/ha, 37%) growing seasons. The application of nitrogen (N) fertiliser in July and September 1980 to an established stylo–Rhodes grass pasture gave lower stylo yields than when applied in August.

Soil moisture stress, pests and competition from Rhodes grass adversely affected the establishment and growth of stylo when sown for grazing trials. During 1985–87 the pastures were continuously grazed from the late wet season (August) into the mid-dry season (March) at 12, 18, 24, 30 an 36 rams/ha. Total herbage and stylo yields declined from 10.3 and 1.15 t/ha, respectively, at the beginning of grazing to 5.36 and 0.08 t/ha, respectively, after seven months of grazing. Daily liveweight gains of sheep declined from 118 g/d in early August to 30 g/d in early November.

The importance of adequate establishment procedures, improved pasture management and incorporation of more legume/persistent species are highlighted.

Evaluation des associations *Stylosanthes*–graminées pour les soles fourragères

Résumé

Des parcours mixtes de Stylosanthes *(*Stylosanthes guianensis *cv. Cook) et d'herbe de Rhodes (*Chloris gayana *cv. Callide) ont été installés entre 1979 et 1985 au National Animal Production Research Institute (NAPRI) à Shika (Nigéria) en vue d'évaluer les modes d'implantation et l'effet des régimes de coupe et de pâture sur la production de fourrage.*

La production de matière sèche de Stylosanthes *était plus élevée avec le semis à la volée qu'avec le semis en lignes. Sa production et sa proportion étaient maximum au cours des saisons de croissance de 1979 (1,64 t/ha; 32%) et de 1980 (3,21 t/ha; 37%) avec un rapport graminées–légumineuses de 3/7. Ses rendements étaient plus faibles lorsque l'engrais azoté était appliqué en juillet et septembre 1980 plutôt qu'en août de la même année.*

L'humidité du sol, les maladies et l'herbe de Rhodes freinaient l'établissement et la croissance de Stylosanthes *dans les essais de pâture. Entre 1985 et 1987, les parcours étaient en permanence soumis à une charge de 12, 18, 24, 30 et 36 béliers/ha de la fin de la saison humide (août) au milieu de la saison sèche (mars). Les productions totales de la graminée*

et de la légumineuse, qui s'établissaient respectivement à 10,3 et 1,15 t/ha au début de la période de pâture, n'étaient plus que de 5,36 et 0,08 t/ha respectivement après sept mois de pâture. Les gains moyens quotidiens des animaux avaient baissé de 118 g/jour début août à 30 g/jour début novembre.

Enfin, cet article met l'accent sur l'importance des méthodes d'installation, des modes de gestion améliorés des parcours et de l'introduction de légumineuses et d'espèces vivaces dans les soles fourragères.

Introduction

Livestock owners manipulate different feed resources throughout the year to increase the plane of nutrition of their animals in order to improve output of milk and/or live weight. Similarly, when farmers invest in sown pastures, proper establishment and management of grass–legume components are necessary to maintain their productivity. The success of stylo establishment depends on factors such as soil, climate and incidence of pests and diseases. The management involving fertilisation and grazing by livestock should be included when evaluating species sown in grass–legume mixtures. This paper reports on research focusing on the establishment, management and productivity of stylo-based pastures subjected to different cutting and grazing regimes carried out between 1979 and 1985.

Effect of seeding ratio and sowing method

Establishment and management

Land preparation before sowing was done in June 1979 and involved disc ploughing once, harrowing twice and raking in. Phosphorus at the rate of 9 kg/ha was applied at planting and again in June 1980. Seven Rhodes grass: stylo seeding ratios (10:10, 10:3, 6:4, 5:5, 4:6, 3:7 and 0:10) were compared as the main plots in the split-plot design. In the subplots three sowing methods of the grass and legume were tested: (a) drilled in alternate rows, 30 cm apart, (b) broadcast and (c) drilled within the same rows, 30 cm apart. An equivalent of 10 kg of pure seed/ha was sown for each ratio. Stylo was treated in water (80^{o}C for 10 minutes) to break hard-seededness. Dry-matter (DM) yields were estimated by cutting at a height of 20 cm above ground level 120 days after sowing.

Herbage production

Total DM yields averaged over two seasons were higher in the mixed than in the sole grass or sole legume pastures (Table 1). A progressive increase from 3 to 10 kg of seed/ha of stylo seed resulted in a twofold increase in legume yield. Despite the lower rainfall in 1980 (600 mm) yields of grass and legume exceeded 1979 yields (average annual rainfall 980 mm) in each treatment except the sole legume. Total DM yields in the first year ranged from 4.34 to 5.10 t/ha and from 7.16 to 8.60 t/ha in the second year (Figure 1).

The 3:7 (30%) ratio also produced highest DM yield and proportion of stylo (1.64 t/ha; 32%) in 1979 and (3.21 t/ha; 37%) in 1980. There was no significant difference in the mean yields (4.76 to 5.33 t/ha) of the grass between sowing methods. The two-year averages of yields of stylo from broadcasting or seeding in mixed or alternative rows were 2.35, 2.06 and 1.84 t/ha, respectively.

Crude-protein (CP) content

At the end of the growing season CP content in grass herbage averaged 3.4% in 1979 and 3.8% in 1980 while the values for stylo were 9.6 and 10.3%, respectively. Sowing method had no influence on protein content.

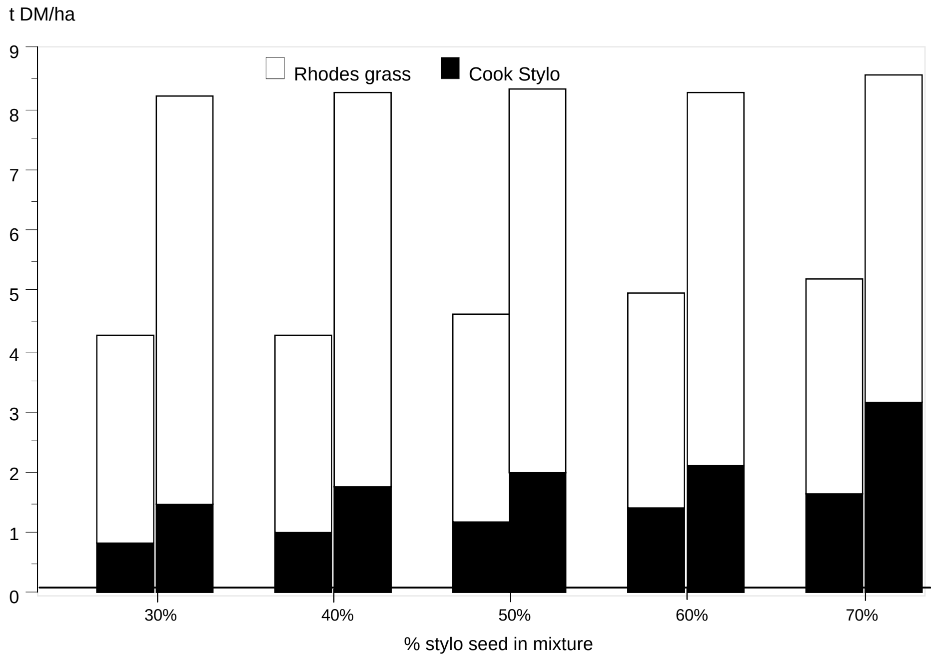
Table 1. *Effect of seeding ratio on mean dry-matter yields (t/ha) of Rhodes grass and stylo.*

Components	Seeding ratio (grass:legume)						
	10:0	7:3	6:4	5:5	4:6	3:7	0:10
Grass	5.8[a]	5.3[ab]	5.4[ab]	4.8[bc]	4.8[bc]	4.5[c]	–
Stylo	–	1.2[d]	1.3[d]	1.6[c]	1.8[c]	2.4[b]	4.2[a]
Grass + stylo	5.8[b]	6.5[ab]	6.7[ab]	6.4[ab]	6.6[ab]	6.9[ab]	4.2[c]

Means in the same row followed by the same superscripts do not differ significantly ($P < 0.05$).

Source: Onifade and Akinola (1986).

Figure 1. *Effect of grass/legume seedling ratios on first and second year yields (1979–1980).*



Source: Agishi and de Leew (1986: p. 476).

Effects of level and time of nitrogen application and cutting regime

Establishment and management

Plots established by broadcasting in 1979 at a seeding ratio of 5:5 (grass: legume) were used in experiments in 1980. All plots were cut in June and again in November 1980. Half of the plots were also cut in July, August and September 1880; the other half was left uncut. Nitrogen (N) was applied to both treatments in subplots at three N levels of 0, 100 and 200 kg/ha.

Grass DM yield was highest in uninterrupted growth and from N application in July and August (Table 2). The unfertilised control and application of N in August appeared to produce the most stylo. Nitrogen level did not affect grass or total yield. Similarly, cutting had no influence on stylo and total DM yields but increased grass yields. Yields decreased with time of N application. As expected stylo yields declined significantly with increasing levels of N application, whereas application of N in July or September lowered yields as compared to a dressing in August.

Generally, defoliation during the growing season increased CP content over the undefoliated control for both the grass (4.6 versus 4.0%) and stylo component (10.2 versus 8.4%). Neither time nor the level of N application affected the CP content of stylo.

Table 2. *Effect of time and level of nitrogen application and of cutting on DM yields (t/ha) of (a) Rhodes grass and (b) stylo.*

(a) Grass	Time of N application			
Cutting	July	August	September	Mean
Cut	6.2	7.1	6.3	6.5^{b}
Uncut	8.0	7.2	6.7	7.3^{a}
Mean	7.1^{a}	7.1^{a}	6.5^{b}	6.9
(b) Stylo N (kg/ha)				
0	2.1	3.0	2.4	2.5^{a}
100	1.8	2.4	2.1	2.1^{b}
200	1.5	2.1	1.6	1.8^{c}
Mean, stylo	1.8^{b}	2.5^{a}	2.0^{b}	2.1
Mean total	8.9	9.6	8.5	9.0

Means in the same row followed by the same superscripts do not differ significantly ($P < 0.05$).

Source: Onifade and Akinola (1990).

Effect of stocking rate

Two Rhodes grass–stylo pastures of about 1.5 ha each were established, one in June 1984 (pasture A) and another in late August 1985 (Pasture B). The latter was established because stylo content was low in pasture A, probably due to an outbreak of fire during a dry spell early in the season. Before broadcasting, the water-treated stylo seeds were dressed with Fernasan D (insecticide + fungicide). The grass:legume seeding ratio was 3:7 with a seeding rate of 5 kg of pure seed/ha.

Pasture A received 200 kg N/ha in 1985 and was continuously grazed by sheep for 168 days between October 1985 and April 1986. Similarly, pasture B was stocked for 210 days from 21 August 1986 until 20 March 1987; both received 30 kg P/ha as single superphosphate at sowing and again in June before the grazing started. Both pastures were subdivided into five paddocks and stocked at the equivalent of 12, 18, 24, 30 and 36 sheep/ha (SR). Herbage on offer was estimated at the beginning of the grazing period and thereafter at six-week intervals.

In Pasture A a dry spell of seven days immediately after planting led to loss of stylo seedlings and seed to ants and birds, showing that seed dressing was not effective. As the growing season progressed Rhodes grass became more dominant and eventually eliminated the stylo. In October 1985, at the end of the second growing season, stylo constituted only 5% of the total (grass + legume + weed) yield.

In Pasture B the proportion of stylo reached 40% by June 1986, at the beginning of the second growing season. However, a delay until 21 August in stocking the pasture led to reduced stylo content of the pasture to 11% (Table 3). Dry-matter yields of stylo from the grazed paddocks were consistently lower ($P < 0.05$) than in the control. Significant reductions in stylo yield and its proportion in the total herbage were observed after two months of grazing, stylo declining to zero in early February after five months of grazing. In contrast, the ungrazed paddock still contained 0.6 t DM of stylo or 10% of the total yields (Table 3).

Table 3. *Effect of stocking rate and grazing duration on DM yield (t/ha) of stylo and total herbage during the 1986–87 grazing period.*

Stocking rate (rams/ha)	Grazing duration (days)							
	0	42	84	126	168	210	Mean	Total
12	1.11	1.21	0.85	0.12	0.06	0.00	0.56^{b}	8.23
18	0.87	1.35	1.00	0.14	0.05	0.00	0.57^{b}	8.00
24	1.54	1.41	0.67	0.29	0.00	0.00	0.65^{b}	7.70
30	0.72	1.11	0.94	0.21	0.00	0.00	0.50^{b}	7.35
36	1.44	1.30	0.99	0.10	0.00	0.00	0.64^{b}	6.93
Control	1.24	1.50	1.23	0.92	0.61	0.43	1.00^{a}	9.22
Mean	1.15^{ab}	1.31^{a}	0.95^{b}	0.30^{c}	0.12^{cd}	0.08^{d}	0.75	
Total yield	10.30	10.20	8.77	6.93	5.95	5.36	7.9	

Means in the same row followed by the same superscripts do not differ significantly (P< 0.05).

Source: Onifade (1991).

CP contents declined with larger grazing (Table 4). The CP contents in the stems (4.7–5.1%) and leaves (8.2–9.7%) of grass were similar at all stocking rates. The CP value for stylo (11.2%) at the lowest stocking rate was significantly higher than in the other treatments. The CP content in the control and for stocking rates of 18 and 36 rams/ha were 9.0, 9.3 and 8.7%, respectively.

Table 4. *Crude-protein (CP) content (%) of pasture components during the 1986–87 grazing period.*

Pasture components	Grazing duration				
	0	84	126	210	SED
Grass-stem	6.8	4.8	4.3	3.5	(0.34)
Grass-leaf	9.5	8.6	7.6	–	(0.13)
Stylo	12.3	8.8	7.3	–	(0.31)

Source: Onifade (1991).

The effect of stocking rate on the growth of sheep was pronounced (Table 5). At the lowest rate average growth over the first 84 days was 120 g/d compared with 55 g/d at the highest rate; losses were much higher and started earlier at the high rates. Overall, sheep

Table 5. *Average sheep daily liveweight gain (g/head) on Rhodes grass–stylo pasture during the 1986-87 grazing period.*

Grazing duration	Stocking rate (sheep/ha)					
	12	18	24	30	36	Mean
14	152	107	154	89	107	118^{a}
42	125	80	80	62	63	82^{ab}
84	71	54	63	36	36	52^{bc}
126	45	36	54	18	0	-30^{d}
168	-18	-27	-9	-45	-54	-30^{d}
210	-27	-27	-63	-63	-71	-50^{d}

Means in the column followed the same superscripts do not differ significantly (P = 0.05).

Source: Onifade (1991).

grew 11.3 kg at 12 sheep/ha (53 g/d) versus 2.3 kg (11 g/d) at 36 sheep/ha. In a previous study it was shown that the optimum stocking was about 20 sheep/ha or about 500 kg live weight per hectare. At this rate, output was 155 kg gain per hectare or 7.7 kg gain per head converting into an average daily gain (ADG) of 37 g/d head.

Conclusions

This assessment of Rhodes grass and Cook stylo in mixed pastures has highlighted the need to improve seeding practices and early grazing of pasture when used for grazing or cut for hay. Sowing as late as the end of August in the Northern Guinea Zone was still successful, although such pastures are best left ungrazed until early in the second growing season. By that time, the pasture would have "thickened up" and able to withstand more intensive grazing.

Applying nitrogenous fertiliser on mixed pasture increased the grass fraction whilst controlled stocking and application of phosphorus were beneficial for the growth, production and persistence of the legume in the mixture. As an important feed resource during the dry season, stylo-based pasture leys need to be managed to increase the nutritional level of grazing animals.

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Section 5

The integration of *Stylosanthes* into cropping systems

Establishment techniques for stylo-associated cropping systems

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Abstract

Livestock production in the subhumid (SHZ) of Nigeria is seriously affected by the low quantity and poor quality of available feed, particularly in the dry season. This feed shortage and the resultant constraints are mainly caused by low soil fertility which also contributes to the low crop yields obtained by arable farmers. ILCA's subhumid programme in Nigeria, adopting a farming systems research approach, has over the years developed the fodder-bank intervention to alleviate the nutritional problems which continue to hamper the livestock industry in the region. Given their impact on soil improvement, *Stylosanthes* species used in fodder banks are also being exploited as pasture leys in crop rotation.

Stylosanthes-based fodder banks have benefitted both crop and livestock production in small-scale agropastoral settings as evidenced by the increasing number of fodder banks in the SHZ of Nigeria. The advantages of ley farming for sustaining food production and methods of integrating *Stylosanthes* into cropping systems are reviewed.

Since intercropping is a common practice in the area ILCA wished to test:

- the compatibility of a forage with a food crop
- the nutritive value of sorghum residue, with and without stylo at the farm level
- reaction of the pastoralists to mixing a cereal crop with a forage.

Techniques de mise en place des cultures associées à composante *Stylosanthes*

Résumé

L'insuffisance et la qualité médiocre des aliments du bétail, notamment pendant la saison sèche, constituent un obstacle majeur au développement de l'élevage dans la zone subhumide du Nigéria.Ces pénuries alimentaires et les problèmes associés sont imputables à la pauvreté des sols, elle-même en partie responsable des faibles rendements des cultures. Sur la base de la stratégie de recherche sur les systèmes agraires, le Programme du CIPEA pour la zone subhumide a mis au point la technologie des banques fourragères pour affronter les problèmes nutritionnels qui freinent le développement de l'élevage dans cette région. Etant donné qu'elles améliorent la fertilité des sols, les espèces de Stylosanthes *utilisées dans les banques fourragères sont également introduites dans la rotation des cultures sous forme de soles.*

Les banques fourragères à base de Stylosanthes *améliorent la production des cultures et du bétail dans les petites exploitations agropastorales, comme en témoigne la vulgarisation rapide de cette innovation dans la zone subhumide du Nigéria. Cet article expose les avantages*

des soles fourragères pour une production alimentaire soutenue ainsi que les méthodes d'intégration de Stylosanthes *dans les systèmes agraires.*

Etant donné enfin que l'association des cultures est une pratique fréquente dans cette région, le CIPEA envisage d'étudier:

- *la compatibilité entre les plantes fourragères et les cultures vivrières*
- *la valeur nutritive des résidus du sorgho associé ou non au* Stylosanthes
- *l'attitude des éleveurs face à l'idée d'associer cultures céréalières et plantes fourragères.*

Introduction

Livestock production in the subhumid zone of Nigeria is seriously affected by feed shortages that become most acute during the long dry season. The nutritive value of natural rangelands on which livestock production is predominantly dependent varies drastically across the year. Pastoralists try to overcome this deficiency by exploiting crop residues during the early part, browsing and exploiting *fadama* resources later in the dry season and occasionally using agro-industrial by-products. All these feeding strategies seem inadequate as cattle still lose 15–20% of their weight, milk yields are low, calf mortality is high and many cows do not conceive because of nutritional anoestrus (Otchere, 1986; Mani et al, pp. 155–165).

A contributory factor to the low quality and productivity of herbage and crops in the subhumid zone is the low fertility of most soils. Total nitrogen is generally low and intensive agricultural production such as continuous cropping, land clearing and mechanised farming has led to nutrient losses through soil erosion, run-off and leaching. Soil fertility maintenance programmes should therefore be incorporated in any farming system (Jones and Wild, 1975). Research has indicated that soil physical and chemical properties could be improved by the incorporation of forage legumes into the cropping systems (Mohamed-Saleem and Otsyina, 1986; Vine et al, 1985).

The most common solution to the nutrition problem is to supplement livestock with agro-industrial by-products such as cottonseed cake, groundnut meal, urea and molasses; however, supplies of these feeds are inadequate for the ruminant population and prices have escalated. Therefore ILCA in Nigeria developed a renewable source of feed based on cultivating forage legumes usually referred to as fodder banks.

Fodder banks

Fodder banks are concentrated units of forage legumes established and managed by agropastoralists near their homestead to provide high protein supplemental feed in the dry season. The selected legumes must nodulate well, fix nitrogen in the soil and retain crude-protein levels above 8% for a greater part of the dry season. Currently, *Stylosanthes guianensis* cv Cook and *S. hamata* cv Verano are the two main species sown in fodder banks. Because of the threat of diseases, screening of other forages is being done in several agro-ecological zones in West Africa with the hope of identifying other promising species (Tarawali, 1990; Tarawali et al, pp. 81–95).

The fodder-bank package is highly versatile in respect of establishment and use. The following guidelines are meant for typical agropastoralists, but mechanical cultivation can be employed if available and affordable. The choice of which animals to feed, how much and when can also be varied according to circumstances (Otsyina et al, 1987; Ajileye et al, pp. 311–316; Mohamed-Saleem and de Leeuw, pp. 139–145).

Establishment

- select an area (normally about 4 ha) close to the homestead
- fence the area with metal or live poles and barbed wire

- prepare land for planting by confining animals in the fenced area for several weeks
- broadcast treated seeds after mixing with 150 kg/ha of single superphosphate fertiliser.

Management

- Allow animals to graze the fodder bank each year early in the wet season to control fast growing grasses until the legume is well established
- leave forage to bulk up and set seed by deferring grazing until the middle of the dry season, i.e. after crop residue grazing
- manage dry-season grazing to ensure sufficient seed drop and adequate stubble for stylo regeneration in the next growing season. Yield and stylo composition of fodder banks at the end of the growing season before grazing are given in Table 1, showing yields between 4.3 and 7.9 t dry matter (DM) ha containing 50–70% stylo.

Table 1. *Average DM yield and stylo composition of fodder banks in ILCA's study areas.*

Location	DM yield (t/ha)	Stylo composition (%)
Kurmin Biri	6.10	60
Abet	4.28	58
Kachia	7.11	68
Kontagora	6.12	52
Ganawuri	7.90	60
Average	6.30	60

Utilisation

ILCA's recommendation aimed at allowing 15–20 lactating and pregnant cows to graze the fodder bank for about two to three hours a day. This grazing pressure should be varied in response to the quantity of fodder available.[1]

Some pastoralists prefer to put the whole herd in the fodder banks even if it leads to overgrazing before the end of the dry season. Others adopt survival feeding whereby they allow emaciated animals to graze the fodder banks to reduce deaths or forced sales; this strategy may be more economical than the delayed financial impact of improved cow nutrition (Mohamed-Saleem and de Leeuw, pp. 139–145).

Benefits to system productivity

Livestock output

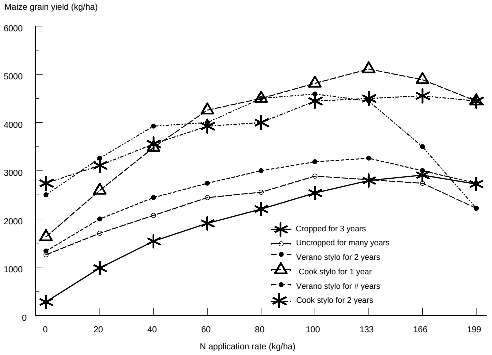
The benefits of cultivated *Stylosanthes* pastures to livestock production have been acknowledged by cattle owners as evidenced by an increase in the number of fodder banks in the region (Ajileye et al, pp. 311–316). Cows grazing fodder banks in the dry season produced more milk, lost less weight and more calves survived (Bayer, 1986). This was supported by evidence from the comparison of herds with and without fodder banks (Tarawali and Pamo, 1992).

1. This converts to a stocking rate of 1.1 TLU (Tropical Livestock Unit) per ha over a five-month period (Jan–May) or 0.45 TLU/ha per annum. For more details on grazing management of fodder banks (see Mani et al, pp. 155–165 and de Leeuw, pp. 325–334).

Effect of legume-ley/crop rotations on crop yield

Cropping is an important component of the fodder bank package both as a means of reducing land tenure constraints and as a part of the forage management strategy (Tarawali et al, 1987). Crops planted within fodder banks outyielded those on natural pasture as was demonstrated for maize (Figures 1a and 1b; Mohamed-Saleem, 1986; Tarawali, 1991), acha (Figure 1c; Tarawali, 1992) sorghum/soyabean (Figure 1d) and millet (Figure 1e; ILCA, 1990; 1991). The superior crop yields in rotation with *Stylosanthes* pastures were attributed to increased total soil-N fixed by the legume and improved physical properties such as bulk density, infiltration rates, and field moisture capacity (Mohamed-Saleem and Otsyina, 1986; Mohamed-Saleem et al, 1986). Thus, the use of *Stylosanthes* fodder banks has been instrumental in increasing both crop and livestock production in the subhumid zone of Nigeria.

Figure 1a. *Fitted curves, following different land-use histories at Kachia Grazing Reserve in 1983.*



Legume-based rotational cropping

The main objective in exploiting the advantages of forage legumes in crop production is to encourage agropastoralists and arable farmers to practise legume-based rotational cropping within their farming systems. In a predominantly livestock-based system, pastoralists can put their cattle on native pasture during the wet season, when they are at their best and on three-quarters of the fodder bank in the dry season. Thus, one-fourth of the fodder bank (or 1 ha) would be converted to crop production to provide additional crop residues and an understorey of *Stylosanthes* pasture as livestock feed.

In a crop-based enterprise, the arable farmer can crop most of his farm and leave a fraction of his land to improved forages for small ruminants and simultaneously increase crop production (ILCA, 1990; Ikwuegbu et al, pp. 167–174). In this system, forage legumes in the crop rotation are essential to minimise soil degradation. Both strategies are feasible, as labour requirements for tilling stylo-based soils are lower than those for a natural fallow

Figure 1b. *Direct and residual effects of N on grain yield of maize inside and outside* Stylosanthes *fallows.*

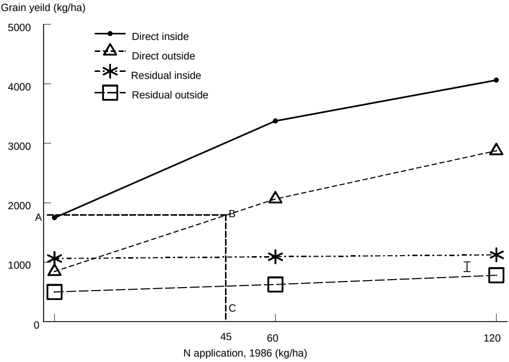


Figure 1c. *Acha inside and outside* Stylosanthes *fallows.*

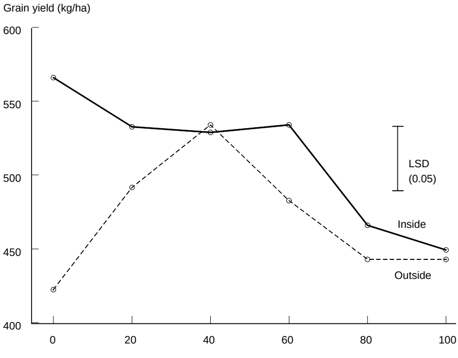


Figure 1d. *Grain yields of crops grown in pure and mixed stands inside and outside fodder banks with N application in second year, 1989 (maize).*

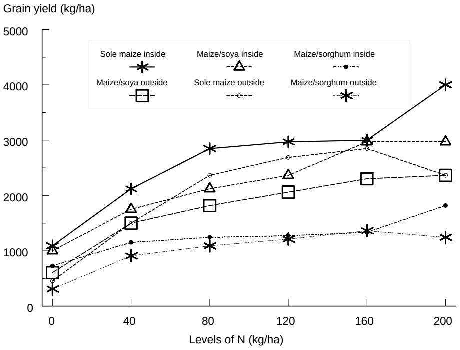
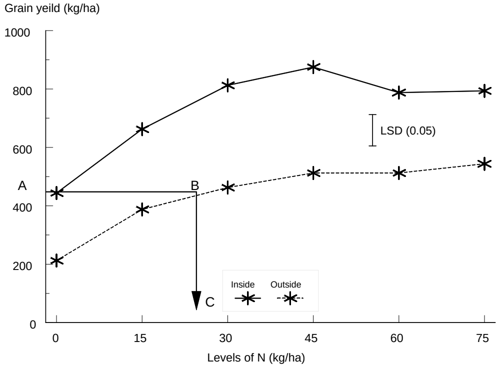


Figure 1e. *Response of millet to levels of N inside and outside* Stylosanthes *fallows.*



(Tarawali et al, 1987). Also, cropping did not affect the dry-matter yield of the succeeding herbage but increased the *Stylosanthes* fraction and its crude-protein content (Table 2).

Table 2. *Effect of cropping on the regenerative capacity of stylo fodder banks expressed as DM, CP yield and botanical composition.*

Land history	Yield (t DM/ha)	Crude protein in stylo (% DM)	Botanical composition (%) Stylo	Grasses	Forbs
Cropped	5.6± 1.8	0.26± 0.04	43± 5	39± 4	18± 6
Cropped for one year	5.4± 0.5	0.38± 0.07	58± 7	23± 4	19± 5
Cropped for two years	6.2± 1.2	0.42± 0.10	56± 5	26± 4	18± 2

Undersowing annual crops

In the SHZ, cereals are usually grown on ridges. Crops such as sorghum, maize and millet are planted either as sole crops or in mixtures with a grain legume such as groundnut, soya bean or cowpea. Since land preparation for the cereal requires the highest labour input among cropping operations, undersowing the crop with a forage legume after the grain crop has been established may be the simplest method. Time of undersowing seems critical for *Stylosanthes guianensis* cv Cook and *S. hamata* cv Verano (Table 3). Planting the stylo three to six weeks after the sorghum, increased the nutritive value of the fodder without reducing sorghum grain yield, but the delay in undersowing requires additional labour (Mohamed-Saleem, 1985). If the two crops must be planted on the same day, other legumes that compete less with the grain crops than stylo may be preferable (Table 4).

Table 3. *Effect of undersowing stylo on sorghum grain yield and total available fodder.*

Time of sowing stylo	Fodder yield (t/DM/ha) Grain yield (kg/ha)		Crop residue (CP%)		Stylo yield t DM/ha (CP%)		Total CP (kg/ha)
			Unimproved sorghum + Verano stylo				
Sole sorghum	1226	(100)[1]	7.50	(2.4)	–	–	180
Sown together	357	(29)	1.30	(2.5)	4.01	(11.4)	490
After 3 weeks	1224	(100)	3.72	(2.0)	1.72	(12.0)	281
After 6 weeks	1287	(105)	4.26	(2.2)	0.70	(12.0)	179
After 9 weeks	1240	(101)	3.92	(2.3)	0.40	(12.8)	42
			Improved sorghum + Cook stylo				
Sole crop	2192	(100)	8.80	(2.9)	–	–	255
Sown together	480	(22)	2.37	(1.4)	4.33	(12.9)	592
After 3 weeks	1550	(71)	3.52	(1.6)	3.21	(12.9)	493
After 6 weeks	1918	(87)	5.39	(1.4)	2.46	(13.8)	415
After 9 weeks	1980	(90)	7.46	(2.9)	0.46	(14.7)	283

1. Per cent of control.

Inter-row sowing

Where a cereal and grain legume are grown in mixture, the forage legume can be planted between the rows. This requires adjustments to the crop geometry. Traditionally, single sorghum stands are planted on every ridge with soya beans in between. By planting a pair of sorghum stands at 0.3 m spacing on alternate rows a plant population equivalent to traditional populations was achieved. In this arrangement, soya bean was planted in the row between pairs of sorghum stands whilst stylo was sown on alternate, crop-free ridges to attain a good compromise for grain and fodder production (Mohamed-Saleem, 1986; Mohamed-Saleem and de Leeuw, pp. 139–145).

Table 4. *Grain and fodder yields of sorghum when planted together with different forage legumes.*

Crop mixture	Grain (kg/ha)	Fodder yield (t DM/ha)		
		Residues	Stylo	Total
Sole sorghum	1296	4.67	–	4.46
+ Verano stylo	313	1.68	2.78	4.46
+ Cook stylo	388	1.55	2.06	3.62
+ *M. atropurpureum*	356	2.11	1.30	3.41
+ *C. pascuorum*	1019	2.99	1.20	4.19
+ *A. vaginalis*	1092	2.52	0.91	3.45
+ *M. lathyroides*	1297	2.74	1.48	4.22

M = *Macroptilium*; C = *Centrosema*; A = *Alisicarpus*.

Superimposed cropping

In superimposed cropping a cereal is grown concurrently with previously established forage legumes. The cereal is grown during the rainy season, during which the legume, e.g. *Stylosanthes*, is kept under control by weeding or herbicide application until the crop is able to withstand competition. The legume is then allowed to generate from its seed stock later in the growing season.

Intersod transplanting

Transplanting millet from seedling nurseries is a standard practice in the SHZ. Occasionally, when rains are late or poor, sorghum is also transplanted. In an experiment, sorghum and millet was transplanted into 30 cm wide flat strips cut through an established *S. hamata* cv Verano pasture at 1 m intervals. This planting on the flat decreased grain yields by 20–22% compared with the traditional practice of planting on ridges. However, the labour to cut the strips using hoes was only one-third of that required for ridging. Also, sorghum transplanted on ridges within established stylo pasture gave much higher grain and fodder yields than sorghum planted in areas without stylo (Table 5).

Table 5. *Effect of land preparation and method of crop establishment with and without stylo on fodder banks on grain and fodder yields of sorghum, Kurmin Biri, 1983.*

Land preparation	Planting method	Grain (kg/ha)	Fodder (t/ha)		
			Crop	Stylo	Total
Sorghum without stylo					
Ridge	Sown	292	2.75	–	2.75
	Transplant	795	4.83	–	4.83
Strip hoe	Sown	84	1.65	–	1.65
	Transplant	583	3.67	–	3.67
Sorghum with stylo cv Cook					
Ridge	Sown	342	2.62	1.44	4.06
No weedicide	Transplant	1093	4.32	1.51	5.83
Strip hoe	Sown	94	1.31	2.20	3.51
No weedicide	Transplant	240	2.05	2.06	4.11
Ridge	Sown	531	3.37	0.75	4.12
Weedicide	Transplant	1563	5.72	0.76	6.48
Strip hoe	Sown	250	2.21	1.08	3.29
Weedicide	Transplant	563	3.75	0.94	4.69

Discussion and conclusions

Increasing the feeding value of crop residues by undersowing or inter-row sowing with legumes will be most attractive to farmers whose cattle produce milk or are used for draft. Undersowing and inter-row sowing with a forage legume in the last year of the cropping cycle is another effective means for establishing legume pastures.

Superimposed cropping and intersod transplanting allows the growing of cereals within established legume pastures (e.g. fodder banks) and is suitable for areas where wet-season grazing is in short supply. Where cropping intensity restricts available wet-season grazing, land could be used for grazing early in the growing season while the same area is subsequently cropped with high-yielding short-duration crops.

Low-input techniques for the establishment, management and utilisation of *Stylosanthes*-based macro- and micro-fodder banks and their benefits to both livestock and crop production have been highlighted elsewhere (Ikwuegbu et al, pp. 167–174). Incorporating *Stylosanthes* species successfully into the cropping systems is likely to lead to sustainable food production in SHZ thereby improving the quality of life of resource-poor farmers.

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Development of millet–stylo cropping systems for sandy soils in the Sahel

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Abstract

Population pressure and frequent feed shortages in the Sahel have decreased the productivity of crops and livestock. The integration of forage legumes into the low-input, cereal-based farming systems of the Sahel may be the key to meeting the increasing food and feed demand. Field experiments were conducted on a Psammentic Paleustalf (siliceous, isohyperthermic) soil from 1988 to 1991 at Sadoré, Niger, to evaluate the effects of *Stylosanthes* spp on millet (*Pennisetum glaucum* (L.) R. Br.) grain yield; fodder yield and nutritive value; and yield of the subsequent millet crop. Each stylo species was grown in alternate single and triple row patterns with millet for one and two years. Millet was grown in rotation following one-year and two-year intercrop; continued cropping of millet served as the control treatment. Intercropping stylo with millet in alternate single rows did not affect millet grain yield during the legume seeding year. The following year, however, when stylo regrew from shoot, total biomass and crude protein were, on average, increased by 45 and 125%, respectively, whereas millet grain yield reduced by 26–83%. After the millet/stylo intercrop, millet grain, stover and nitrogen yields were greater than those of continuous millet. A system is proposed for short-term intercropping of millet and stylo to reduce the need for N fertilisation of the following millet crop.

Mise au point de systèmes culturaux à base de mil et de *Stylosanthes* pour sols sableux dans le Sahel

Résumé

La pression démographique et les fréquentes pénuries d'aliments du bétail diminuent la productivité des cultures et du bétail dans le Sahel. L'intégration de légumineuses fourragères dans les systèmes agraires extensifs à base de céréales rencontrés dans cette région permettra peut-être de satisfaire la demande croissante de denrées vivrières et d'aliments du bétail dans le Sahel. De 1988 à 1991, des essais ont été effectués sur arénosols et planosols (sols siliceux et isohyperthermiques) à Sadoré (Niger) pour évaluer l'effet de diverses espèces de Stylosanthes *sur le rendement en grain, la production fourragère et la valeur nutritive du fourrage du mil (*Pennisetum glaucum *(L.) R. Br.) ainsi que sur les rendements d'une culture subséquente de mil.Une ou trois rangées de* Stylosanthes *ont été alternées avec le mil au cours d'essais d'une durée d'un et de deux ans. Cette association a été suivie d'une culture de mil pur; les parcelles témoins étaient consacrées en permanence au mil. L'association comportant des rangées uniques alternées n'avait aucun effet sur le rendement en grain du mil pendant l'année de grenaison. En deuxième année cependant, lorsque les rejets de la légumineuse avaient commencé à donner des repousses, la production totale de biomasse et la teneur en*

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protéines brutes avaient augmenté en moyenne de 45 et de 125% respectivement, alors que le rendement en grain avait baissé de 26 à 83%. Suite à l'association de mil et de Stylosanthes, *le rendement en grain, la production de paille et la teneur en azote du fourrage du mil étaient supérieurs à ceux de la culture de mil témoin. Un système d'association de courte durée entre le mil et le stylosanthes a été proposé en vue de réduire les besoins en engrais azotés de la culture subséquente de céréale.*

Introduction

The declining land productivity of the Sahel increased the need to develop a sustainable land-use system in the region. Millet is the main cereal grown in the Sahel for human consumption; its stover serves as the major feed source for livestock during the long dry season. Increase in population pressure has caused an expansion of cultivated areas at the expense of grazing lands with a subsequent reduction of the length of fallow periods (Spencer, 1985). This, in addition to the non-use of fertiliser, has reduced the productivity of both crops and livestock. There is a need to incorporate forage legume into millet-based farming systems of the Sahel to limit the degradation of the natural resource base while sustaining food and feed production.

Forage legume–cereal intercropping has been shown to increase the quantity and feeding value of biomass yields compared to cereal mono-cropping (Waghmare and Singh, 1984; Mandal et al, 1990). The presence of the legume improved the utilisation of crop residues due to increased protein yield. However, yield depressions of the main crop have often been reported (Shelton and Humphreys, 1975; Mohamed-Saleem, 1985). Beneficial effects of forage legume used as green manure, hay crop, fodder bank, or intercrop on the yield of the subsequent non-legume crops have also been recognised. Mohamed-Saleem and Otsyina (1986) reported that maize (*Zea mays* L.) grain yields following *Stylosanthes hamata* (L.) Taub. "Verano" on fodder banks were three times as high as yields following maize without N fertilisation. Large yield increases have also been observed with wheat (*Triticum durum* L.) grown after lupin (*Lupinus* spp) (Doyle et al, 1988), rice (*Oryza sativa* L.) following cowpea (*Vigna unguiculata* (L.) Walp.), and sorghum (*Sorghum bicolor* (L.) Moench) grown after various legume cover crops (Hargrove, 1986; Peterson and Varvel, 1989).

Other advantages of forage legumes included improvement of soil physical and chemical properties (Badaruddin and Meyer, 1989), control of soil erosion (Fussell et al, 1987), reduction of pest and disease incidence (Hoyt and Leitch, 1983) and increased performance of animals fed crop residues as a basal diet (Mosi and Butterworth, 1985). There is little information on forage legume effects in the sandy soil of the Sahel although *Stylosanthes fruticosa* (Retz.) Alston and *S. hamata* have been shown to be potentially valuable crops (ICRISAT, 1987). This study was designed to determine the productivity of millet–stylo intercropping and rotation systems in the Sahel.

Materials and methods

Field experiments were conducted from 1988 to 1991 at the Sahelian Center of the International Crop Research Institute for the Semi-Arid Tropics (ICRISAT). The center is located at Sadoré (latitude 13°15'N, longitude 2°18'E) in the Republic of Niger. The well-drained, sandy soil of the station is acidic (pH = 5.6 in 1:1 soil:water mixture) and low in native fertility (West et al, 1984). Long-term yearly rainfall averaged 560 mm.

Two intercropping strategies (one-year intercrop and two-year intercrop) and two rotation schemes (one-year rotation and two-year rotation) were evaluated using seven cropping patterns. Each experiment was conducted for two years. The seven cropping patterns were:

- pure millet (PM)
- pure *S. fruticosa* (Sf)
- intercrop millet–Sf in alternate single rows (MSf1R)
- intercrop millet–Sf in alternate triple rows (MSf3R)
- pure *S. hamata* (Sh)
- intercrop millet–Sh in alternate single rows (MSh1R)
- intercrop millet–Sh in alternate triple rows (MSh3R).

The specific cropping sequences are listed in Table 1.

Table 1. *Cropping sequences and dates of evaluation of millet–stylo intercropping and rotation systems.*

Experiment no.	Cropping history[1] Intercropping	Exp. no.	Rotation
1	F–<u>MS</u> (1988)	5	F–MS–<u>M</u> (1989)
2	F–<u>MS</u> (1989)	6	F–MS–<u>M</u> (1990)
3	F–MS–<u>MS</u> (1989)	7	F–MS–MS–<u>M</u> (1990)
4	F–MS–<u>MS</u> (1990)	8	F–MS–MS–<u>M</u> (1991)

1. Cropping systems preceding the experiment: F= natural fallow; MS= millet–stylo intercrop; M= sole millet crop; the underlined system represents the year of evaluation which is in parentheses.

For the one-year intercrop (experiments 1 and 2), Sf and Sh were interseeded with millet cultivar CIVT on newly cleared land. Millet was sown two to three weeks before the stylo. In the two-year intercrop (experiments 3 and 4), millet was replanted on land previously used for one-year intercrop on which stylo would regrow from the previous crop stubble. Cropping patterns were randomly assigned to 9 by 12 m plots. An annual application of 13 kg P/ha as single superphosphate was broadcast before planting and incorporated into 40- to 50-cm tall ridges with an oxen-drawn plough after the first rains. Millet was sown in pockets 1.2 m apart on ridges 0.75 m apart. Seedlings were thinned three weeks later to three per pocket. At approximately 30 days post-emergence, millet was top-dressed with 15 kg N/ha as calcium ammonium nitrate in a single application. The plots were hand-weeded twice during each growing season.

The stylo lines were sown in continuous rows on firm ridges, 0.75 m apart. Seed was properly inoculated with a mixture of *Rhizobium* strains (cowpea, stylo and *Macroptiloma* types). For the one-year intercrop, the herbage was harvested only once — at the end of the cropping season. In the two-year intercrop, stylo regrew from the stubble of the previous year's crop and the herbage was harvested twice, approximately 60 and 120 days after millet emergence.

Yields were measured by hand-harvesting and weighing the biomass from the innermost 3 by 6 m of each plot. Subsamples of millet panicle and stover were sun-dried to constant weight for dry-matter (DM) yield determination. Panicles were threshed to determine grain yield. Subsamples of stylo herbage were oven-dried (75°C, 48 h) for DM determination. All plant samples were milled to pass through a 1 mm screen and acid-digested using a micro-kjeldahl procedure; nitrogen (N) concentration was determined, after distillation, by titration (Nelson and Sommers, 1980). The relative DM yields of intercrop millet (RYM) and stylo (RYS) were calculated as (DM yield in intercrop)/(DM yield in pure crop) for each component crop in an intercrop. Land equivalent ratio (LER) was calculated as per Willey (1979) where for each intercrop, LER = RYM + RYS. Soil water was measured in the two-year intercrop with a neutron probe (Solo 25, Nardeux Humisol, France) every 15 days throughout the growing season. Measurements were taken at 10, 20 and 30 cm and at every subsequent 20 cm to a depth of 170 cm. Water-use efficiency (WUE) was computed using the formula:

WUE = (DM or grain yield, kg/ha)/(total water use, mm).

Both one-year rotation (experiments 5 and 6) and two-year rotation (experiments 7 and 8) were laid out and managed similarly. Millet was grown in all the plots following the aforementioned cropping patterns. Stylo crowns and early season regrowth were incorporated into the ridges. Cultural practices and sampling methods were conducted as described above, but no N fertiliser was applied.

All data were analysed by ANOVA using the general linear model procedures (SAS Institute, 1982). When there was a significant overall treatment effect ($P < 0.10$), single degree of freedom orthogonal contrast was used to compare 1) PM to the mean of intercrop, 2) millet–Sf to millet–Sh intercrops, and 3) alternate single row to alternate triple rows intercrops.

Results

Pure millet crop produced higher ($P < 0.01$) grain yields than the average of intercropped millet in both the one- and two-year intercrops (Tables 2 and 3). Yield decline varied with planting strategy and planting pattern. For the one-year intercrop, a non-orthogonal contrast indicated no difference ($P < 0.05$) between PM and either MSf1R or MSh1R. Grain yields tended to be lower in the alternate triple-row planting patterns than in the alternate single-row planting (Table 2).

Table 2. *Grain and total herbage (DM) yields, and crude-protein (CP) concentration of millet and stylo in one-year intercrop.*

Cropping pattern[1]	1988				1989			
	Grain	DM		CP	Grain	DM		CP
	kg/ha							
Pure millet	910	2220	(0)[2]	45	1080	2700	(0)	43
Intercrop MSf1R	760	2110	(8)	50	800	2420	(1)	58
Intercrop MSf3R	440	1450	(14)	53	610	2720	(12)	63
Intercrop MSh1R	630	2350	(33)	75	1020	2450	(1)	53
Intercrop MSh3R	580	2230	(37)	72	440	1630	(20)	60
CV%	12	31		12	30	35		16
Contrast[3]								
Millet vs intercrop	0.01	0.61		0.01	0.01	0.27		0.03
Intercrop 1R vs 3R	0.09	0.25		0.94	0.15	0.43		0.39
Intercrop MSf vs MSh	0.96	0.14		0.01	0.28	0.11		0.71

1. Cropping pattern abbreviations: M = millet; Sf= *Stylosanthes fruticosa*; Sh= *S. hamata; 1R= alternate single-row planting arrangement; and 3R= alternate triple-row planting arrangement.*

2. Number in parentheses is stylo percentage in total DM.

3. Probability levels (F-test) for single-degree-of-freedom orthogonal contrast.

In the two-year intercrop, the mean grain yield of intercropped millet was 26 to 83% lower ($P < 0.01$) than that of PM (Table 3). Stylo effect on millet grain yield seemed dependent upon yearly growing conditions. Cropping patterns with Sh reduced millet grain ($P < 0.01$) yielded more than those with Sf in 1990 but not in 1989. Alternate triple-row planting of millet with either stylo yielded, on average, 43% less grain than alternate single-row planting in 1989 ($P = 0.02$) whereas in 1990 the former planting system outyielded the latter by 62% (Table 3).

Table 3. *Grain and total herbage (DM) yields, and crude-protein (CP) concentration of millet and stylo in two-year intercrop.*

Cropping pattern[1]	1988				1989			
	Grain	DM		CP	Grain	DM		CP
	kg/ha							
Pure millet	640	2660	(0)[2]	60	830	3200	(0)	29
Intercrop MSf1R	310	3240	(63)	94	430	3750	(40)	73
Intercrop MSf3R	110	3120	(80)	111	610	3000	(38)	64
Intercrop MSh1R	270	5700	(82)	107	220	4350	(70)	95
Intercrop MSh3R	140	4940	(83)	113	440	3580	(63)	85
CV %	39	17		10	14	12		10
Contrast[3]								
Millet vs intercrop	0.01	0.01		0.01	0.01	0.07		0.01
Intercrop 1R vs 3R	0.02	0.27		0.22	0.01	0.01		0.04
Intercrop MSf vs MSh	0.44	0.01		0.09	0.01	0.01		0.01

1. Cropping pattern abbreviations: M= millet; Sf= *Stylosanthes fruticosa;* Sh= *S. hamata*; 1R= alternate single-row planting arrangement; and 3R= alternate triple-row planting arrangement.

2. Number in parentheses is stylo percentage in total DM.

3. Probability levels (F-test) for single-degree-of-freedom orthogonal contrast.

When averaged over years across experiments stylo herbage yield was greater in alternate triple-row than in alternate single-row treatments and greater in two-year intercrop than in one-year intercrop; Sh produced two times as much herbage as Sf ($P = 0.09$). The combined millet and stylo DM yields varied with planting strategies and cropping patterns. In the one-year intercrop, there was no difference between the average DM yield of the intercrop treatments and that of PM (Table 2). Land-equivalent ratio of intercrop treatments ranged from 0.79 to 1.12 in 1988 and from 0.94 to 1.07 in 1989, indicating little or no land-use advantage of intercropping in one-year intercrop.

In the two-year intercrop, the combined DM yield was greater ($P < 0.01$ in 1989 and $P = 0.07$ in 1990) in the intercrop treatments than that of PM (Table 3). Dry-matter yield was higher ($P < 0.01$) in alternate single-row than in the alternate triple-row intercrop in 1990 and tended in the same direction in 1989. Land-equivalent ratio indicated a 16 to 22% land-use advantage for DM production in alternate single row intercrops.

Mean crude-protein (CP) concentration of intercrop DM was greater ($P < 0.03$) than that of PM in both one-year and two-year intercrops (Tables 2 and 3). Nonetheless, CP concentration of all harvested DM was generally at or below 70 g/kg in the one-year intercrop. In the two-year intercrop, however, CP concentration of the harvested fodder was generally above 70 g/kg with the exception of MSf3R in 1990.

Water-use efficiency (WUE) calculated on a total DM basis indicated that millet-stylo intercrop produced more ($P < 0.01$) DM per unit of water uptake than pure crop of each intercrop component (Table 4). The DM production efficiency was higher ($P < 0.01$) with alternate single-row planting than with alternate triple-row treatment. In contrast, WUE for millet grain production was 40% to 68% lower in intercrop than in PM ($P < 0.01$). Alternate triple-row intercrops produced more grain per unit of water consumed than alternate single-row treatments ($P = 0.05$).

Table 4. *Water-use efficiency (WUE) for dry matter and grain production and millet plant height at 60 days after planting of two-year intercrop.*

Cropping pattern[1]	WUE[2] Grain	WUE[2] Dry matter	Millet plant height
	kg/mm	kg/mm	
Millet	9.3	2.2	147
Intercrop MSf1R	10.2	1.1	133
Intercrop MSf3R	9.0	1.3	102
Intercrop MSh1R	14.5	0.7	87
Intercrop MSh3R	12.2	1.0	101
CV %	17	25	16
Contrast[3]			
Millet vs intercrop	0.01	0.01	0.01
Intercrop 1R vs 3R	0.01	0.05	0.41
Intercrop MSf vs MSh	0.01	0.01	0.02

1. Cropping pattern abbreviations: M= millet; Sf= *Stylosanthes fruticosa;* Sh= *S. hamata*; 1R= alternate single-row planting arrangement; and 3R= alternate triple-row planting arrangement.

2. WUE= Output (dry matter, grain)/total water use.

3. Probability levels (F-test) for single-degree-of-freedom orthogonal contrast.

The yield benefit of millet–stylo intercropping on subsequent millet crop is shown in Table 5. Millet grain and DM yields following intercrop tended to be greater than those following millet in both one-year and two-year rotation schemes. Yield advantage was even greater when millet followed pure Sf or Sh crops. Compared to the yield loss incurred during the previous seasons due to intercropping, grain-yield increase of two-year rotation does not compensate the cumulated yield loss. However, for the one-year rotation system, the sequences F–MSf1R–M and F–MSh1R–M outyielded the loss of the preceding season.

Discussion

Low intercrop millet grain yield was partly due to the reduced millet plant population in the intercrop treatments compared with PM. This is consistent with the substitutive theory proposed by Willey (1979). Yield variations caused by growing conditions, especially rainfall, are common in the Sahel (Fussell et al, 1987; Sivakumar, 1988). May to October rainfall was 11% higher in 1989 and 29% lower in 1990 than the long-term annual mean of 560 mm. During 1989, more than 40% of the precipitation fell during August and occurrences of drought were frequent during crop establishment. Drought conditions in the 1990 growing season developed during the stem-elongation period and caused moisture stress to the millet plants. Moisture stress was more severe in alternate single-row than alternate triple-row planting patterns and more in millet–Sh than in millet–Sf treatments

Table 5. *Average-yield advantage of millet following millet–stylo cropping systems without nitrogen fertiliser application.*

Previous cropping systems[1]	One-year rotation		Two-year rotation +	
	Grain	Stover	Grain	Stover
		t/ha		
Millet	0^2	0	0	
Intercrop MSf1R	0.21	0.36	0.22	0.69
Intercrop MSf3R	0.29	0.88	0.34	0.88
Intercrop MSh1R	0.15	0.39	0.18	0.31
Intercrop MSh3R	0.08	0.11	0.15	0.79
S. fruticosa, 0.24	0.74	0.20	0.23	
S. hamata, 0.37	0.52	0.12	0.98	
Contrast[3]				
Millet vs intercrop	0.11	0.17	0.15	0.06
Intercrop MSf vs MSh	0.12	0.12	0.10	0.09
Millet vs stylo	0.07	0.05	0.09	0.08

1. Previous cropping system abbreviations: M= millet; Sf= *Stylosanthes fruticosa*; Sh= *S. hamata*; 1R= alternate single-row planting arrangement; and 3R= alternate triple-row planting arrangement.

2. Yield advantage= (millet yield following intercrop – millet yield following millet).

3. Probability levels (F-test) for single-degree-of-freedom orthogonal contrast.

(visual observations). Thus millet plant height measured in 1990, 60 days after planting, ranked as PM > MSf1R > MSf3R > MSh1R > MSh3R (Table 4). Intercropped stylo presumably competed directly with millet for the limited soil resources resulting in reduced millet growth and grain yields. Competition for both light and soil resources have been reported to reduce yield of intercrop components (Namibiar et al, 1983; Izaurralde et al, 1990).

Low stylo herbage yields of one-year intercrop contributed little to intercrop total DM, leading to no yield advantage of intercropping over millet monoculture. The LER values were within the ranges of those reported by Nnadi and Haque (1988) with maize–lablab and sorghum–lablab intercrops. Inversely, the high stylo yield obtained in the two-year intercrop led to a greater DM yield and CP concentration in intercrop than PM. This increased productivity (DM, CP) may alleviate the frequent feed shortage experienced during the long dry season in the Sahel, provide enough protein supplement to sheep diets in a short-term feeding system and provide a more efficient use of the limited soil water supply. Nonetheless, two-year intercropped stylo were so competitive that millet grain yield was greatly depressed, causing a low WUE for grain production.

Conclusion

The study showed that interseeding (one-year intercrop) Sh or Sf in alternate single row patterns with millet did not affect millet grain yield or total DM output. Growing pure millet in rotation the following year offered a yield increase of 0.15 to 0.21 t/ha with no N application. When millet was sown into year-old established stylo (two-year intercrop), grain yield reduced significantly while total DM yield and CP concentration increased substantially. There is an indication that millet grain yield reduction was due in part to increased competition for water. Although large grain yield reduction was observed in the two-year intercrop systems, major benefits may derive from the increase in DM output and feeding value. Growing millet the third year in rotation (MS–MS–M) provided a maximum increase of 0.34 t/ha, which however, did not compensate for the grain loss incurred over the preceding two intercropping seasons. With the increasing importance of pastoral systems to the economy of the Sahel, intercropping millet and stylo for one year followed by sole millet cropping offers an alternative to support food and feed production without exhausting the production resource base.

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Fixation de l'azote et bilan du phosphore dans quelques systèmes culturaux à mil–légumineuses à Sadoré (Niger)

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Résumé

De 1986 à 1989, différents systèmes culturaux incluant le mil (*Pennisetum glaucum*) et certaines légumineuses (*Vigna unguiculata, Sesbania pachycarpa* et *Stylosanthes hamata*) ont été évalués à Sadoré, au Centre sahélien de l'ICRISAT. Le mil a été semé en culture pure ou en association avec des légumineuses. Au cours de la dernière année (1989), le mil a été cultivé en culture pure dans toutes les parcelles afin d'évaluer les effets résiduels des légumineuses.

Différents paramètres ont été évalués pour effectuer un bilan de N et P, notamment la biomasse, les quantités d'azote et de phosphore exportées par le mil et les légumineuses associées et la fertilité du sol.

Il ressort des résultats enregistrés que *Stylosanthes hamata* était meilleur que les autres légumineuses. La présence de légumineuses a permis d'augmenter la production totale de biomasse à l'hectare. *Stylosanthes hamata* a donné les meilleurs rendements, entraînant ainsi des exportations de N et de P plus élevées.

La fixation d'azote était négative et dépendait des conditions hydriques et du rendement des légumineuses. Le bilan de l'azote était négatif dans les différents traitements mais ce phénomène était moins marqué cependant que dans les associations comportant *Stylosanthes*.

Nitrogen fixing and phosphorus balance in selected agricultural millet/legume systems in Sadoré, Niger

Abstract

From 1986 to 1989, various crop systems involving millet (Pennisetum glaucum*) and some legumes (*Vigna unguiculata, Sesbania pachycarpa *and* Stylosanthes hamata*) were assessed at the ICRISAT Sahelian Center in Sadoré. Millet was sown alone or mixed with the legumes. In 1989, the last year of the trial, millet was grown alone on all plots to assess the residual effect of the legumes.*

Various parameters were used to determine the nitrogen and phosphorus balance, including biomass production, N and P exports by millet and legumes and soil fertility.

The results show that Stylosanthes hamata *was superior to other legumes. Total biomass production per hectare was higher in mixtures involving legumes.* Stylosanthes hamata *gave the highest yields and led to higher N and P exports.*

Nitrogen fixing was negative and was influenced by water conditions as well as legume yield. N balance was negative for all treatments, although this was less marked with mixtures including Stylosanthes.

Introduction

Au cours des deux dernières décennies, l'augmentation annuelle de la production céréalière dans la région soudano-sahélienne était de l'ordre de 1% alors que le taux de croissance annuelle de la population était proche de 3%. L'augmentation de la production était essentiellement due à l'extension des superficies cultivées et à l'exploitation de terres marginales jusque-là vouées au pâturage.

Les paysans ont réduit voire même supprimé la période traditionnelle de mise en jachère. Tout cela conduit inéluctablement à la dégradation des ressources édaphiques.

L'emploi des engrais permet d'améliorer la production par une augmentation de la productivité par unité de surface cultivée et peut contribuer à promouvoir la restauration des sols, permettant ainsi de stabiliser le système. Cependant, les paysans de la région peuvent difficilement consacrer leurs faibles revenus à ces intrants, raison pour laquelle notre programme de recherche vise à identifier des systèmes de faible coût adaptables en milieu paysan.

Les apports d'engrais ont été et sont l'objet de nombreux travaux de recherche. Le phosphore est l'élément majeur déficitaire dans les sols sahéliens et une dose économique de 24 kg P_2O_5/ha (ICRISAT, 1987) a été fortement recommandée. L'utilisation d'azote, autre élément déficitaire, est plus critique. Son apport sur le mil au niveau du paysan ne peut être généralisé pour diverses raisons. L'introduction des légumineuses dans les cultures de céréales procure une source d'azote grâce à la fixation de l'azote et le transfert de celui-ci à la céréale. L'association des légumineuses et d'autres cultures non légumineuses pourrait servir à remplacer partiellement ou entièrement l'azote provenant des engrais. Un autre aspect tout aussi important est l'amélioration de la valeur nutritive des chaumes de mil par addition de fanes de légumineuses (Renard et Garba, 1989), en vue d'atténuer les problèmes de l'alimentation du bétail dans la région.

L'association du mil avec une légumineuse, notamment pérenne permet une meilleure utilisation des ressources naturelles du sol, en particulier l'eau et les éléments nutritifs (Garba et Renard, 1991). Cependant, la densité et le mode de gestion doivent permettre d'augmenter la productivité et de minimiser les effets de la compétition.

Au Centre sahélien de l'ICRISAT (CSI) à Sadoré, des recherches ont démarré sur des systèmes culturaux associant le mil avec une légumineuse à grain, le niébé et certaines légumineuses fourragères, *Sesbania pachycarpa* DC et *Stylosanthes hamata* (L.) Taub. Le niébé est traditionnellement associé au mil au Sahel. Alors que *Sesbania pachycarpa* est une adventice locale annuelle largement répandue au Niger, *Stylosanthes hamata* est une légumineuse semi-pérenne originaire de Colombie (Humphreys, 1981).

On présente ici les résultats du bilan de phosphore et de l'estimation de la fixation azotée dans les systèmes adaptés pour la période de quatre ans allant de 1986 à 1989.

Matériels et méthodes

L'expérience a été conduite de 1986 à 1989 au CSI de Sadoré (Niger). Les caractéristiques du Centre, la climatologie et les propriétés du sol ont été données par Sivakumar (1986) et Sivakumar *et al.* (1990).

Les années 1986, 1988 et 1989 ont été caractérisées par une pluviométrie très supérieure à la moyenne et des pluies bien réparties dans l'espace et dans le temps. La saison 1987 était plus critique et avait débuté très tard.

Le mil (*Pennisetum glaucum* [L.] R. Br.) cv. CIVT a été semé en culture pure ou en association avec le niébé (*Vigna unguiculata* [L.] Walp.), *Sesbania pachycarpa* DC ou deux cultivars de *Stylosanthes (S. hamata* [L.] Taub.), cv. 147 en provenance du Centro Internacional de Agricultura Tropical (CIAT) en Colombie et Verano en provenance d'Australie.

Le dispositif expérimental est constitué de blocs aléatoires randomisés avec 13 traitements et 4 répétitions. Les parcelles élémentaires ont une dimension de 16 m sur 8. Parmi les 13 traitements on en a retenu 5 (tableau 1) où le mil a été associé de façon continue aux diverses légumineuses mentionnées ci-dessus. De 1986 à 1988, le mil était semé en culture pure ou en association. En 1989, toutes les parcelles ont été semées en mil pur afin de comparer les effets résiduels des traitements des années antérieures.

Tableau 1. *Traitements de l'essai d'association mil–légumineuses effectué au CSI de Sadoré (Niger) de 1986 à 1988*

Traitement	1986–1988
1	M
2	M/N
3	M/S
4	M/147
5	M/V

M = mil; 147 = *Stylosanthes hamata* cv. 147; N = niébé; S = *Sesbania pachycarpa;* V = *Stylosanthes hamata* cv. Verano.

Le mil et le niébé étaient semés à une densité de 10 000 poquets/ ha et les légumineuses fourragères en lignes continues à 4 kg de semences/ha. Le mil était semé dès les premières pluies et les légumineuses, deux ou trois semaines plus tard. Avant le semis 13 kg de P/ha ont été apportés dans toutes les parcelles et 15 kg/ha d'azote au premier sarclage.

La fertilité du sol a été suivie durant toute la période de l'essai. Le prélèvement d'échantillons de sol a été effectué au début et à la fin de chaque campagne sur une profondeur de 20 cm à l'aide d'une sonde. Cinq prélèvements ont été effectués à différents endroits dans chaque parcelle.

Les éléments suivants, à savoir le pH (eau), le pH (KCl), et les taux de matière organique, d'azote et de phosphore ont été analysés par les méthodes usuelles.

Les résultats du bilan de phosphore et les estimations des quantités d'azote fixé (à partir du bilan d'azote) sont présentés ci-après.

La fixation de l'azote a été estimée à partir de la formule du bilan de l'azote donnée par Greenland (1977):

$$N = \text{gains} - \text{pertes}$$

ou

$$N_2 - N_1 = F + M + Dr + S - C - L - V - E$$

où

	$N_2 - N_1$	est la variation de la teneur en azote entre les temps T_1 et T_2
Gains:	F	le taux de fixation de l'azote
	M	l'azote apporté par les engrais
	Dr	l'azote N des pluies et des poussières
	S	l'azote retourné à la surface du sol par les racines des plantes et la migration de la solution du sol

Pertes:	C	l'azote exporté par les récoltes et la végétation
	L	l'azote perdu par lixiviation
	V	l'azote perdu par volatilisation
et	E	l'azote perdu par érosion.

Des estimations de ces différents termes ne sont pas toujours disponibles dans la bibliographie.

En ce qui concerne les gains, les apports atmosphériques ont été estimés à 3,9 kg/ha dans la partie sud du Sahel (Penning de Vries et Djiteye, 1982) et à 4,3 kg/ha à Samaru au Nigéria (Jones, 1971). Dans le cas présent, on a retenu la moyenne de 4,2 kg/ha/an. Les apports minéraux par la matière organique sont variables et sont ignorés dans le cadre de l'essai. Il reste les engrais minéraux, soit 15 kg N/ha/an, et la fixation azotée, qui est à déterminer.

En ce qui concerne les pertes, l'essentiel porte sur les exportations par les récoltes et la végétation. Les pertes par érosion et ruissellement n'ont pas été évaluées à Sadoré; quant au ruissellement, il est négligeable sur ces sols sablonneux. Les pertes par lixiviation peuvent être importantes. Cependant, selon Penning de Vries et Djiteye (1982) et ICRISAT (1985), l'azote incorporé ne s'infiltre jamais au-delà des racines des plantes. Ces pertes sont donc négligeables. Par contre, les pertes par volatilisation sont importantes et des pertes de 37% à 53% des quantités apportées ont été enregistrées au CSI en fonction des différentes sources d'azote (Bationo et Mokwunye, 1991). Les pertes surviennent quand l'engrais est épandu à la surface du sol. Pour les calculs effectués ici, on a considéré la moyenne des pertes soit 45% de 15 kg/ha. Chaque année, les pertes sont estimées à 6,75 kg de N/ha.

La formule devient:

$$F = N_2 - N_1 - M - Dr + C + V$$

où

	F	est la fixation azote
	N_2	la teneur en eau en fin de campagne
	N_1	la teneur en eau en début de campagne
	M	l'apport d'engrais (15 kg/ha/an)
	C	l'exportation par la récolte (rendement x teneur en N)/100
et	V	la volatilisation (6,75 kg/ha/an).

Le bilan du phosphore est plus simple. Il ressort des informations disponibles dans la bibliographie que le phosphore n'est ni entraîné par lixiviation, ni adsorbé de façon irréversible par les colloïdes des sols de ces régions. Bien qu'une petite quantité de phosphore puisse être libérée lors de la minéralisation, cette contribution reste insignifiante en zone de savane (Pieri, 1989). Deux méthodes peuvent être utilisées pour ce bilan, à savoir le bilan entrées/sorties et le bilan apparent du stock de phosphore minéral. Le bilan apparent, qui de l'avis de Pieri (1989) donne une bonne idée du stock en phosphate du sol, a été adopté pour les calculs effectués ici.

Résultats

Production de biomasse

Le tableau 2 donne la production de biomasse du mil et des légumineuses au cours de la période d'essai.

Tableau 2. *Production de biomasse (t/ha) du mil et des légumineuses associées de 1986 à 1989 au CSI de Sadoré (Niger)*

Traitement	1986		1987		1988		1989
	Mil	Légumi-neuses	Mil	Légumi-neuses	Mil	Légumi-neuses	Mil
M	4,09	–	0,02^x	–	2,48	–	1,88
M/N	3,85	0,08	0,05^x	0,18^x	2,01	0,17^x	2,00
M/S	2,26	0,03	0,18	0,36	1,15	0,71	2,43
M/147	3,76	0,02	0,16	1,74	2,99	3,04	2,96
M/V	4,68	–	0,48	0,18	1,91	5,37	3,27
ES	1,17	1,17	0,09	0,27	0,28	0,31	0,48
CV%	59,64	94,78	107,6	87,57	24,88	27,22	37,97

x Valeurs exclues de l'analyse de variance.

M = mil; 147 = *Stylosanthes hamata* cv. 147; N = niébé; S = *Sesbania pachycarpa;* V = *Stylosanthes hamata* cv. Verano.

En 1986, la production de mil était élevée mais il n'y avait pas de différence significative entre les traitements. La production de fourrage des légumineuses était très faible et le niébé était parmi les trois légumineuses associées celle dont le rendement était le plus élevé.

En 1987, le mil a connu un mauvais établissement, des vents de sable ayant enseveli et détruit ses plantules. Les rendements des cultures de mil, associées ou non au niébé, étaient insignifiants. Dans les autres associations, quelques rendements intéressants ont été obtenus, ce qui laisse penser que les légumineuses avaient protégé le mil contre les vents de sable. La production des légumineuses de 1987 dépasse largement celle de 1986 et les légumineuses ont profité du plein ensoleillement, particulièrement *S. hamata* cv. 147.

En 1988, le mil était bien installé et des rendements élevés ont été obtenus, même si la différence n'était pas significative entre les traitements. La production des légumineuses était aussi élevée, particulièrement pour les deux cultivars de *Stylosanthes*.

En 1989, les rendements du mil associé aux légumineuses étaient plus élevés que ceux du mil pur et du mil associé au niébé. Cette différence significative est due à un effet résiduel des légumineuses.

Exportations de N et de P

Les tableaux 3 à 6 présentent les quantités de N et P exportées par le mil et les légumineuses au cours de la période d'essai.

Tableau 3. *Exportations de N et P (kg/ha) par le mil et les légumineuses à Sadoré en 1986*

Traitement	N			P		
	Mil	Légumi.	Total	Mil	Légumi.	Total
M	60,49	–	60,49	8,15	–	8,15
M/N	50,13	2,96	53,09	10,42	0,36	10,78
M/S	39,06	0,98	40,04	6,15	0,11	6,26
M/147	56,30	0,54	56,84	8,01	0,06	8,07
M/V	54,63	–	54,63	6,76	–	6,76
ETM	± 16,58	± 0,70	± 16,61	æ3,10	± 0,08	± 3,12
CV(%)	63,60	93,26	62,65	78,61	95,96	77,86

M = mil; 147 = *Stylosanthes hamata* cv. 147; N = niébé; S = *Sesbania pachycarpa;* V = *Stylosanthes hamata* cv. Verano.

Tableau 4. *Exportations de N et P (kg/ha) par le mil et les légumineuses à Sadoré en 1987*

Traitement	N			P		
	Mil	Légumi.	Total	Mil	Légumi.	Total
M	0,35[x]	–	0,35[x]	0,06[x]	–	0,06[x]
M/N	0,87[x]	7,02[x]	7,89[x]	0,14[x]	0,55[x]	0,69[x]
M/S	2,97	12,17	15,14	0,51	0,74	1,25
M/147	3,13	44,82	47,95	0,49	2,91	3,40
M/V	8,37[x]	4,44[x]	12,81	0,94[x]	0,34[x]	1,28[x]
ETM	± 1,52	± 8,27	± 9,43	± 0,20	± 0,50	± 0,36
CV(%)	104,78	96,62	85,34	112,90	87,91	64,95

x Valeurs exclues de l'analyse de variance.

M = mil; 147 = *Stylosanthes hamata* cv. 147; N = niébé; S = *Sesbania pachycarpa;* V = *Stylosanthes hamata* cv. Verano.

Tableau 5. *Exportations de N et P (kg/ha) par le mil et les légumineuses à Sadoré en 1988*

Traitement	N			P		
	Mil	Légumi.	Total	Mil	Légumi.	Total
M	34,37	–	34,37	3,67	–	3,67
M/N	32,57	4,38	36,95	3,14	0,44	3,58
M/S	28,49	23,97	52,46	3,14	1,14	4,28
M/147	34,72	62,44	97,16	6,54	3,54	10,08
M/V	28,98	112,16	141,14	2,27	5,84	8,11
ETM	± 6,75	± 8,32	± 9,58	± 0,63	± 0,51	± 0,70
CV(%)	42,45	33,57	26,45	33,36	37,33	23,47

M = mil; 147 = *Stylosanthes hamata* cv. 147; N = niébé; S = *Sesbania pachycarpa;* V = *Stylosanthes hamata* cv. Verano.

Tableau 6. *Exportations de N et P (kg/ha) par le mil à Sadoré en 1989*

Traitement	N total	P total
M	23,29	2,68
M/N	28,52	3,32
M/S	31,84	3,83
M/147	42,47	6,42
M/V	37,76	4,08
ET	± 6,48	± 0,91
CV (%)	40	45

M = mil; 147 = *Stylosanthes hamata* cv. 147; N = niébé; S = *Sesbania pachycarpa;* V = *Stylosanthes hamata* cv. Verano.

En 1986, le mil était le plus gros exportateur d'azote et de phosphore mais il n'y avait pas de différence significative entre les traitements. Très peu productives cette année, les légumineuses avaient exporté peu d'azote et de phosphore, le niébé en ayant exporté les plus grandes quantités. La présence des légumineuses a peu influencé les quantités totales de N et P exportées.

En 1987, l'essentiel des exportations était imputable aux légumineuses les plus productives notamment *Stylosanthes* cv. 147. Le mil étant mal installé, ses exportations étaient faibles. En conséquence, les exportations totales les plus élevées avaient été enregistrées dans l'association M/147.

En 1988, année de bonne pluviométrie, le mil et les légumineuses ont exporté des quantités substantielles d'azote et de phosphore. Les exportations d'azote du mil n'étaient pas significativement différentes d'un traitement à l'autre. Par contre, celles des légumineuses étaient significativement différentes et les cultivars de *Stylosanthes* avaient exporté le plus d'azote, d'où des exportations totales plus élevées dans le cas des associations comportant cette espèce. Pour le phosphore, les associations comportant les *Stylosanthes* ont exporté des quantités significativement différentes de celles des autres traitements.

En 1989, année également de bonne pluviométrie, les exportations de N et P étaient plus élevées après les associations, en particulier après les cultivars de *Stylosanthes*. Cette différence était hautement significative après le cultivar 147.

Fixation d'azote

Le tableau 7 présente les estimations de la quantité d'azote fixée dans les différents traitements de 1986 à 1989.

Tableau 7. *Fixation d'azote (kg/ha) à Sadoré de 1986 à 1989*

Traitement	1986	1987	1988	1989
M	80,04	-57,35	7,92	8,04
M/N	37,96	-48,80	5,51	12,64
M/S	56,79	-26,06	11,76	12,72
M/147	76,39	13,73	75,71	20,35
M/V	130,38	-60,14	114,94	26,89

M = mil; 147 = *Stylosanthes hamata* cv. 147; N = niébé; S = *Sesbania pachycarpa;* V = *Stylosanthes hamata* cv. Verano.

En 1986, les quantités totales d'azote fixées étaient plus élevées que celles des deux autres années par traitement, mais les différences n'étaient pas significatives.

En 1987, la fixation d'azote n'a pas été suffisante pour compenser les exportations et un déficit en azote a été observé dans tous les traitements, à l'exception de l'association M/147.

La campagne 1988 a permis une bonne fixation d'azote. Elle était plus élevée dans les associations, en particulier avec les deux cultivars de *Stylosanthes hamata*. Les quantités enregistrées étaient alors significativement supérieures à celle du mil pur et des associations incluant les légumineuses annuelles comme le niébé et *Sesbania*. La différence entre ces trois derniers traitements n'était pas significative.

En 1989, les légumineuses étaient absentes de tous les traitements mais on a noté cependant une certaine fixation d'azote dans tous les cas. Cette fixation était plus importante après les associations en particulier avec les deux cultivars de *Stylosanthes*, ce qui confirme bien l'effet résiduel des légumineuses.

Bilan de l'azote

Les tableaux 8 et 9 présentent le bilan de l'azote et du phosphore respectivement. Négatif pour le premier, ce bilan est positif pour le phosphore dont on a apporté cependant une dose de 13 kg/ha/an.

Tableau 8. *Bilan estimé de l'azote pour diverses associations mil–légumineuse (kg/ha/an) à Sadoré de 1986 à 1989*

Traitement	Exportation	Fixation	Bilan
M	118,5	38,55	-79,95
M/N	106,57	7,31	-99,26
M/S	139,48	-21,77	-111,71
M/147	244,4	186,18	-58,22
M/V	246,34	212,07	-34,27

M = mil; 147 = *Stylosanthes hamata* cv. 147; N = niébé; S = *Sesbania pachycarpa;* V = *Stylosanthes hamata* cv. Verano.

Tableau 9. *Bilan estimé du phosphore (kg/ha/an) pour diverses associations mil-légumineuse à Sadoré de 1986 à 1989*

Traitement	1986	1987	1988	1989
M	4,85	12,94	9,33	11,64
M/N	2,24	12,31	9,42	11,26
M/S	6,74	11,75	8,71	15,07
M/147	4,93	9,59	2,92	8,22
M/V	6,24	11,72	4,89	10,26

M = mil; 147 = *Stylosanthes hamata* cv. 147; N = niébé; S = *Sesbania pachycarpa;* V = *Stylosanthes hamata* cv. Verano.

Discussion

Divers résultats obtenus ailleurs montrent que la compétition par les légumineuses peut avoir un effet dépressif sur le rendement de la céréale dans l'association (Snaydon et Harris, 1981; Haque, 1984; Chetty, 1983; Dalal, 1974; Schmidt et Frey, 1988). Celui-ci peut être imputable à des causes diverses, y compris la géométrie de l'association et la compétition pour l'eau et les éléments nutritifs.

Dans le cas de l'association mil–niébé, on a montré au Centre sahélien que le choix du cultivar de niébé et la date de semis étaient particulièrement importants en la matière (Ntare et Fussell, 1988). L'application d'engrais (N et P) permet d'augmenter les densités des deux cultures à condition que l'eau ne soit pas un facteur limitant.

Dans le présent essai, un effet négatif de la légumineuse a été observé sur la céréale mais n'était pas significatif. D'autres essais menés en 1989 sur l'association mil–*Stylosanthes* ont en revanche permis de mettre en évidence un effet significativement négatif (Kouamé *et al.*, 1991).

Une gestion appropriée de l'association, telle que la fauche de *Stylosanthes* en cours de saison, permet de réduire cet effet de compétition. Le fourrage ainsi produit peut être stocké ou vendu sur le marché urbain.

Fixation de l'azote

On considère généralement que les écosystèmes naturels sont en équilibre pour ce qui est de l'économie d'azote (Swift et Sanchez, 1984). Par contre, les bilans azotés de tous les systèmes de cultures étudiés s’avèrent largement déficitaires. Ce déficit est essentiellement imputable d’une part à la non-compensation de l’azote exporté par les cultures et d’autre part aux pertes dans les eaux de surface et particulièrement au drainage (Pieri, 1989).

Ces systèmes ne peuvent se maintenir sans apport d’azote minéral (engrais) ou biologique (processus de fixation). L’apport le plus courant provient de l’association entre les bactéries du genre *Rhizobium* et les racines des légumineuses. Mais d’autres processus sont le fait de bactéries libres, en particulier associées aux racines des graminées et de céréales. Enfin, la minéralisation des formes organiques (protéines, acides aminés) constitue également une source importante d’azote.

L’expression fixation d’azote de bilan recouvre donc ces divers aspects et ne s’applique pas strictement à l’azote d’origine rhizobienne.

Les quantités d’azote (tableau 7) étaient variables et la quantité fixée était étroitement liée aux conditions pluviométriques.

En 1986, les quantités élevées enregistrées proviennent d’un effet résiduel du niébé cultivé sur la parcelle au cours de la campagne précédente. La quantité réellement fixée grâce aux légumineuses était faible car leur rendement était peu élevé. En effet, il existe une corrélation étroite entre la quantité d’azote fixée et la production de matière sèche des légumineuses (Skerman, 1982; Vallis *et al.*, 1983).

En 1987, année de déficit hydrique, la fixation a été très faible et les légumineuses bien installées ont puisé dans les réserves du sol. Ce même phénomène a été observé chez l’arachide par Wetselaar et Ganry (1982) qui rapportent qu’une lame d’eau inadéquate peut entraîner une chute de rendement (de 21%) alors que si la quantité d’azote fixée est réduite de près de 70%, l’arachide en puise alors dans les réserves du sol.

En 1989, la fixation d’azote a été influencée par l’effet résiduel des légumineuses. Le bilan de la période de quatre années d’essai (tableau 8) est négatif pour tous les traitements mais est beaucoup moins déficitaire cependant dans l’association avec *Stylosanthes* (M/147 et M/V). Celui-ci contribue donc plus que les autres légumineuses à améliorer le bilan général de l’azote.

Bilan du phosphore

Le bilan du phosphore est positif et cela en raison de l’application chaque année d’une dose de 13 kg P/ha. On observe que les associations avec les légumineuses pérennes, lorsque celles-ci sont bien établies (1988), exportent nettement plus que les autres associations. Sans apport de P, ce bilan serait largement déficitaire.

Conclusion

La fixation d’azote dépend des conditions hydriques et minérales du sol et du rendement des légumineuses. En année de déficit hydrique, la fixation est très faible et la légumineuse puise dans les réserves du sol. En année normale ou bonne, lorsque les légumineuses sont bien établies, elle est très efficace pour les espèces pérennes (cultivars de *Stylosanthes hamata*).

Le bilan du phosphore est positif en raison d’un apport annuel, mais les associations mil–*Stylosanthes* ont exporté plus de P que les autres.

Les résultats montrent bien le rôle positif que l’espèce *Stylosanthes hamata* pourrait jouer dans les systèmes culturaux de la région. Cependant, le système reste à parfaire. Il faudra notamment poursuivre les recherches afin de trouver une densité et une géométrie favorables aux deux composantes de l’association.

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Introduction de *Stylosanthes hamata* dans les systèmes agropastoraux au Mali: revue bibliographique

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Résumé

Compte tenu de la baisse de la fertilité des sols et du raccourcissement de la durée des jachères, de nombreux travaux ont été effectués au Mali, notamment dans le sud du pays, en vue de promouvoir l'introduction des soles fourragères pluriannuelles dans les systèmes agropastoraux. Celles-ci sont destinées à produire en quantité suffisante du fourrage de bonne qualité, à restaurer la fertilité des sols et à combattre l'érosion.

Les résultats enregistrés montrent que *Stylosanthes hamata* se comportait mieux que les autres espèces étudiées dans cette région. Sa production fourragère cumulée sur trois ans atteignait 20 tonnes par hectare, soit beaucoup plus que celle des parcelles témoins avoisinantes. En zone semi-aride, ses performances étaient moindres et même parfois très médiocres.

Après trois années, il avait sur les facteurs physico-chimiques du sol un effet positif mais non significatif. Par contre, il avait un effet résiduel net sur la culture subséquente de céréale et convient donc assez bien pour la régénération des zones dégradées.

L'introduction des soles fourragères a été bien perçue par les paysans qui y voient de nombreux avantages, tant et si bien que les superficies consacrées à ces cultures augmentent d'année en année. Les principales contraintes évoquées étaient l'insertion de la sole dans le calendrier agricole, la protection contre le bétail et la production de semences.

Introduction of *Stylosanthes hamata* in agropastoral systems in Mali: A review of bibliography

Abstract

In view of the continuing decrease in soil fertility and duration of the fallow period, many research programmes were carried out in Mali, especially in the south of the country, to encourage the introduction of long-term fodder plots in agropastoral systems. This was designed to increase production of high-quality forage, restore soil fertility and control erosion.

The results show that Stylosanthes hamata *performed better than other species screened in the area. Over a three-year period, its cumulative fodder production was 20 tonnes per hectare, which was substantially higher than that of nearby control plots. In semi-arid zones however, its performance was lower and sometimes extremely poor.*

Three years after establishment, S. hamata *had a positive but not significant effect on the structure and chemical composition of the soil. However, it had a net residual effect on a subsequent cereal crop and therefore can be used to rehabilitate degraded soils.*

This innovation was well received by farmers who see many advantages in it; hence, a continuous yearly increase in the land area devoted to fodder crops. However, they identified a number of constraints to adoption, including problems related to the integration of these plots in the agricultural work schedule, the need to protect them against livestock as well as problems related to seed production.

Introduction

Depuis quelques décennies, suite à l'introduction de nouveaux paquets technologiques et de la culture attelée, l'agriculture s'est considérablement développée au Mali, et plus particulièrement dans la zone sud. Ce développement s'est traduit par une augmentation des superficies cultivées et des effectifs du cheptel.

A cela s'ajoutent l'accroissement démographique, la baisse de la pluviométrie et la sédentarisation de l'élevage, lesquels ont entraîné une surexploitation des ressources naturelles. Celle-ci a eu pour conséquence une dégradation des ressources naturelles, laquelle a entraîné une diminution de la durée de la jachère et de la superficie des jachères, une baisse de la fertilité des sols et une diminution des rendements agricoles et de la production du secteur de l'élevage.

Face à cette situation, le Gouvernement malien a prôné et encouragé la mise au point de méthodes de lutte contre la dégradation des sols, y compris l'introduction des soles fourragères pluriannuelles, considérées comme une technologie appropriée en la matière.

C'est ainsi qu'une multitude de projets de recherche, appuyés par divers organismes (Institut royal des tropiques, Centre de recherches pour le développement international, Agency for International Development des Etats-Unis, Centre international pour l'élevage en Afrique, etc.), ont vu le jour sur la conservation des ressources des terroirs.

Effectués sous la responsabilité de l'Institut d'économie rurale (IER), et plus spécialement de la Division de recherches sur les systèmes de production rurale (DRSPR), ces travaux sont exécutés par des équipes pluridisciplinaires opérant dans trois zones, à savoir la zone de la Compagnie malienne pour le développement des textiles (CMDT) à Sikasso, Koutiala, et San, la zone CMDT de Bougouni et la zone de l'Opération Haute Vallée (OHV), c'est-à-dire les cercles de Banamba, Koulikoro, Kati, Kangaba et le district de Bamako.

Plusieurs thèmes de recherche ont ainsi été abordés. Ainsi, dans la zone cotonnière, la DRSPR mène, en collaboration avec le Projet agro-écologique (PAE), le Projet de lutte anti-érosive (PLAE) et la CMDT, organisme de vulgarisation de la zone, des recherches sur l'intégration agriculture-élevage et le maintien de la fertilité des sols notamment par l'introduction de légumineuses fourragères dans la rotation.

Dans la zone CMDT de Bougouni (Madina-Diassa) et autour de Bamako, le CIPEA a exécuté un programme de recherche visant à promouvoir l'intégration des activités agricoles et pastorales à travers le développement des cultures fourragères et l'agroforesterie. Le même thème a été exécuté dans la zone Haute Vallée (cercles de Kangaba et Banamba) par l'Opération Haute Vallée et l'USAID.

En zone semi-aride, d'autres recherches ont également été effectuées sur les cultures fourragères en collaboration avec l'USAID.

Enfin, depuis 1991, le projet Production soudano-sahélienne (PSS) effectue dans la région de Ségou des essais sur diverses espèces fourragères dont *Stylosanthes*.

La présente étude passe en revue l'ensemble des travaux effectués dans le cadre de l'introduction de *Stylosanthes* dans les systèmes culturaux, avec pour objectifs la production de fourrage pour la complémentation alimentaire du cheptel en saison sèche, l'amélioration de la fertilité des sols et la lutte contre l'érosion.

Ces différents aspects seront examinés en fonction des zones agroclimatiques. Par ailleurs la situation actuelle des sols sera examinée, notamment en ce qui concerne la production fourragère en 1992, la persistance et la capacité de resemis et de compétition de *Stylosanthes* après une ou plusieurs années après son installation. Enfin, la perception paysanne de l'introduction des cultures fourragères d'une façon générale et de *Stylosanthes* en particulier dans les systèmes agropastoraux sera présentée.

La zone d'étude

La zone d'étude englobe toute la région communément appelée Sud-Mali, et qui correspond à la zone d'intervention de la CMDT, ainsi que la zone de l'Opération Haute Vallée (OHV).

Climat

La majeure partie de la zone jouit d'un climat de type soudanien, avec des variantes soudano-sahéliennes au nord-est et soudano-guinéenne au sud. Il existe du nord au sud un gradient pluviométrique délimitant trois zones climatiques, à savoir une zone semi-aride (soudanien nord), une zone subhumide (soudanien sud) et une zone humide (guinéen nord).

Les caractéristiques de ces zones sont présentées au tableau 1.

Tableau 1. *Caractéristiques climatologiques de la zone d'étude*

Zone	Semi-aride	Subhumide	Humide
Pluviométrie			
moyenne (mm)	500–900	900–1100	1100–1300
durée en jours	50–60	60–100	90–120
mois le plus pluvieux	août (220 mm)	août (300 mm)	août (400 mm)
Température			
moyenne annuelle	27–28	26–27	28
maximum	35 (mai)	31 (avril–mai)	33 (avril)
minimum	22 (janvier)	22 (janvier)	25 (décembre)
Evapotranspiration potentielle			
moyenne annuelle (mm/an)	2300–2800	1900–2500	2300
maximum annuelle (mm/mois)	280	270	280
minimum annuelle (mm/mois)	160	130	135

On distingue une saison des pluies allant de juin à octobre, suivie d'une saison sèche de novembre à mai. La pluviosité annuelle varie fortement d'un site à l'autre et pour le même site d'une année à l'autre (tableau 2). L'écart type de la pluviosité est variable, allant de 15–20% en zone humide à 30–50% en zone semi-aride. Cette variabilité a des conséquences importantes sur la production des pâturages et des cultures.

Végétation

Le PIRT (Projet Inventaire des ressources terrestres) (1986) a identifié 10 zones agro-écologiques dans le Sud-Mali, une zone dont la végétation est presque toujours perturbée par l'homme en quête de bois de chauffage ou de nouvelles terres de culture. Elle présente plusieurs variantes allant des forêts claires aux savanes arborées et arbustives.

Dans les zones cultivées, la végétation est une savane parc où ne sont épargnés que quelques grands arbres directement utiles à l'homme tels que *Vitellaria paradoxa*, *Parkia biglobosa*, *Acacia albida* et *Adansonia digitata*.

Quant à la végétation des jachères, elle est dominée au nord par *Guiera senegalensis*, *Piliostigma reticulatum* et *Ziziphus mauritiana* et au sud par *Annona senegalensis* et *Deutarium microcarpum* (PIRT, 1986).

Sur les plateaux et les glacis, la végétation est une savane arborée ouverte en général, mais plus dense au sud. Elle est dominée au nord par *Pterocarpus lucens*, *Combretum* sp., et au sud par *Isoberlinia doka*, *Deutarium microcarpum* et *Pterocarpus erinaceus*.

Des forêts galeries se rencontrent le long des cours d'eau. Au nord, la strate herbacée est dominée essentiellement par des plantes annuelles, notamment *Andropogon pseudapricus*, *Loudetia togoensis*, *Schoenefeldia gracilis*. Plus au sud, certaines graminées vivaces comme *Andropogon gayanus*, *Hyparrhenia* sp. ou annuelles comme *Pennisetum pedicellatum* ou *Diheteropogon hagerupii* deviennent plus fréquentes.

Résultats

L'introduction des soles fourragères en vue de la production de fourrage et de la régénération des sols a commencé au Mali depuis 1974 et se poursuit encore, notamment en zone CMDT. Ainsi, pour la campagne 1991/92, le PLAE a distribué 200 kg de semences de *Stylosanthes hamata* pour l'introduction des soles fourragères dans 25 villages situés autour de Koutiala. Pour la campagne 1992/93, le même projet prévoit de distribuer 1 000 kg de semences de *Stylosanthes*.

Les soles de *Stylosanthes* introduites dans l'assolement ont été implantées pour une période de trois ans avant d'être mises en culture sous céréales. L'arrière-effet de *Stylosanthes* sur le rendement des céréales a pu ainsi être évalué. Après l'installation de *Stylosanthes*, des mesures ont été effectuées pour suivre la production de fourrage des jachères. Des échantillons de sol prélevés avant et après l'installation de *Stylosanthes* ont été analysés en vue d'évaluer l'influence de la jachère sur la fertilité du sol.

De nombreuses données ont donc été collectées, notamment sur la production fourragère annuelle ou cumulée sur trois ans, l'évolution de la fertilité des sols, le rendement céréalier après une sole fourragère et l'érosion du sol.

Les travaux effectués dans la zone Sud-Mali ont permis d'établir des fiches techniques résumant toutes les données nécessaires pour l'installation des soles fourragères, y compris la zone agro-écologique, les catégories cibles, le calendrier agricole, le type de site, le mode de semis, la préparation du sol, l'entretien de la sole, la récolte de semences, etc. Ces fiches peuvent être obtenues auprès de la DRSPR.

Production fourragère des soles

En zone CMDT

En 1986, neuf soles fourragères ont été installées dans trois villages suivant un dispositif en split-plot, avec deux niveaux de clôture (avec et sans), deux blocs par niveau de clôture, trois doses de phosphate naturel de Tilemsi (PNT) (0, 300 et 600 kg/ha), et quatre traitements dont trois espèces fourragères et une jachère naturelle comme témoin.

La superficie d'une sole était de 10 507 m^2 répartis en 48 sous-parcelles. On trouvera au tableau 2 la répartition des espèces par village.

Tableau 2. *Répartition des espèces des soles fourragères*

Village	N° du traitement	Espèces
	1	*Cenchrus ciliaris* + *Stylosanthes hamata*
	2	*Macroptilium atropurpureum* + *Clitoria ternatea*
Tominian	3	*Stylosanthes hamata* pur
	4	jachère naturelle
	1	*Brachiaria ruziziensis* + *Stylosanthes hamata*
Koutiala	2	*Cenchrus ciliaris* + *Stylosanthes hamata*
	3	*Stylosanthes hamata* pur
	4	jachère naturelle
	1	*Brachiaria ruziziensis* + *Stylosanthes hamata*
Fonsébougou	2	*Panicum maximum* + *Stylosanthes hamata*
	3	*Stylosanthes hamata* pur
	4	jachère naturelle

Les mesures effectuées sur ces soles ont permis de comparer le taux de couverture du sol par les différentes espèces ainsi que la production de biomasse fourragère. On trouvera au tableau 3 les données relatives au recouvrement végétal des espèces des soles fourragères.

Stylosanthes hamata apparaît comme l'espèce la plus performante. Cependant, pour avoir une bonne couverture du sol, les soles doivent être protégées contre le bétail, surtout au nord.

Tableau 3. *Taux de recouvrement (%) des espèces des soles fourragères après deux saisons des pluies en zone CMDT*

Zone	Pluviosité (mm)	Espèce					
		Stylosanthes		Brachiaria		*Cenchrus*	
		C	NC	C	NC	C	NC
Nord	600	75	28	45	3	12	1
Centre	750	98	85	41	13	14	2
Sud	900	84	72	55	22		

Source: DRSPR, données non publiées.

C= clôturé; NC= non clôturé.

Il ressort des chiffres de production de biomasse sur trois ans que la production fourragère était considérable et augmentait en fonction de la pluviosité, atteignant 20 tonnes en moyenne au sud. Si l'on suppose que le tiers de cette production peut être utilisé, un hectare pourrait nourrir 2,3 UBT pendant cinq mois de la saison sèche.

Le tableau 4 présente la productivité moyenne de biomasse des soles fourragères en zone CMDT pour une période de trois ans.

Tableau 4. *Productivité moyenne des soles fourragères pour trois années en zone CMDT*

Zone	Pluviosité (mm)	Biomasse (t MS/ha)	
		Totale	Coupe[a]
Nord	600	8	6,4
Centre	750	14	11,2
Sud	900	20	16

[a] En coupe, on considère 20% de pertes.

Source: DRSPR, 1992a.

Les mesures effectuées après une année montrent que la production annuelle varie entre 2 et 6 tonnes/ha dans le sud, ce qui dénote d'importantes différences interannuelles et intersites. Celles-ci peuvent s'expliquer par l'existence de poches de sécheresse, les semis tardifs, l'utilisation d'engrais et la géomorphologie. En culture pure, *Stylosanthes hamata* a un meilleur recouvrement, mais il semble que l'association avec *Brachiaria* donne des rendements plus élevés (tableau 5, 6 et 7).

Tableau 5. *Production de biomasse de la sole fourragère de Nangazanga Traore à Faniena, un an après l'installation (1989, zone sud)*

Traitement	Biomasse (kg de MS/ha)	Différence avec le témoin	Observations
Stylosanthes + *Brachiaria*	6500	776	*Stylosanthes* = 1/3 de la biomasse
Brachiaria pur	5610	–144	*Brachiaria* isolé, présence de *Stylosanthes*
Stylosanthes pur	6720	966	Bonne couverture du sol
Jachère naturelle	5754	–	Présence de *Stylosanthes* par endroits, *Brachiaria* absent

Source: DRSPR, 1990.

Tableau 6. *Production de biomasse de la sole fourragère de Niagale Traore à Fonsébougou, un an après l'installation (1989, zone sud)*

Traitement	Biomasse (kg de MS/ha)	Différence avec le témoin	Observations
Stylosanthes + *Brachiaria*	3744	1586	Espèces spontanées rares
Brachiaria pur	2957	799	Degré de salissement entre 9 et 55%
Stylosanthes pur	3019	861	Degré de salissement moindre, de 0 à 30%
Jachère naturelle	2158	–	Uniquement espèces non introduites

Source: DRSPR, 1990.

Après un feu, les soles peuvent encore produire des quantités importantes de fourrage; mieux, il semblerait même, comme on a pu le constater sur l'une des parcelles après le passage accidentel d'un feu, que le passage du feu stimule cette production (tableau 8).

Tableau 7. *Estimation de la production de biomasse par sole fourragère dans la zone de Fonsébougou (1986)*

Traitement	Kg/ha
Jachère naturelle	1440
Stylosanthes hamata	2189
Brachiaria ruziziensis	1830
Stylosanthes + *Brachiaria*	3572

Source: DRSPR, 1987.

Tableau 8. *Production de biomasse de l'ancienne sole fourragère de Niagale à Fonsébougou après un feu*

Traitement	Biomasse (kg de MS/ha)	Différence avec le témoin	Observations
Stylosanthes + *Brachiaria*	8865	3665	*Brachiaria* absent
Brachiaria pur	7880	2680	*Brachiaria* isolé
Stylosanthes pur	5400	200	Bonne couverture du sol par *Stylosanthes* isolé
Jachère naturelle	5200	–	*Stylosanthes* isolé, *Brachiaria* absent

Source: DRSPR, 1990.

En zone OHV

Dans cette zone, 11 villages ont installé des jachères améliorées depuis 1989, toutes mises en valeur pendant la campagne 1991/92, à l'exception de celle du village de Landé, au sud de la zone. Il existe donc actuellement peu de soles fourragères pluriannuelles sous le contrôle de l'OHV, les soles actuelles étant celles installées par le CIPEA dans la zone péri-urbaine de Bamako.

Le tableau 9 présente des données relatives à la quantité et à la qualité du fourrage produit sur les jachères du sud après deux années d'installation.

Tableau 9. *Effet de deux types de jachère sur la quantité et la qualité du fourrage produit en zone OHV*

Type de jachère	Biomasse (t/ha)	Cellulose	N	P
Stylosanthes hamata	6,3	41	0,8	0,05
Jachère naturelle	4,1	42	0,6	0,06
Niveau de signification	*	n. s.	n. s.	n. s.
CV	34	18	34	19

* Significatif au seuil de 5%; n. s. = non significatif.

Source: DRSPR, 1990.

Après la deuxième année, la jachère améliorée a une production de fourrage plus élevée, mais de même valeur fourragère avec cependant un léger avantage en azote.

Les productions moyennes calculées par zone confirment l'influence de la pluviosité sur la productivité des soles (tableau 10). En effet, la production de biomasse varie de 3 à 7 tonnes/ha pour une pluviosité annuelle allant de 560 à 1 000 mm en moyenne.

Tableau 10. *Effet de la pluviosité sur la quantité et la qualité du fourrage de deux types de jachère dans différents villages de la zone OHV*

Village	Localisation	Pluie (mm)[a]	Biomasse (t/ha)		Phosphore	
			JNA	JAA	JNA	JAA
Balanzan	Sud	937	3,66	6,76	0,04	0,07
Kanika	Nord	566	3,50	3,20	0,05	0,07
Gouani	Est	1050[b]	4,20	5,20	0,08	0,11

JNA = jachère naturelle

JAA = jachère améliorée (ensemencée de *Stylosanthes*).

[a] moyenne de 1987–1991.

[b] estimée sur la base des isohyètes.

Source: DRSPR, 1992b.

La production de biomasse était significativement différente entre les villages du sud et ceux de l'est, de même qu'entre ceux du nord et ceux de l'est pour les mêmes variétés. Par ailleurs le fourrage provenant de la jachère améliorée était plus riche en phosphore.

Madina-Diassa et Sotuba

Le CIPEA a testé de 1987 à 1988 la faisabilité des banques fourragères sur trois sites. Deux d'entre eux étaient localisés à Madina-Diassa dont un sableux et l'autre argileux, le troisième à Sotuba. Ces banques, en fait des jachères améliorées, étaient destinées à assurer au bétail une alimentation complémentaire de saison sèche.

Sur chaque site, une superficie de 4 ha à Madina-Diassa et de 6 ha à Sotuba a été labourée, fertilisée avec du superphosphate simple (120 kg/ha) et ensemencée de *Stylosanthes hamata* (10 kg/ha).

L'installation de ces banques a été précédée d'essais de criblage destinés à identifier les espèces ou variétés adaptées aux différents sites. *Stylosanthes guianensis* s'est révélée la plus productive, suivi de *S. scabra* et de *S. hamata*. Mais les deux premières étant très sensibles à l'anthracnose, elles furent abandonnées au profit de *S. hamata*.

Le bilan des données recueillies sur les différents sites est présenté au tableau 11.

Tableau 11. *Principales données recueillies sur les banques fourragères à Madina-Diassa et Sotuba*

Paramètres	Madina (site sableux)		Diassa (site argileux)		Sotuba (site sableux)	
	1987	1988	1987	1988	1987	1988
Pluviométrie (mm)	1105	1069	1105	1069	829	1088
Densité du *Stylosanthes* (m^2)	18	1492	14	820	40	1570
Hauteur du *Stylosanthes* (cm)	49	83	53	88	74	72
Biomasse totale (kg MS/ha)	1800	5540	3825	6129	8000	10200
Stylosanthes (%)	39	87	12	25	78	71
Graminées (%)	36	7	51	54	9	18
Dicotylédones (%)	25	6	37	21	13	11

Source: CIPEA, données non publiées.

La faible production enregistrée en 1987 à Madina-Diassa est due à une mise en place tardive de l'essai (semis en août). En deuxième année, la production de biomasse était importante sur sol sableux suite à un bon niveau de resemis naturel. Sur sol argileux, *Stylosanthes* a souffert de la forte compétition des autres herbacées qui représentaient 75% de la biomasse totale. Dans cette zone, il ne saurait donc être question de généraliser l'introduction de *Stylosanthes* à tous les types de sol.

Au Centre de recherches zootechniques de Sotuba (CRZ), des essais ont été menés de 1988 à 1989 pour étudier la réponse de *Stylosanthes hamata* au phosphore. En effet, l'intégration des soles fourragères dans les systèmes agropastoraux nécessite d'établir les besoins en éléments nutritifs des espèces introduites et de fixer des critères pour juger de leur rentabilité. Les engrais étant considérés comme l'un des facteurs primordiaux pour augmenter la productivité des cultures, deux sources de phosphore ont donc été testées, à savoir le phosphate naturel de Tilemsi (PNT) et le superphosphate simple. Après deux années de production, aucune différence n'a été enregistrée entre la production de *Stylosanthes* des parcelles ayant reçu ces deux types de phosphore (tableau 12). Par contre, une différence significative existait entre la production des parcelles de *Stylosanthes* et celle de la jachère témoin.

Tableau 12. *Effet du niveau et de la forme de phosphore sur la production (kg/ha) de* Stylosanthes hamata *au CRZ de Sotuba*

Année		P0	SPS150	Niveau phosphore			Témoin
				PNT150	PNT300	PNT450	
1988	*S.hamata*	3240a	2098a	4071a	2293a	3089a	0
	Autres herbacées	1920b	2779a	1151b	1573b	1502b	3044a
	Total	5160a	4877a	5222a	3866a	4591a	3044b
1989	*S.hamata*	8226a	8183a	7563a	8799a	7623a	231b
	Autres herbacées	816a	1122a	994a	816a	754a	2994b
	Total	9042a	9305a	8557a	9615a	8377a	3225b

Les moyennes suivies de la même lettre ne sont pas significativement différentes.

P0 = sans phosphore; SPS150 = 150 kg de superphosphate simple/ha; PNT150 = 150 kg de phosphate naturel de Tilemsi/ha,etc.

Source: CIPEA, 1989.

En zone péri-urbaine de Bamako

Dans le cadre d'un programme conjoint exécuté par l'Institut d'économie rurale (IER) et le CIPEA pour l'amélioration de la production laitière autour de Bamako, des banques fourragères ont été installées dans quatre villages à savoir Falan, Sanankoroba, Bancoumana et Tienfala.

La production de biomasse en première année fut décevante dans les quatre villages en raison d'un semis tardif. Mais en deuxième année, elle était appréciable sur tous les sites (tableau 13).

Tableau 13. *Production de biomasse des soles fourragères de la zone péri-urbaine de Bamako*

Village[a]	Pluviosité (mm)		Biomasse (kg de MS/ha)	
	1990	1991	1990	1991
Falan	812	943	2877	8635
Sanankoroba	816	938	1985	5200
Bancoumana	774	888	2580	6200

[a] Les données n'ont pu être collectées à Tienfala.

Source: CIPEA, données non publiées.

N.B. Dans la zone semi-aride de Banamba (pluviosité 500 à 600 mm), le CIPEA a tenté d'améliorer les jachères avec *Stylosanthes*. Les différentes espèces testées n'ont malheureusement pas pu s'établir de façon satisfaisante car elles n'ont pu supporter la saison sèche et leur production de semences était trop faible pour leur permettre de repousser au cours de la saison suivante (Bartholomew, 1988).

Effet sur la fertilité du sol

L'influence de la jachère améliorée sur la régénération de la fertilité du sol et l'arrière-effet sur le rendement des céréales ont été rapportés dans de nombreux travaux. Cette influence doit être appréciée à travers les réponses à un certain nombre de questions.

Ainsi, une jachère améliorée de 3 ou 5 ans possède-t-elle la même capacité de régénération qu'une jachère naturelle de 15 à 20 ans?

Une jachère améliorée peut-elle permettre de diminuer sensiblement les problèmes d'érosion? Peut-on exploiter une jachère améliorée, donc exporter une partie des éléments nutritifs et s'attendre en même temps à une régénération des capacités productives du sol?

Avant de répondre à ces trois questions, il importe de faire un bref rappel des fonctions d'une jachère naturelle.

Selon Nye et Greenland (1960), la jachère de longue durée vise à restaurer le niveau des éléments nutritifs et de carbone, à améliorer la structure du sol, à supprimer les mauvaises herbes et les parasites et à empêcher l'érosion. Ces auteurs rapportent également que le taux de matière organique dans un système de culture est toujours inférieur à celui d'une végétation naturelle. En zone soudanienne, le niveau de carbone dans une végétation de jachère tournerait autour de 60% d'équilibrium d'une végétation vierge.

Les effets d'une jachère de courte durée sur les propriétés physiques du sol sont comparables à ceux d'une culture céréalière. Sur le plan des propriétés chimiques, elle ralentit le processus d'appauvrissement sans entraîner une amélioration. En revanche, elle augmente le niveau de calcium (tableau 14).

Tableau 14. *Bilan annuel probable des éléments nutritifs au Sud-Mali dans une jachère à graminées annuelles et dans quelques cultures (kg/ha)*

Eléments nutritifs	Jachère	Mil	Sorgho	Arachide
N	–5	–47	–32	–40
P	+ 1	–3	–3	–3
K	–7	–37	–27	–38
Ca	+ 13	+ 4	+ 5	–25
Mg	+ 1	–7	–5	–20

Source: Van der Pol, 1990.

On peut distinguer trois stades dans l'évolution d'une jachère. D'une durée d'environ quatre ans, le premier stade est caractérisé par la prédominance des graminées annuelles. La régénération du sol est négligeable car les graminées annuelles épuisent le sol et, si l'on ajoute les pertes par érosion, l'exportation de carbone peut atteindre 100 kg/ha. La fin de ce stade est marquée par le remplacement des graminées annuelles par des graminées pérennes.

Le deuxième stade est dominé par les graminées pérennes qui, par un recyclage partiel interne de leurs éléments nutritifs, contribuent à augmenter le taux de matière organique du sol, et au bout de quinze ans, on assiste à une amélioration de certaines caractéristiques du profil cultural (amélioration de l'infiltration).

Le troisième stade enfin est caractérisé par une prédominance des arbustes et une augmentation de la teneur en éléments nutritifs.

Zone CMDT

La DRSPR a rapporté des résultats enregistrés en zone CMDT sur l'effet des soles fourragères sur la fertilité du sol et le rendement des céréales. Alors que des données sont disponibles sur l'évolution des taux d'azote et de phosphore, la teneur en carbone et l'état physique du sol ont été généralement peu étudiés.

Les soles ont été établies en 1988 avec ou sans fertilisation sur des parcelles de 1 ha. La durée de la sole était en général de trois ans avant l'installation de la culture. Des échantillons de sol prélevés un an et quatre ans après l'installation de la sole dans chaque village ont été analysés. Après trois années, les jachères ont été mises en culture.

Il ressort des résultats des analyses que les jachères améliorent les facteurs physico-chimiques du sol, même si l'effet de la sole fourragère ne semblait pas supérieur à celui du témoin dans l'ensemble de la zone.

Le pH des sites, qui était globalement acide ($4{,}55 < \text{pH } H_2O < 5{,}68$), a augmenté de 0,5 pour l'ensemble des sites. Une hausse de la quantité de phosphore assimilable a été observée en zone humide. Après trois années, le rapport C/N allait de 8 à 12, contre 22 à 25 au départ, ce qui représente une amélioration (DRSPR, 1992c).

L'influence de la jachère améliorée sur le rendement de cultures subséquentes de céréales a été signalée dans plusieurs études. D'une façon générale, les rendements en grains du sorgho sur les soles sont nettement meilleurs que ceux des parcelles avoisinantes (tableau 15).

Tableau 15. *Arrière-effet de l'implantation de* Stylosanthes *sur la production du sorgho de l'ancienne sole de Niagalé à Fonsébougou*

Traitement	Rendement grain (kg/ha)
Stylosanthes + *Brachiaria*	995
Stylosanthes + *Brachiaria* en lignes alternées	979
Brachiaria pur	848
Stylosanthes pur	953
Jachère naturelle	518

Source: DRSPR, 1990.

Une comparaison avec les rendements du témoin montre des écarts de 477 kg, 461 kg, 435 kg et 330 kg/ha. Il apparaît également que les traitements avec *Stylosanthes hamata* donnent un rendement supérieur aux autres.

Cependant, il convient de signaler que seuls le site et la clôture ont un effet positif significatif sur l'ensemble des soles mises en culture (DRSPR, 1992).

Zone OHV

Dans cette zone, l'effet bénéfique de la jachère sur la fertilité du sol a aussi été signalé, bien que cela n'ait pas été étayé par des chiffres concrets. Les soles sont restées en place pendant trois ans avant d'être mises en culture.

L'influence de la jachère améliorée sur le rendement du sorgho a été signalée à Dalacana et Niaganabougou, deux villages de la zone sud (tableau 16). Les résultats montrent qu'il n'y avait pas de différence significative entre les rendements obtenus avec les deux types de jachère. De même, l'effet de la fertilisation n'était pas significatif entre les deux pratiques de jachère.

Tableau 16. *Effet de la jachère améliorée sur le rendement du sorgho à Dalacana et Niaganabougou (zone OHV)*

Traitement (kg/ha)		Type de jachère	Rendement (kg/ha)		
Dalacana	Niaganabougou		Moyenne	PNT	Urée
0	0	paysanne	1054	1603	1328
300	50	paysanne	1646	1427	1536
0	0	améliorée	1670	1982	1826
300	50	améliorée	1798	2004	1901

Source: DRSPR, 1992b.

CRZ de Sotuba

En 1988, un deuxième essai avait été réalisé au CRZ de Sotuba avec pour objectif de mesurer l'effet résiduel de *Stylosanthes hamata* sur une culture subséquente de sorgho. Les résultats ont montré un arrière-effet assez net sur la production de grains du sorgho. Alors que la production n'augmentait pas de façon significative avec une application d'urée, un apport de phosphore l'augmentait en revanche de façon sensible (tableau 17).

Tableau 17. *Effet des niveaux d'azote et de phosphore et d'une culture de* Stylosanthes *sur le rendement en grain du sorgho*

Traitement	Rendement (t/ha)
Culture précédente	
sans *Stylosanthes*	1,37
avec *Stylosanthes*	1,56
Azote	
N0	1,42
N25	1,51
N50	1,45
Phosphore	
P0	1,02
P50	1,90

Source: CIPEA, données non publiées.

Effet sur l'érosion du sol

Comme indiqué plus haut, le paysage agraire du Sud-Mali s'est rapidement transformé depuis une trentaine d'années suite au développement de la culture du coton et à l'introduction de la traction animale, avec comme conséquences une augmentation des effectifs animaux et des superficies cultivées, une diminution de la durée des jachères et une dégradation notable des parcours. A titre d'exemple, citons le cas de Kaniko où plus de la moitié des terres sont cultivées et 75% de l'ensemble de la superficie est plus ou moins dégradée (KIT, 1992). On comprend donc que l'un des soucis majeurs des paysans consiste à trouver des techniques simples capables de freiner le ruissellement.

Des expérimentations menées depuis 1980 par la DRSPR ont conduit à l'élaboration d'un modèle de lutte anti-érosive diffusé dans toute la zone CMDT. Celui-ci comprend des ouvrages de diversion et d'évacuation des eaux (drains de ceinture, exutoires, diguettes de diversion), des travaux de freinage du ruissellement (cordons pierreux, haies vives, bandes d'arrêt enherbées), la pérennisation des systèmes de protection (haies vives, plantation d'arbres en bordure des parcelles, réintroduction de l'arbre dans les champs) et des techniques culturales adaptées (grattage en sec ou en demi-humide, fumure organique et buttage cloisonné).

Dans les zones dégradées, diverses espèces sont utilisées pour l'installation des bandes enherbées, les plus importantes étant *Andropogon gayanus* et *Stylosanthes hamata*.

En 1991, le plan de lutte anti-érosive des villages prévoyait 1 100 m de bandes enherbées réparties dans trois villages de la zone de Tominian. Avec des dimensions de 100 m sur 5, les bandes étaient labourées puis ensemencées avec 300 g de *Stylosanthes*, 300 g de *Cenchrus ciliaris* ou 1,5 kg d'*Andropogon gayanus*.

Dans les zones de Sikasso et de Koutiala, environ 21 km de bandes enherbées ont été réalisées dans 11 villages. Ces bandes ont un effet visible sur le ruissellement et surtout sur les pertes d'engrais.

La régénération de la végétation dans ces bandes a été évaluée en juillet et septembre par la méthode des points quadrants alignés sur trois parcelles clôturées de 35 m sur 70. Les parcelles 1 et 2 ont été semées à la volée avec un mélange de *Stylosanthes hamata* et de *Cenchrus ciliaris* et leur surface a été recouverte d'une couche de tiges de céréales et de coton de quelques centimètres d'épaisseur. La surface nue de la parcelle 3 a en outre été soumise à un grattage superficiel.

Il ressort des résultats des mesures de régénération effectuées en 1991 que *Stylosanthes hamata* était bien représenté dans les parcelles 1 et 2, mais très discret dans la parcelle 3. Par ailleurs, le recouvrement végétal a augmenté jusqu'à 70% alors qu'il n'était que de 38% dans la parcelle 3. La réinstallation de la végétation sur les terrains dénudés, en vue de la lutte contre l'érosion, pourrait se faire avec des bandes enherbées couvertes de résidus de récolte. Il a en outre été constaté que le grattage n'avait pas d'effet sur l'établissement de *Stylosanthes* en première année. Enfin, deux graminées, à savoir *Andropogon pseudapricus et Pennisetum pedicellatum* étaient dominantes. Etant donné que ces deux espèces sont indicatrices d'une amélioration de la fertilité du sol, l'influence bénéfique de *Stylosanthes hamata* sur la fertilité du sol est ainsi indirectement établie.

Les paysans et la sole fourragère

L'introduction des soles fourragères en milieu paysan est une pratique récente au Mali. Une telle initiative ne va pas sans problème car le paysan, souvent méfiant et très attaché à ces coutumes, hésite beaucoup dès qu'il s'agit de substituer une nouvelle pratique à succès “douteux” à une activité établie de longue date. Comme pour toute innovation, le succès passe par un certain nombre de conditions. Ainsi, on doit se demander si l'innovation prend en compte une préoccupation réelle du paysan, si la motivation de celui-ci est suffisante pour en assurer le succès, si elle est rentable, compte tenu du temps, de l'espace et de l'énergie nécessaires en comparaison avec l'activité principale du paysan, et si son rendement est supérieur au rendement habituel.

Cette liste n'est guère exhaustive et pourra s'allonger en fonction des caractéristiques de chaque zone.

Après l'installation des soles, des enquêtes ont été menées pour recueillir l'opinion des paysans sur cette innovation. Elles avaient pour but de mettre en évidence ses contraintes et ses avantages, mais aussi de rapporter comment les paysans perçoivent globalement l'introduction des soles fourragères dans leur terroir.

Les réactions enregistrées étaient très variables suivant les années, les zones et le niveau d'équipement des paysans. Certains d'entre eux n'étaient intéressés que par la production fourragère des soles, alors que d'autres accordaient plus d'importance à la lutte contre l'érosion. Les paysans les moins bien équipés étaient moins intéressés par les soles fourragères, car disposant de peu d'animaux, mais d'une façon générale, avaient bien accueilli cette innovation après trois années d'expérience.

Les avantages cités sont la production de fourrage de bonne qualité, bien appété par les animaux et qui permet non seulement de limiter la divagation et d'obtenir de la fumure dans les champs, mais également d'augmenter la production du bétail car les mises-bas interviennent en début de saison sèche dans de nombreux villages, c'est-à-dire au moment où l'alimentation du bétail devient difficile. Par ailleurs, la sole fourragère améliore l'alimentation des vaches laitières et réduit la mortalité des veaux. Elle permet en outre de maintenir les boeufs de labour dans de bonnes conditions physiques, de restaurer la fertilité des sols (les feuilles tombant sur le sol jouant, selon les paysans, le rôle de fumure organique), de combattre l'érosion, d'accroître les revenus monétaires par la vente des fanes ou des semences (1 kg de semence de *Stylosanthes* coûte 5 000 FCFA en zone OHV) et de supprimer les mauvaises herbes.

L'un des problèmes majeurs évoqués par les paysans est la difficulté d'insertion des soles dans le calendrier agricole, surtout lorsque les paysans sont mal équipés ou que la date de démarrage de la saison des pluies change régulièrement. Par ailleurs, la période de fauche coïncide avec la récolte des céréales et les soles doivent être protégées contre les animaux étrangers car en l'absence de clôture, l'utilisation du fourrage devient collective, ce qui en diminue l'impact sur le troupeau du propriétaire. Enfin l'approvisionnement en semences n'est pas toujours facile, car la technique de production utilisée nécessite une formation préalable.

L'objectif de l'installation des soles est fonction de la situation particulière de chaque village (tableau 18).

Tableau 18. *Opinion des paysans sur le degré de priorité (%) des objectifs de la sole fourragère*

Village	Nbre de participants	Degré de priorité (%) de l'objectif		
		Fertilité	Lutte contre l'érosion	Fourrage
Kola	23	30	56	14
Karangana	32	47	0	53
Ségain	44	45	5	50
Touroumadié	22	9	45	45

Source: DRSPR, 1992d.

La production de fourrage était l'objectif visé par la majorité des paysans, à l'exception du village de Kola où la priorité allait à la lutte contre l'érosion.

L'introduction des soles fourragères en milieu paysan est donc une innovation qui gagne du terrain d'année en année et dont les conséquences dépassent largement le cadre des villages de prévulgarisation, dans la mesure où ces soles contribuent à améliorer la productivité globale d'une région entière. La demande accrue de semences de cultures fourragères ces dernières années est un signe de l'intérêt manifeste des paysans pour les cultures fourragères en général et pour *Stylosanthes* en particulier. Il est donc nécessaire de renforcer cette action en vue de freiner la dégradation de l'environnement et améliorer les systèmes de production agropastoraux.

Conclusion

En conclusion, on peut dire que la sole fourragère peut permettre de résoudre en partie le problème de la pénurie de fourrage en zone Sud-Mali. Le fourrage produit sur les soles pendant trois années est considérable et sa qualité est légèrement supérieure à celle du témoin. *Stylosanthes* améliore les facteurs physico-chimiques du sol, mais son effet n'est pas meilleur que celui du témoin. Après trois ans, le rapport C/N est amélioré et son influence sur les rendements de la culture subséquente de sorgho est nettement positif. Par ailleurs, grâce à un bon recouvrement du sol, *Stylosanthes* convient bien pour la régénération des zones dégradées.

La sole fourragère pluriannuelle a été bien acceptée en zone Sud-Mali par les paysans qui y voient beaucoup d'avantages, notamment la production de fourrage, l'augmentation de la productivité du cheptel, la lutte contre l'érosion, la suppression des mauvaises herbes avant la culture du sorgho, la lutte contre la divagation du bétail et une augmentation de la production de fumier. Les principales contraintes évoquées sont la difficulté d'insertion de la sole dans le calendrier agricole, la nécessité de protéger la sole contre les animaux et les problèmes rencontrés dans la production de semences.

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Modélisation de l'impact technico-économique de l'introduction de *Stylosanthes hamata* dans les systèmes agraires villageois au Sud-Mali

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Résumé

Une des caractéristiques essentielles des systèmes agraires villageois au Sud-Mali est la pratique de la jachère. Celle-ci se justifie par ses multiples fonctions, y compris le maintien de la fertilité des sols, la lutte contre les adventices et la production de fourrage destiné à améliorer l'alimentation du bétail.

L'analyse de l'évolution des jachères montre que celles-ci sont de plus en plus limitées dans le temps et dans l'espace en raison de la forte pression démographique et de l'accroissement des effectifs animaux. Cette situation a conduit l'équipe de la Division de recherches sur les systèmes de production rurale (DRSPR) à rechercher de nouveaux modes de gestion des jachères.

Lancées en 1984, ces recherches en milieu réel ont porté sur l'introduction d'espèces pérennes de légumineuses fourragères (*Stylosanthes hamata*). Celles-ci ont été associées à *Brachiaria ruziziensis*, une graminée pérenne, sous forme de soles fourragères sur jachères de courte durée.

Les résultats de trois années dénotent, par rapport aux espèces annuelles (niébé fourrager), une meilleure adaptabilité de *Stylosanthes hamata* et une productivité plus élevée.

Cette phase expérimentale a été suivie d'une analyse économique de l'adoption de cette espèce, sur la base d'un modèle simple de programmation linéaire, en vue d'évaluer son impact sur l'ensemble du système.

Il ressort des résultats enregistrés qu'une fois garantis les débouchés des productions animales, la culture de *Stylosanthes hamata* permettait un accroissement du revenu des exploitants grâce à l'adoption d'activités plus productives basées sur l'utilisation de la fumure organique.

Modelling the technical and economic impact of the introduction of *Stylosanthes hamata* into rural agricultural systems in southern Mali

Abstract

Fallows are one of the main characteristics of rural agricultural systems in southern Mali. This is because they perform several functions, including soil fertility conservation, weed control and fodder production for improving livestock feeding.

An analysis of their features shows that due to high human population pressure and increasing livestock numbers, fallow plots are increasingly smaller in size and last shorter *periods of time. This led the Département de recherche sur les systèmes de production rurale (DRSPR) to look into new fallow-management techniques.*

On-farm trials started in 1984 on the introduction of perennial fodder legumes, including Stylosanthes hamata. *These were mixed on short fodder fallow plots with* Brachiaria ruziziensis, *a perennial grass.*

The results of a three-year study show that Stylosanthes hamata *was better adapted and more productive than annual species like the fodder cowpea.*

This experimental phase was followed by an economic analysis of the adoption of this species, based on a simple linear programming model, to assess its global impact on the system.

The results show that provided there is a reliable market for animal products, the adoption of Stylosanthes hamata *by farmers increased their income through the adoption of more productive activities based on the use of organic manure.*

Introduction

Le Sud-Mali est une zone à haut potentiel productif à l'échelle nationale qui, avec seulement 8% de la superficie totale du pays, abrite plus du tiers de la population nationale avec une croissance démographique qui atteint dans certains endroits 3% par an. Cette zone à vocation agricole est devenue depuis 1985 la première zone d'élevage à l'échelle du pays, se substituant aux zones traditionnelles d'élevage.

Cette évolution est la conséquence directe de deux phénomènes, à savoir la capitalisation des agriculteurs dans l'élevage en vue de mieux sécuriser les revenus (à partir du coton notamment), et la sédentarisation des éleveurs transhumants suite à plusieurs décennies de sécheresse.

Compte tenu de cette évolution, la pression sur la ressource terre a atteint un niveau tel que les jachères qui jouent des fonctions multiples (maintien de la fertilité des sols, production de fourrage, etc.) sont de plus en plus limitées dans le temps et dans l'espace.

De plus, les conditions macro-économiques (suppressions des subventions des intrants agricoles, déréglementation du marché céréalier, etc.) ne semblent pas inciter les agro-éleveurs à une utilisation intensive des facteurs de production d'origine industrielle (engrais minéraux, aliments du bétail, etc.).

Ces évolutions récentes posent le problème du maintien des aptitudes productives de la terre, c'est-à-dire celui de la fertilité des sols (Pieri, 1989; Van der Pol, 1990).

C'est dans ce contexte que l'équipe de la Division de recherches sur les systèmes de production rurale (DRSPR) a entrepris des recherches sur les alternatives techniques envisageables pour la reproductibilité des systèmes agraires villageois.

Celles-ci se situeraient entre deux des trois principaux systèmes de production identifiés par Badouin (1979). Le premier est un système de conservation de la fertilité du sol associé à la pratique de l'agriculture dite paysanne, c'est-à-dire basée sur des ressources productives que le secteur agricole est capable de produire lui-même (intégration des productions végétales et animales). Quant au second, il s'agit d'un système où la capacité productive de la terre est imputable en grande partie à une utilisation intensive d'engrais minéraux.

La revue bibliographique et les contacts avec les structures de recherche et de développement de la sous-région (Ferme semencière de Farakoba, Burkina Faso; SODEPRA, Côte d'Ivoire) ont permis d'identifier deux espèces fourragères pérennes qui pourraient être utilisées pour augmenter la production de fourrage et améliorer les jachères, à savoir une légumineuse (*Stylosanthes hamata*) et une graminée *(Brachiaria ruziziensis)*.

Les premières interrogations se sont portées sur l'adaptabilité de ces espèces au niveau de la zone de recherche.

Une des hypothèses de travail était que *Stylosanthes hamata* a une influence positive sur l'ensemble du système. Celle-ci se traduirait dans un premier temps par l'augmentation de la capacité de charge animale par suite de l'accroissement du disponible fourrager.

Dans un deuxième temps, l'accroissement possible des effectifs animaux entraînerait une augmentation de la disponibilité en fumure organique. Cela permettrait de maintenir la fertilité par l'adoption d'alternatives techniques basées sur une forte consommation de fumure organo-minérale.

De plus, la minéralisation de l'importante biomasse qui tombe et la fixation symbiotique de l'azote par les nodosités des racines (Skerman, 1982) contribueront à améliorer la fertilité des sols.

Cependant, l'influence de *Stylosanthes* ne peut être significative que dans un environnement économique favorable au développement à la fois des productions végétales et de l'élevage.

Après une précision des options méthodologiques, une synthèse des expérimentations hors champ économique sera réalisée sur la base de la production de biomasse et de la valeur nutritive. Ensuite, le cadre général du modèle sera décrit et sa validation effectuée pour un village donné.

Enfin, à partir de cette situation de base, les conséquences éventuelles de l'adoption de cette espèce par les agro-éleveurs sur les systèmes agraires seront analysées.

Méthodologie

Phase expérimentale

Dans la phase expérimentale d'essai sur les espèces fourragères, le nombre d'agro-éleveurs est limité à trois, répartis entre deux villages de recherche (zone de Fonsébougou). Au niveau de chaque exploitant, une parcelle de 1 ha est délimitée sur des jachères courtes et clôturée avec du fil de fer barbelé. Le dispositif expérimental est un bloc dispersé destiné à comparer des cultures pures ou associées de *Stylosanthes hamata*, de *Brachiaria ruziziensis* et une jachère naturelle d'un quart d'hectare également protégée.

Le sol est préparé par un labour intervenant en général après l'installation des autres spéculations. Ces soles fourragères n'ont fait l'objet d'aucun travail d'entretien après installation (sarclage par exemple) dans le souci d'éviter une contrainte supplémentaire au niveau du système.

Aucune fertilisation minérale n'a été apportée au départ mais une application de 300 kg par hectare de phosphate naturel de Tilemsi (PNT) s'est révélée nécessaire à la suite de la carence des sols en phosphore, carence révélée par les résultats de la première année.

L'évaluation de la production de biomasse et l'inventaire floristique ont été effectués en collaboration avec les éleveurs impliqués dans la recherche thématique.

Pour ce qui est de l'exploitation du fourrage produit, l'expérience malheureuse du niébé fourrager (difficulté de le récolter en période jugée optimale par les zootechniciens, laquelle coïncide avec une période de forte demande de main-d'oeuvre pour la récolte du maïs et du coton) et surtout l'exportation massive de biomasse contraire à l'objectif du test, ont conduit à ne pas prévoir d'activité de fauchage. L'exploitant est libre d'introduire ses animaux en pâture directe à une période jugée contraignante en matière de disponibilité fourragère au niveau des pâturages naturels.

Ces aspects d'ordre agrotechnique sont suffisamment détaillés ailleurs dans un dispositif plus complexe (Diarra *et al.*, 1992).

Après trois années d'expérimentation, *Stylosanthes* s'est révélé comme l'espèce la mieux adaptée. Ces conclusions sont confirmées par les résultats obtenus par la suite en testant la même espèce et d'autres espèces fourragères dans différentes zones du Sud-Mali (Diarra *et al.*, 1992).

Modélisation

La méthode choisie en vue de l'évaluation des conséquences possibles de l'adoption de cette espèce est une modélisation quantitative du fonctionnement des systèmes agraires permettant d'analyser les différents mécanismes qui déterminent la situation d'équilibre observée. Elle est basée sur les mécanismes de fonctionnement internes de ces systèmes.

Inutile de s'attarder ici sur le cadre théorique des modèles de comportement, présenté en détail par ailleurs (Petit, 1976; Boussard, 1970, 1987; Boussard et Bourliaud, 1974; Boussard et Daudin, 1988). En tant qu'outils descriptifs, ces modèles permettent de répondre à la question de savoir ce qui se passerait dans l'éventualité de l'adoption de la culture de *Stylosanthes* par les agro-éleveurs.

Certes, comme l'ont signalé Hayami et Kikuchi (1980), l'analyse de l'évolution d'un système agraire demande très souvent une approche interdisciplinaire faisant appel à la fois aux ressources et aux techniques de l'anthropologie, de la sociologie et de la science politique. Cependant, notre approche se veut disciplinaire, privilégiant le point de vue économique sur la dynamique des systèmes étudiés. Les aspects politiques et socio-culturels ne sont pas pour autant ignorés dans cette analyse, mais sont considérés comme des variables exogènes aux systèmes de représentation élaborés. Cette analyse économique permettra de déterminer l'influence de ces variables sur les systèmes.

Elle suppose l'utilisation de méthodes qui permettent d'établir la disponibilité et la demande en ressources productives et en produits, agricoles ou non, aussi bien au niveau de la communauté qu'au niveau des différents marchés assurant le lien entre celle-ci et le reste de l'économie. De ce fait, l'approche méthodologique s'inspire beaucoup de l'approche systémique développé au Sud-Mali depuis plus d'une décennie (Kleene *et al.*, 1989; Joldersma *et al.*, 1991). Elle privilégie trois niveaux d'intervention, à savoir le système de culture relatif à l'ensemble des productions végétales, le système de production relatif à la gestion des ressources productives et le système agraire relatif à l'intersection d'un écosystème, d'un système social et d'un système technique de mise en valeur (Benoit-Cattin *et al.*, 1991).

La modélisation mathématique par l'utilisation de la programmation linéaire permet d'intégrer ces trois niveaux en tenant compte des relations avec l'environnement économique à travers le marché des intrants et des extrants.

A partir de cette situation de base représentée par les ressources naturelles disponibles, les pratiques actuelles et les habitudes sociales dans le contexte socio-économique, une analyse prospective est effectuée par intégration des scénarios d'alternatives techniques basées sur les résultats de la recherche système sur *Stylosanthes hamata*.

Un modèle utilisant comme outil d'analyse la programmation linéaire a été construit et validé au niveau d'un système agraire villageois (Kébé, 1989; Benoit-Cattin *et al.*, 1991).

Une particularité de cette approche est son échelle d'application, à savoir le système agraire villageois. Le choix de cette échelle tient au fait qu'elle permet de prendre en compte les interactions entre système agraire, système de production et système de culture.

De plus, le fonctionnement des activités de productions animales dans l'espace et dans le temps déborde le cadre de l'exploitation agricole dans des systèmes transitoires à jachère courte. Et pourtant, elles jouent un rôle important en ce qui concerne la gestion des aptitudes productives de la terre, l'utilisation des sous-produits de récolte, la mise en valeur des jachères par les cultures fourragères comme *Stylosanthes*, la fourniture d'animaux de trait et la consommation humaine.

Enfin, ce niveau "méso-économique" intermédiaire entre la micro-économie (exploitation agricole) et le niveau des agrégats macro-économiques permet de simplifier la prise en compte des problèmes d'accès à la terre et à la main-d'oeuvre.

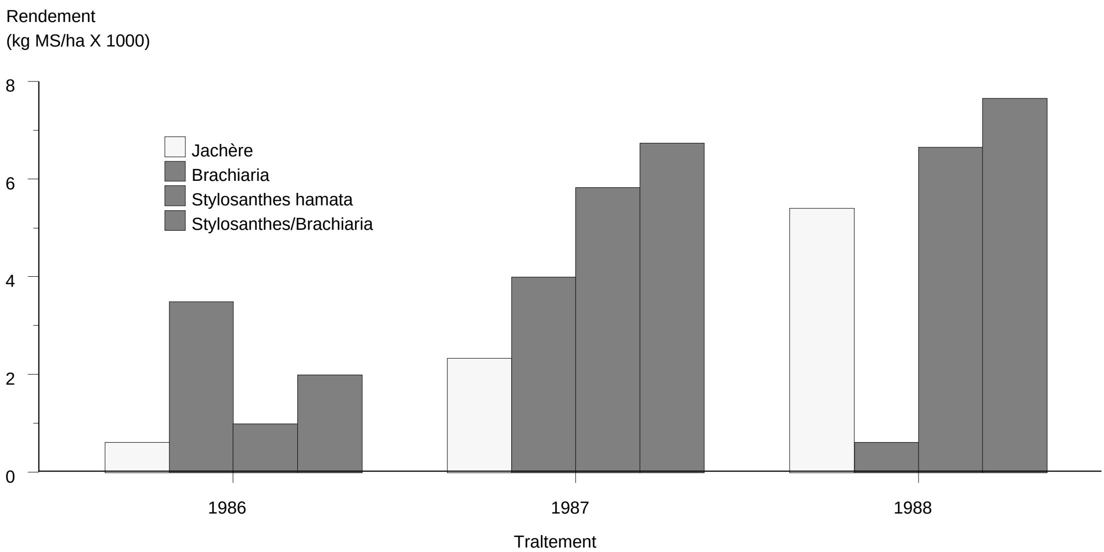
Résultats et discussion

Productivité en biomasse

L'évaluation de la productivité en biomasse révèle une prédominance de la graminée en première année d'installation, probablement due au faible taux de levée de *Stylosanthes*.

A partir de la deuxième année *Stylosanthes* colonise l'ensemble des soles, justifiant l'évolution au niveau de certains traitements qui à priori peut paraître surprenante. Cette situation justifierait très probablement l'évolution constatée au niveau de la jachère naturelle protégée: de 2 300 kg/ha de matière sèche en deuxième année d'expérimentation, le rendement est passé à plus de 5 000 kg/ha de matière sèche. De plus *Brachiaria*, qui semble dominer au cours de la première année, a presque disparu en trois ans d'expérimentation (figure 1).

Figure 1. *Rendements en biomasse de la jachère naturelle et des soles fourragères à Fonsébougou de 1986 à 1988*



Source: DRSPR, 1989.

Il est très probable que l'influence de *Stylosanthes* ait masqué l'effet sur les caractéristiques physiques et chimiques du sol constaté par Diarra *et al*. (1992) au niveau du second dispositif mis en place à partir de 1988. En effet, ces auteurs ont observé une différence significative entre les différents sols et la situation initiale en termes d'amélioration de ces caractéristiques. Par contre, selon les mêmes auteurs, cette différence ne saurait être attribuée au *Stylosanthes* dans la mesure où il n'y avait aucune différence entre le traitement *Stylosanthes* et le témoin c'est-à-dire la jachère naturelle, protégée ou non.

Effets anti-érosifs

L'effet de *Stylosanthes* sur l'humidité du sol a pu être évalué. Les résultats enregistrés confirment l'hypothèse d'une influence positive de cette espèce par rapport à la jachère naturelle dégradée (DRSPR, 1986).

Qualité du fourrage produit

L'avantage le plus immédiat pour l'agro-éleveur est l'accroissement de la production fourragère dans une zone où les contraintes fourragères sont assez sérieuses (Breman et Traoré, 1987; Leloup et Traoré, 1989).

En plus des aspects quantitatifs, une analyse bromatologique a été effectuée pour comparer la qualité des divers fourrages produits. Les résultats enregistrés semblent également confirmer l'idée selon laquelle le fourrage de *Stylosanthes* était de meilleure qualité que ceux des autres espèces spontanées et introduites (tableau 1).

Tableau 1. *Résultats de l'analyse bromatologique des espèces fourragères et d'une jachère naturelle*

Paramètres	*Stylosanthes hamata* (pur)	*Stylosanthes* + *Brachiaria*	Brachiaria *ruziziensis* (pur)	Jachère naturelle
Protéines brutes	6,19	4,75	2,75	2,63
Cellulose	41,54	45,68	38,08	43,41
Cendres	5,42	5,31	6,79	6,25
Azote total	0,89	0,76	0,44	0,42

Source: DRSPR, 1987.

Arrière-effet sur la production de sorgho

La mise en culture de ces parcelles après trois années d'expérimentation montre un relatif effet positif de *Stylosanthes* sur la fertilité du sol. En effet, les rendements de 950 kg/ha de sorgho sur sole à *Stylosanthes* sont similaires ou même supérieurs aux rendements moyens obtenus lorsque le sorgho suit le coton (rotation biennale) ou le maïs (rotation triennale) sans apport d'engrais sur la variété locale. Ces résultats doivent être interprétés avec prudence dans la mesure où ils ne portent que sur une seule année avec un nombre restreint de répétitions. Ils donnent cependant une indication des effets potentiels de *Stylosanthes* sur la reproductibilité d'un système transitoire entre le système à défriche–brûlis et un système à culture permanente avec intégration des jachères dans l'assolement.

Ces aspects d'ordre agrotechnique sont des éléments de validation des hypothèses d'adaptabilité des différentes espèces introduites, notamment *Stylosanthes hamata*. Cette espèce et certaines autres sont au stade dit de prévulgarisation dans la démarche recherche système. La construction d'un modèle simple permet de mieux comprendre les conditions d'adoption par les agro-éleveurs.

Description sommaire du modèle

Introduction

Le modèle est appliqué à l'échelle du système agraire du village de Fonsébougou. Situé dans la frange sud de la zone Sud-Mali, ce village fait partie d'un ensemble de quatre villages qui ont fait l'objet de recherches diverses depuis plus d'une décennie (Kleene *et al.*, 1989). Qui plus est, c'est là qu'ont démarré les recherches sur les différentes espèces fourragères dont *Stylosanthes*.

La population de Fonsébougou est à majorité Sénoufo, une ethnie dont l'activité principale est l'agriculture. La culture attelée et l'investissement dans l'élevage de revenus issus du coton ont été à l'origine de l'apparition récente d'agro-éleveurs sédentaires. Le village compte plus de 1 000 habitants répartis en plusieurs familles, qui sont "les plus grandes unités sociales qui regroupent l'ensemble des ménages reconnus comme descendants d'un même ancêtre".

On peut considérer ce village comme précurseur de l'évolution technique et agraire de la zone. Il a presque atteint la limite d'un système transitoire à jachère courte. Ainsi rapportée aux surfaces cultivables, la densité de population est supérieure à 100 habitants au km^2. En d'autres termes, toutes les terres cultivables le sont effectivement et certaines zones considérées comme marginales, compte tenu des techniques actuelles, connaissent même déjà un début de mise en valeur (Jansen et Diarra, 1990).

Certaines des données utilisées pour la modélisation à l'échelle de ce système agraire villageois sont exhaustives au niveau du village. D'autres proviennent d'une enquête de suivi-évaluation permanent effectuée auprès d'un échantillon de plus de 20 exploitations (DRSPR, 1988, 1989). De plus, en termes d'alternatives techniques genre *Stylosanthes*, la plupart des données utilisées sont les résultats d'expérimentations conduites au niveau du village.

Ces données hétérogènes sont réunies en un ensemble plus cohérent sous forme d'un modèle simple avec comme outil d'analyse la programmation. Des informations plus détaillées sont présentées plus loin sur les différentes composantes de ce modèle.

Les besoins monétaires

Les besoins monétaires autres que ceux nécessaires à l'achat de céréales ou d'intrants sont pris en compte dans le modèle par le biais de la maximisation à l'échelle d'une année, objectif poursuivi par les habitants du village.

Par hypothèse, l'agriculteur choisit les combinaisons productives avec comme objectif l'obtention d'un résultat optimum dont le revenu monétaire disponible après paiement des intrants (semences, engrais, insecticides) et la satisfaction des besoins céréaliers de base semblent constituer une bonne approximation. L'aspect risque, qui semble assez important au niveau d'un système tributaire des aléas climatiques et d'un environnement économique incertain, est pris en compte dans un autre modèle par la méthode du Target Motad (modèle à revenu minimum) de Bauer cité par Hazell et Norton. (1986).

Les revenus et les dépenses dépendent du niveau des prix des produits et des ressources productives et donc de l'environnement économique. Les prix utilisés dans le modèle sont pour le coton le prix officiel qui n'a pour ainsi dire pas évolué de façon structurelle depuis 1985, et pour les céréales les prix observés au niveau des différents marchés locaux par le Système d'information sur le marché céréalier (SIM).

Allocation des ressources productives

La terre

Les résultats de l'analyse des disponibilités en terre au niveau du système agraire villageois proviennent d'interprétations de photographies aériennes effectuées par Jansen et Diarra (1990).

Ces résultats sont simplifiés au niveau du modèle. Quatre unités de paysage sont retenues. L'un des critères de ce choix est surtout lié à la différence de gestion. Cependant, il est peu probable qu'on retrouve ces quatre unités au niveau de tous les terroirs villageois.

Constituée par le plateau, l'unité 1 correspond en général à la zone dite sylvicole ou sylvo-pastorale, avec des sols peu profonds qui se prêtent peu à l'activité agricole et présentent des affleurements de cuirasse à certains endroits.

L'unité 2 ou versant amont correspond d'un point de vue technique à des zones à pente élevée qui, selon Hijkoop *et al.* (1991), devraient être mises en défens puisque assez sensibles à l'érosion hydrique. Dans la réalité, ces zones sont des zones de passage des animaux en période de culture.

L'unité 3 ou versant aval est la première zone agropastorale avec des sols gravillonnaires plus profonds que les deux premiers. Jadis à vocation plus pastorale qu'agricole, ces zones de transition sont de plus en plus cultivées en raison de la forte pression démographique.

L'unité 4 enfin, ou bas glacis, correspond à la zone de culture par excellence avec des sols profonds. C'est ici qu'apparaissent les premiers signes de saturation avec une importante réduction de la durée de la jachère et une relative fixité des parcelles.

D'un point de vue socio-économique, le choix de ces unités procède du souci d'identifier les modifications de stratégies de gestion de l'espace agraire intervenant au niveau des communautés villageoises lorsque les meilleures terres sont mises en valeur sans que l'on dispose d'alternatives techniques permettant d'améliorer la productivité de la terre et du travail.

Les consommations intermédiaires

Les consommations intermédiaires traduites dans le modèle en terme de contraintes aux activités productives sont classées en consommations intermédiaires d'origine industrielle (urée, complexe-coton, etc.) et autofournies telles que la fumure organique. De plus, une distinction est établie entre celles destinées aux productions végétales et celles affectées aux productions animales. Dans la structure de base du modèle, les normes retenues sont celles réellement utilisées par les agro-éleveurs des différentes zones (base de données DRSPR 1988-1989 complétée par des enquêtes informelles de l'auteur). Les normes recommandées par la recherche et le développement n'interviennent que dans le cadre des scénarios d'alternatives.

Les biens d'équipement

Les biens d'équipement sont destinés à appuyer ou à remplacer la main-d'oeuvre d'origine familiale. Dans le modèle de base, les besoins en moyens de transport sont fonction du volume des récoltes et de la distance par rapport aux villages exprimée en nombre de voyages par jour de récolte. Cette contrainte n'est pas imposée au modèle. Seuls les différents besoins sont exprimés pour chaque activité de production en termes de nombre de charrettes.

Les attelages

Les besoins en attelage tiennent compte des surfaces cultivables et des exigences de chaque activité productive. Les résultats d'enquêtes du DRSPR font état de 5 ha par attelage soit 0,4 attelage par ha.

Les contraintes de liquidité

La liquidité financière est un facteur déterminant du choix d'investissement des agro-éleveurs. Même si, en ce qui concerne les activités de productions végétales, l'avancement des consommations intermédiaires en crédit campagne semble atténuer les effets de cette contrainte, reste que le risque lié aux productions végétales fait de cette contrainte financière un paramètre important. De plus, l'hypothèse alternative du passage du marché des intrants au secteur privé donne à cette contrainte toute son importance.

Les activités de production

Les productions végétales

Au niveau du modèle, les spéculations pratiquées par les agro-éleveurs ont été simplifiées et certaines alternatives ont été introduites comme *Stylosanthes* qui, au niveau du village, a fait l'objet d'expérimentations et est en voie de vulgarisation par l'organisme de développement.

Pour identifier ce qui incite les agro-éleveurs à adopter des méthodes plus ou moins intensives, on a retenu pour les activités de productions végétales décrites dans le système de culture, des scénarios d'intensification à base de consommations intermédiaires d'origine industrielle (engrais minéraux) et/ou autofournies (fumure organique). Par souci de simplification, les activités de productions végétales ont été réparties en trois catégories, selon qu'elles font appel à des techniques actuelles, des méthodes plus intensifiées ou des techniques extensives.

En ce qui concerne les activités utilisant des techniques actuelles, les spéculations retenues au niveau du système de culture sont principalement le coton, le maïs en culture pure, le maïs en association avec le mil, le sorgho et le niébé fourrager. Les pratiques actuelles en matière de fertilisation du coton sont assez proches des doses vulgarisées: 150 kg par hectare d'engrais complexe (14-22-12) et 50 kg par hectare d'engrais urée.

S'agissant des activités faisant appel à des techniques plus intensifiées, on a adopté des scénarios d'alternatives basés sur la fertilisation organo-minérale combinant la dose d'engrais minéraux vulgarisée et un apport complémentaire de fumier destiné à maintenir l'humus du sol par référence aux expérimentations en cours au niveau du village depuis 1984.

Ces techniques de fertilisation peuvent être adoptées lorsqu'un certain niveau d'intégration de l'élevage à l'agriculture est atteint. Une augmentation de la capacité de charge animale par suite d'un accroissement du disponible fourrager contribuera à améliorer la gestion du troupeau et à augmenter la production de fumure organique. C'est à ce niveau que le rôle de *Stylosanthes* semble déterminant. Les spéculations concernées sont le coton et le maïs en culture pure et en association avec le petit mil.

En ce qui concerne enfin les techniques dites extensives, un autre scénario est la substitution totale de la fumure organique (fumier) aux engrais minéraux. Les performances et les coûts monétaires de ces techniques sont inférieurs à ceux des autres techniques.

Un des points communs à ces différentes techniques est que la stratégie paysanne de gestion des récoltes — céréalières notamment — tient compte d'éventuels aléas climatiques.

En ce qui concerne la gestion du stock céréalier, la caractéristique essentielle des agricultures traditionnelles est la constitution de stocks dits de sécurité en prévision de mauvaises récoltes. Pour les "gros" exploitants, le stock minimal dans les greniers est l'équivalent-céréale d'au moins une consommation annuelle de la cellule familiale.

Les productions animales

On a modélisé le système d'élevage de façon simple en essayant autant que possible de rendre compte des interactions entre agriculture et élevage.

Les parcours et les jachères sont considérés comme des activités qui produisent du fourrage consommé par le secteur de l'élevage à différentes périodes de l'année. A cet effet, plusieurs variables ont été examinées, notamment en ce qui concerne les ressources fourragères.

***Le niébé fourrager* (NIEBE).** Le niébé fourrager a été introduit récemment par la recherche. Son adoption semble rencontrer un certain nombre de difficultés d'ordre technique amenant dans certains cas à la reconversion des parcelles au niébé grain. Dans la pratique, la production de niébé fourrager ne bénéficie d'aucun apport de fertilisant et peut donner des rendements de l'ordre de 2 000 kg de matière sèche de fourrage par hectare.

***Stylosanthes hamata* en association (STYLO).** La culture fourragère à base d'espèces pérennes est d'introduction récente sur des jachères de courte durée de l'ordre de 4 à 5 ans. Il s'agit en fait de deux espèces, une légumineuse, *Stylosanthes hamata* et une graminée, *Brachiaria ruziziensis*, semées en lignes. Les rendements sont de l'ordre de 6 000 kg de matière sèche par hectare. Nous avons considéré que les semences sont achetées alors que des possibilités d'autofourniture de semences ont été testées. De plus, une analyse économique effectuée a intégré l'aspect protection (fil de fer barbelé ou grillage) tout en valorisant le fourrage par l'hypothèse d'une substitution totale à l'aliment bétail (Diarra *et al.*, 1992). Approche fort intéressante à laquelle il est généralement reproché de ne pas tenir compte de l'interaction entre cette spéculation et les autres spéculations du système de culture. Cette interaction concerne non seulement la concurrence vis-à-vis des ressources productives (terre et travail par exemple), mais également la complémentarité aussi bien pour l'arrière-effet que pour l'effet indirect par une augmentation de la disponibilité en fumure organique (fumier).

Le système de protection actuel en fil de fer barbelé ou en grillage semble constituer une solution intermédiaire compte tenu de l'évolution de systèmes agraires. Dans un système à jachère courte fortement tributaire des aléas climatiques, les agriculteurs n'ont pas intérêt, d'un point de vue économique, à réaliser de tels investissements (Boserup, 1970). Il s'agit là de mesures d'accompagnement en attendant le passage à un système de culture permanente.

***Les parcours* (PARCOURS).** Les parcours correspondent aux zones non cultivables avec des espèces de qualité médiocre. La productivité en fourrage est estimée à 1 700 kg de matière sèche par hectare par an et des teneurs en unité fourragère de 0,15 à 0,20 unité fourragère (UF) par kilogramme de matière sèche produite.

***Les jachères* (JACHERE).** Les jachères sont situées sur les zones cultivables et ont une productivité de l'ordre de 2 600 kg de matière sèche par hectare par an pour la strate herbacée (Leloup et Traoré, 1989) et des teneurs en UF de l'ordre de 0,35 à 0,4 par kilogramme de matière sèche produite.

***L'élevage* (ELEV).** L'activité élevage est exprimée en UBT (unité de bétail tropical). Elle consomme des pailles de céréales, du fourrage produit sur les parcours, les jachères et les soles fourragères en fonction des différentes périodes. Elle produit du fumier, de la viande et du lait ainsi que des bovins destinés à l'attelage.

L'évaluation du prix de la viande se fait sur l'hypothèse d'un croît annuel de 25 kg et de 50 kg par UBT estimé à 350 FCFA le kilo.

Pour ce qui est de la production laitière, les résultats utilisés dans le modèle sont de Jager (1990). Ceux-ci font état d'une production d'environ 290 litres de lait par vache, exclusion faite de la part destinée aux veaux pour la zone de Koutiala.

L'hypothèse du modèle suppose une autoconsommation de 10% de la production de lait.

Le calendrier d'affouragement établi s'étale sur trois périodes en fonction des disponibilités fourragères. La production de fourrage est exprimée en UF et les besoins sont calculés par référence aux normes retenues dans le mémento “Intégration agriculture–élevage” (CMDT/DRSPR, 1987). Celles-ci distinguent les besoins d'entretien, de travail fort et de croissance pour les bovins de trait des besoins d'entretien et de travail léger pour le reste du troupeau. Le ratio bovin de trait aux autres bovins est de l'ordre de 0,3 pour le village de Fonsébougou.

Le calendrier d'affouragement retenu est une adaptation simplifiée de Leloup et Traoré (1989). On peut distinguer trois périodes différentes, à savoir novembre à février, mars à juin et juillet à octobre.

Pendant la première période, l'alimentation du bétail est essentiellement constituée de sous-produits de culture, principalement du fourrage de maïs et une faible proportion de paille de sorgho. Une bonne partie des jachères naturelles et seulement une faible proportion des parcours sont utilisées. En ce qui concerne les pailles de maïs, l'hypothèse retenue est que 50% d'entre elles sont récupérables à des fins fourragères, avec 0,4 UF par kilogramme de matière sèche.

Au cours de la deuxième période, l'essentiel du fourrage provient des jachères et éventuellement de *Stylosanthes*, avec très peu de sous-produits. Les jachères étant limitées dans l'espace et dans le temps par suite de l'extension des superficies cultivées, c'est la période la plus difficile en ce qui concerne l'alimentation des animaux.

En troisième période enfin, les animaux sortent des zones de culture et se nourrissent essentiellement sur les parcours.

Relations agriculture-élevage. Compte tenu des relations de complémentarité et de concurrence qui existent entre les activités de production animale et de production végétale, un certain nombre de contraintes ont été retenues au niveau du modèle.

Les relations de complémentarité s'expriment par la production fourragère sur la zone de culture (sous-produits de récolte, soles fourragères) à destination des productions animales et par la production de fumure organique et de bovins de trait en vue des productions végétales.

Les relations de concurrence sont en grande partie liées à l'extension des superficies cultivées au détriment des jachères, ce qui empêche les effectifs animaux du système de se maintenir.

La population

L'absence de données précises sur l'évolution démographique du village a conduit à intégrer la variable démographique au modèle, ce qui en accroît la flexibilité et la valeur heuristique. Les données d'enquête permettent de situer cette population aux environs de 1 100 habitants. Elle fournit la main-d'oeuvre et a des besoins de consommation.

La main-d'oeuvre

Il ressort des observations effectuées sur le terrain que lorsque la culture attelée est généralisée comme à Fonsébougou, la période des récoltes est la plus contraignante comme en témoigne la mobilisation de toutes les ressources disponibles pendant cette période, y compris enfants et personnes âgées. Dans le modèle, deux phases ont été retenues, à savoir le mois de septembre, correspondant à la récolte du maïs, du niébé fourrager et d'une petite partie du coton et le mois de novembre correspondant à la récolte du coton et du sorgho-mil.

Les temps de travaux utilisés sont la synthèse des résultats de Brossier et Jager (1984) et de DRSPR (1988, 1989).

Pour cette période de récolte, les échanges de travaux entre les différentes catégories d'exploitations sont tels que les inégalités s'équilibrent par le biais des associations au niveau du village, le recours à la main-d'oeuvre extérieure étant extrêmement rare. Compte tenu de la réalité observée, il n'a pas été explicité d'activités de vente ou d'achat de travail à l'extérieur.

Les besoins de consommation alimentaire

Les interactions entre production et consommation humaine se situent essentiellement au niveau des céréales. Pour tenir compte des habitudes alimentaires locales, on a considéré que ces céréales, à raison de 265 kg par habitant, peuvent provenir des activités produisant des mils et des sorghos; le maïs rentrant peu dans l'alimentation, on a considéré que sa consommation pouvait atteindre 10% de la consommation totale.

Des détails relatifs à l'écriture matricielle de ce modèle sont disponibles dans Benoit-Cattin *et al.* (1991).

Résultats du modèle

La solution de base

L'obtention d'une solution de base en harmonie avec les connaissances qu'on a de la situation réelle est une étape importante dans la construction et la validation d'un modèle. Tel que celui-ci a été construit, son calibrage dépend principalement des contraintes de terre et du calendrier d'affouragement. Cette solution correspond à une combinaison optimale des techniques actuellement utilisées par les paysans de Fonsébougou et ce, sans contrainte sur leur niveau d'équipement (tableau 2).

Tableau 2. *Comparaison entre modèle et réalité au niveau du village*

		Solution du modèle		Situation réelle		
Unité	Activités	Valeur absolue (ha)	%	Valeur absolue (ha)	%	Avec *Stylosanthes*
ha	Coton I	152	20,29	n.d.	–	206
ha	Coton II	239	31,90	255	32,56	240
ha	Coton III	0	0	n.d.	n.d.	0
ha	Maïs I	0	0	n.d.	n.d.	0
ha	Maïs II	0	0	n.d.	n.d.	126
ha	Maïs III	0	0	n.d.	n.d.	0
ha	Maïs/petit mil	11	1,46	88	11,23	0
ha	Mil	0	0	n.d.	n.d.	0
ha	Sorgho	347	46,32	440[a]	56,19	351
ha	*Stylosanthes*	0	0	n.d.	n.d.	99
ha	Sup. tot. cultivée	749	100	783	100	1 022
ha	Jachère	219	27	313[b]	n.d.	0
UBT	Elevage	760	–	800	–	1 029
UBT	Boeuf de labour	228	–	231	–	309
UBT	Vache	0	–	n.d.	–	0
	Charrette	67	–	59	–	124

n.d. = non disponible.

[a] Sorgho/mil selon estimation CMDT (Doumanaba).

[b] D'après Jansen et Diarra (1990).

N.B. Les chiffres utilisés dans le tableau comme situation réelle sont ceux fournis par la CMDT et sont pour la plupart des estimations (surfaces en céréales notamment).

La valeur atteinte par la fonction objectif correspond à un revenu monétaire moyen de 42 700 FCFA par habitant, ordre de grandeur tout à fait réaliste.

La superficie cultivable de 816 ha (Jansen et Diarra, 1990) se partage entre la jachère (27%) et les cultures (73%) exclusion faite des 152 ha de coton extensif sur le non cultivable; autrement dit, la jachère durerait en moyenne moins longtemps que la rotation culturale (système proche de la culture permanente).

Dans le modèle, la superficie cultivée est semée à 48% de céréale et à 52% de coton, soit respectivement 0,32 ha et 0,35 ha par habitant. Les résultats du suivi-évaluation permanent effectué par la DRSPR (1989) pour ce village font état de 49% des surfaces cultivées en coton contre 50% pour les céréales (échantillon de 21 exploitations).

Les prix appliqués dans le modèle pour les productions céréalières sont très proches des prix de vente en période de récolte. Cela justifie très probablement le fait qu'il n'y ait pas eu d'excédent commercialisable, la production étant équivalente à la quantité de céréales autofournie.

Il ressort d'une analyse de la sensibilité du modèle aux variations du prix de vente des céréales que le prix de vente du sorgho doit atteindre 75 FCFA par kg au lieu de 45 FCFA dans le modèle avant qu'il n'y ait des excédents commercialisables. Ces résultats semblent assez proches de la réalité au niveau du village ou d'un groupe de villages où les contraintes de liquidité sont assez rares en raison du revenu coton. La plupart des ventes de céréales s'effectuent en début de campagne agricole lorsque les prix sont assez intéressants. Cette situation a débouché sur la naissance d'un groupe de “gros paysans” qui font des transactions hors marché avec des commerçants grossistes de la ville de Sikasso.

Les habitudes alimentaires au niveau du village étant dominées par le sorgho/mil, on a imposé au maïs une limite d'autoconsommation de l'ordre de 10% des besoins de consommation. Celle-ci s'est traduite dans le modèle par une prédominance de la culture du sorgho, laquelle occupe près de 98% des surfaces cultivées en céréales.

Le coton est cultivé en partie selon les normes vulgarisées (COT II), la possibilité de mettre en culture les zones dites non cultivables (versant amont) de qualité médiocre. Seule une productivité faible avec utilisation de fumure organique a permis de desserrer la contrainte de terre avec la mise en valeur de 37% des surfaces soumises à la culture extensive du coton (COT I).

Pour l'élevage, le modèle donne le chiffre de 759 UBT pour le troupeau contre la valeur de 800 UBT enregistrée par Leloup et Traoré (1989) dont 228 bovins de trait (231 bovins de trait selon la base de données CMDT).

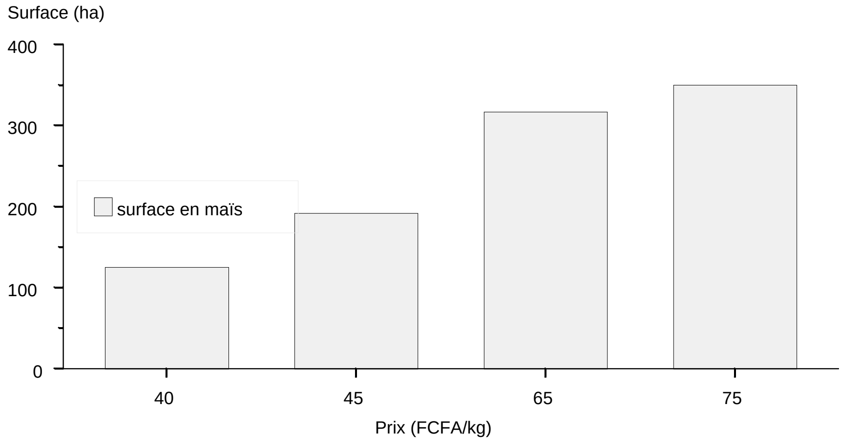
L'effet de *Stylosanthes*

L'introduction de *Stylosanthes* modifie profondément le système. Cela était prévisible puisque *Stylosanthes* intervient sur la contrainte fourragère de la période de mars à juin. La solution obtenue montre comment les paysans pourraient accroître leurs revenus de 21% en substituant 99 ha de *Stylosanthes* et 120 ha de maïs à de la jachère. Ils disposent ainsi de plus d'animaux (1 029 UBT contre 759) donc de plus de fumier, ce qui leur permet de mettre en valeur 60 ha supplémentaires de coton extensif. De plus, les revenus supplémentaires procurés par l'élevage (vente de viande) permettent de générer des ressources financières pour l'achat d'intrants nécessaires à la culture de maïs.

Une analyse de sensibilité du modèle aux variations de prix des céréales dans un modèle avec *Stylosanthes* montre qu'une faible variation du prix du maïs de l'ordre de 5 FCFA suffit pour que la solution change (apparition dans la solution de la forme associative du maïs). En revanche, il faudrait augmenter le prix du maïs d'environ 25 FCFA dans le modèle sans *Stylosanthes* pour qu'il devienne intéressant d'un point de vue économique. Cela s'explique par le fait que *Stylosanthes,* en se substituant partiellement à la jachère, permet de remédier à la contrainte de l'affouragement et de dégager des surfaces jusque-là occupées par le maïs (figure 2).

Une hypothèse alternative permet de mieux comprendre les difficultés rencontrées pour intégrer *Stylosanthes* dans le système à jachère courte, bien qu'il s'agisse d'une culture très productive et peu contraignante pour le calendrier agricole.

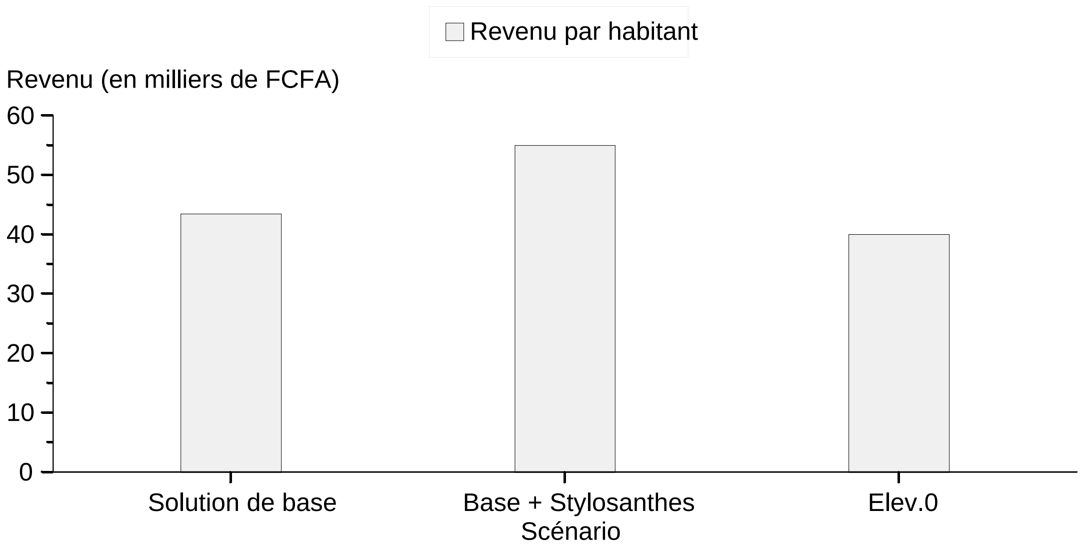
Figure 2. *Evolution des surfaces en maïs en fonction du prix*



La non-valorisation monétaire de l'activité élevage se limiterait à la production de fumure organique (fumier) et à la fourniture d'animaux de trait avec maintien des prix de productions végétales (céréales notamment).

Les résultats du modèle permettent de comprendre le comportement actuel des agro-éleveurs. En termes de revenus monétaires, les résultats d'une telle alternative sont du même ordre que ce qu'on peut observer actuellement avec un revenu d'environ 40 000 FCFA par habitant (figure 3). Le système ne fait plus que du coton avec les doses vulgarisées, du sorgho et du maïs intensif (avec fertilisation organo-minérale) en faible proportion. L'activité vache laitière fait son apparition en remplacement de la production de viande avec des résultats économiques inférieurs.

Figure 3. *Evolution du revenu par habitant*



Cependant, il importe de noter que le modèle est très sensible à l'augmentation du prix des céréales (maïs notamment). Il suffit en effet d'une augmentation du prix de vente du maïs de l'ordre de 2 FCFA par kg pour que la situation change avec un accroissement des surfaces en maïs intensif et une substitution partielle du coton dit extensif au coton vulgarisé.

Conclusion

De par sa forte productivité en fourrage, *Stylosanthes* est certes une alternative technique et peut-être économique pour les systèmes pratiqués par les agro-éleveurs. De meilleure qualité par rapport aux résidus de récolte (céréaliers notamment) et à la production des parcours naturels, ce fourrage permet de résoudre le problème d'affouragement à une période assez contraignante de l'année. De plus, des effets positifs sur la fertilité du sol et contre l'érosion hydrique semblent en partie confirmés même si le faible nombre de répétitions impose une certaine prudence.

Simple dans sa forme, ce modèle est de ce fait réducteur. C'est du reste le facteur commun de tous les modèles dont le principal objectif est de représenter la réalité ou du moins ce que l'on peut en appréhender. L'avantage reste qu'on dispose d'un outil certes imparfait mais permettant d'évaluer à priori la pertinence des alternatives techniques proposées.

De fait, l'intérêt de *Stylosanthes* dans le système agraire a été clairement perçu. Cependant, le paramétrage de certains coefficients de la fonction objectif (prix des produits notamment) révèle que cette influence est en partie fonction de la pression démographique et de l'existence de débouchés plus sûrs aussi bien pour les productions animales que pour les productions végétales consommatrices des produits de l'élevage (maïs notamment).

Ces résultats restent à confirmer au niveau d'autres sites surtout dans des situations où la pression démographique n'est pas aussi élevée (adaptation du modèle au zonage agro-écologique). De plus, la prise en compte du risque permettra de mieux formaliser le comportement économique des agro-éleveurs dans un système fortement tributaire des aléas climatiques et d'un environnement économique incertain.

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Arrière-effet de deux années de culture de légumineuses fourragères tropicales sur une culture de maïs

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Résumé

Cette étude a été effectuée à Bouaké et à Korhogo (Côte d'Ivoire) pour évaluer l'effet résiduel de précédents culturaux avec ou sans fertilisation (P et K) sur la croissance et le rendement en grains secs du maïs. De juin 1982 à novembre 1983, des parcelles de *Stylosanthes hamata* et *S. guianensis* cv. Cook fertilisées ou non avec P et K ont été soumises à trois coupes agrostologiques suivies d'exportation de la biomasse. Elles ont reçu une culture de maïs entre novembre 1983 et mai 1984 après enfouissement de la biomasse produite.

La hauteur moyenne des plants de maïs après les cultures fourragères non fertilisées était de 100 cm et de 48 cm pour *S. hamata* respectivement à Bouaké et à Korhogo. Pour *S. guianensis*, les chiffres correspondants étaient de 97 cm et de 65 cm respectivement à Bouaké et à Korhogo.

Sur parcelles fertilisées, la hauteur du maïs était de 128 cm et 71 cm pour *S. hamata* contre 123 cm et 67 cm pour *S. guianensis* respectivement à Bouaké et à Korhogo.

Les précédents culturaux fertilisés avaient une influence positive sur le développement végétatif et le rendement en grains secs du maïs sur les deux sites, les meilleurs résultats ayant cependant été obtenus à Bouaké.

Residual effect of two years of tropical forage legume crops on a subsequent maize crop

Abstract

This study was carried out in Bouaké and Korhogo, Côte d'Ivoire, to assess the residual effect of fertilised nitrogen (N) and phosphorus (P) and unfertilised forage legume crops on the growth and dry grain yield of a subsequent maize crop. From June 1982 to November 1983, Stylosanthes hamata *and* S. guinaensis *cv Cook plots either fertilised or not with N and P were cut three times and biomass removed. Between November 1983 and May 1984, maize was sown on these plots after the biomass was buried.*

On unfertilised plots, the average height of maize plants was 100 and 48 cm high in Bouaké and Korhogo, respectively, following S. hamata *as against 97 and 65 cm, respectively, after* S. guinaensis.

On fertilised plots, maize was 128 and 71 cm high in Bouaké and Korhogo, respectively, following S. hamata *compared with 123 and 67 cm, respectively, after* S. guianensis.

Fertilisation had a positive effect on vegetative development and dry grain yield of a subsequent maize crop at both sites, with the best results recorded in Bouaké.

Introduction

Le maintien de la fertilité des sols en milieu tropical dans les conditions diverses d'exploitation est un des problèmes fondamentaux et permanents de la recherche agronomique (Roberge et Raffin, 1974). Cette situation concerne particulièrement l'azote, premier facteur limitant de la production agricole en zone tropicale subhumide (Gervy, 1985). L'apport d'azote sous forme d'engrais minéral est onéreux, ce qui limite son utilisation en Afrique (IFDC, 1980; Gervy, 1985). L'alternative la plus économique consiste donc à exploiter la capacité des légumineuses fourragères de fixer des quantités cibles d'azote atmosphérique pouvant être transférées au sol et utilisées par d'autres cultures (Haque et Jutzi, 1984).

Dans le cadre de l'intégration agriculture–élevage, après deux années de culture de légumineuses fourragères fertilisées ou non (*Stylosanthes hamata* et *Stylosanthes guianensis* cv. Cook) en 1982 et 1983, il a été réalisé des précédents culturaux (variété de légumineuses et niveau de fumure) sur la croissance végétative et le rendement grain sec du maïs CJB non fertilisé.

Matériels et méthodes

Les essais ont été menés en Côte d'Ivoire, plus précisément en zone nord (Korhogo) à l'antenne de Karakoro et en zone centre (Bouaké) à la station du Centre de recherches zootechniques (CRZ).

Des analyses de sols ont été effectuées systématiquement avant l'installation des cultures de *Stylosanthes*. Les résultats enregistrés sont présentés en annexe.

Ces sols, avec un pH supérieur à 6, étaient de texture sableuse pour les deux sites, avec une forte proportion de gravillons à Korhogo (51%) et pauvres en phosphore (P résines < 5%). Le complexe adsorbant était moyennement saturé dans un cas comme dans l'autre, variant de 38 à 53,8%. La teneur en matière organique était satisfaisante aussi bien à Korhogo (1,13%) qu'à Bouaké (1,55%).

Précédents culturaux

Deux espèces de légumineuses fourragères tropicales (*Stylosanthes* cv. Verano et Cook) ont été cultivées en 1982 avec ou sans apport de P et K et soumises à trois coupes au cours de la période de 18 mois allant de juin 1982 à novembre 1983.

Réalisation de l'essai

Le composite jaune de Bouaké (CJB), variété de maïs utilisée, a un cycle semis–récolte de 100 à 105 jours. Les semences proviennent du département Elevage de l'IDESSA (Institut des savanes). Un dispositif en blocs avec 4 répétitions a été utilisé. Au nombre de 32 (2 précédents culturaux x 4 traitements fertilisations x 4 répétitions), les parcelles de l'essai avaient été disposées en randomisation totale. Chacune avait une superficie de 30 m^2 (6 m x 5 m) avec 7 lignes de semis à écartement de 80 cm. L'intervalle entre les plants sur la ligne était de 25 cm, soit une densité de semis de 50 000 plants/ha. Les parcelles étaient séparées par des allées de 2 m.

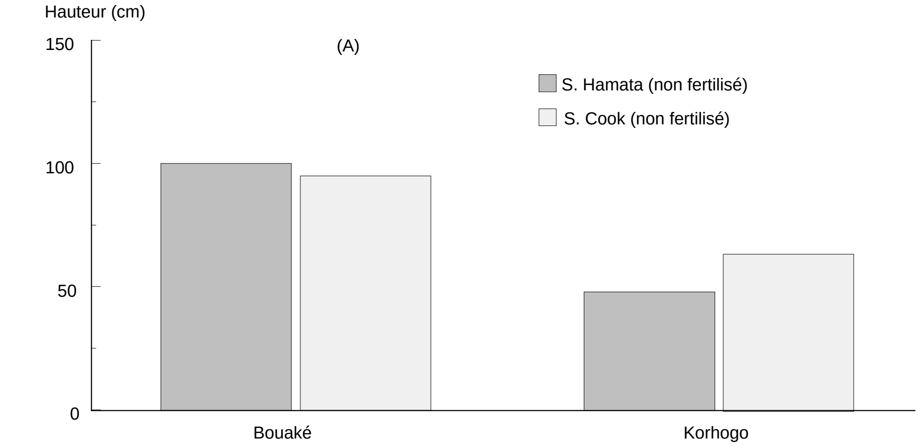
Deux observations agronomiques ont été réalisées uniquement sur les lignes centrales (5 au total), en excluant les deux lignes de bordure. Dès l'apparition de la floraison mâle, la hauteur de végétation de 5 plants par parcelle soit 20 plants au total pour chaque traitement avait été mesurée. La récolte des épis secs a été effectuée en octobre 1984. Ils avaient été séchés à nouveau puis égrenés et le poids sec en grain pour chaque traitement (précédent cultural et type de fumure) a été déterminé.

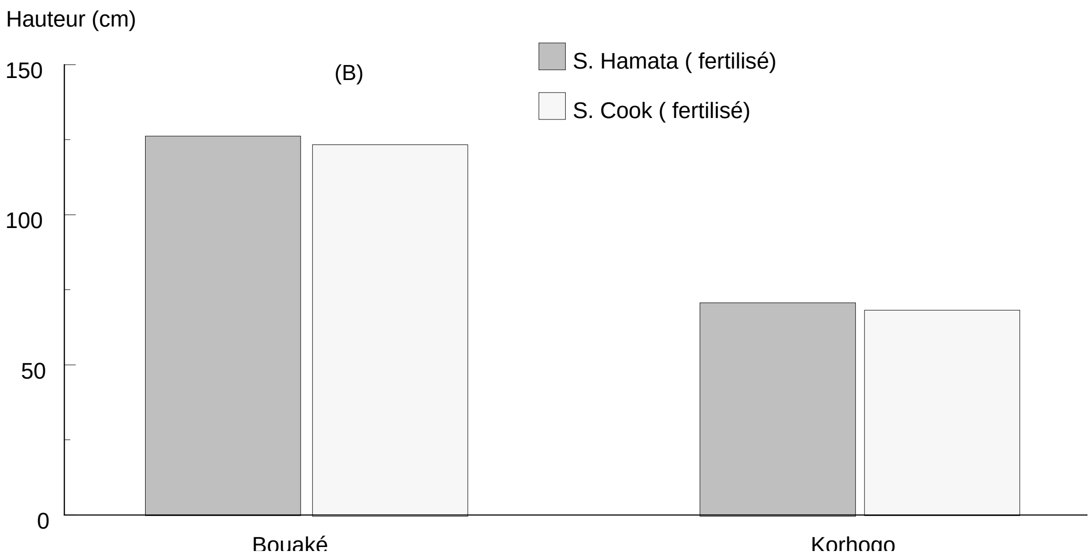
Résultats

Croissance du maïs

Les résultats obtenus sont présentés à la figure 1 pour les précédents culturaux non fertilisés et fertilisés.

Figure 1. *Hauteur du maïs à la floraison mâle, après des légumineuses non fertilisées (A) et fertilisées (B)*





Sur parcelles non fertilisées la hauteur moyenne du maïs après *S. hamata* était plus élevée à Bouaké qu'à Korhogo. La même situation a été observée avec *S. cook* dans les deux localités, avec la différence que cette légumineuse semblait induire une croissance relativement plus importante que *S. hamata* à Korhogo.

Sur parcelles fertilisées quel que soit le site, les deux légumineuses induisaient chez le maïs une croissance en hauteur plus importante tant à Korhogo qu'à Bouaké. La meilleure croissance avait cependant été observée sur ce dernier site après les deux précédents culturaux.

Pour un site donné et quel que soit le niveau de fertilisation, la croissance du maïs était indépendante des précédents culturaux.

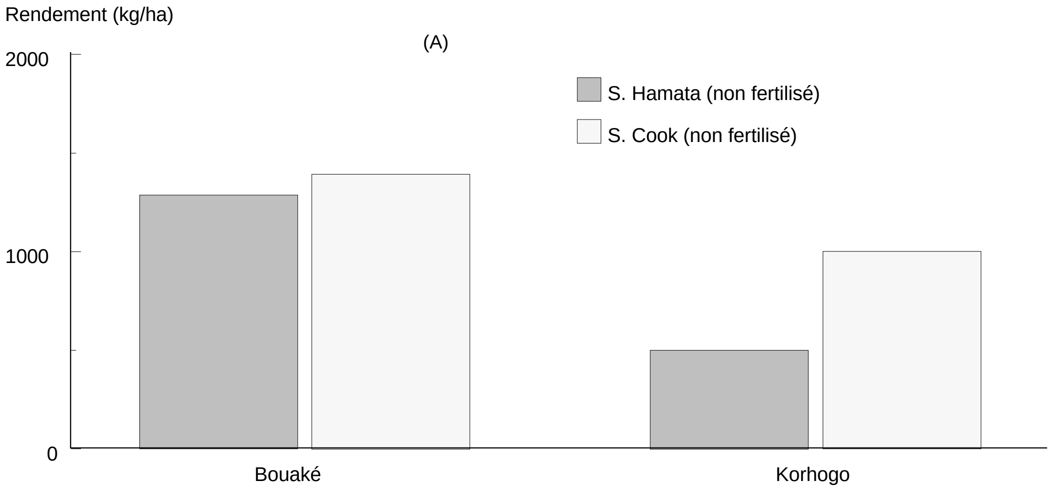
Rendement en grain sec du maïs

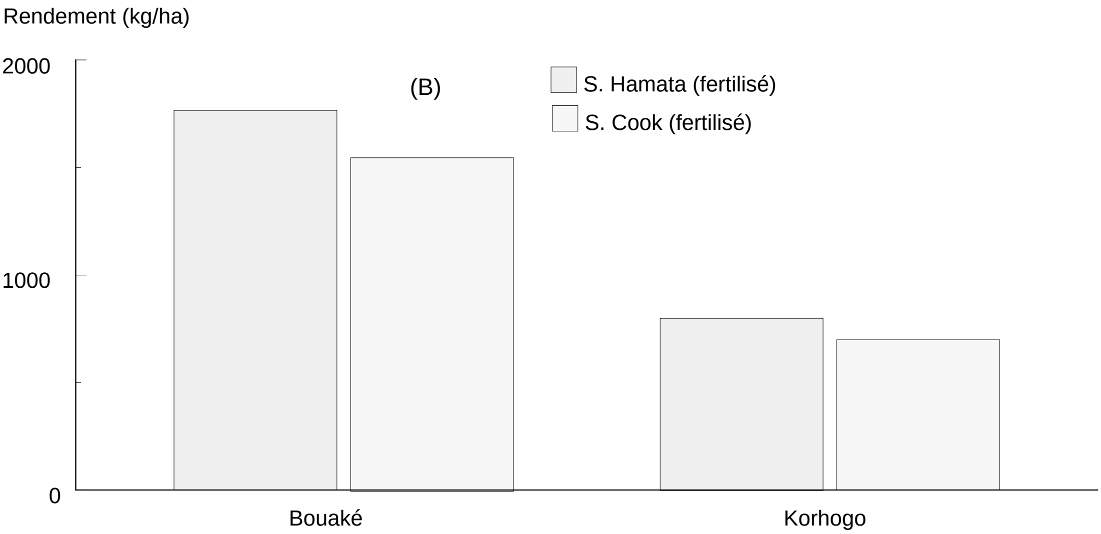
La figure 2 présente les rendements de maïs enregistrés respectivement après les précédents culturaux avec et sans fertilisation.

Sur parcelles non fertilisées, le rendement moyen de maïs après *S. hamata* était plus élevé à Bouaké qu'à Korhogo. Les rendements induits aussi bien à Bouaké qu'à Korhogo semblaient relativement plus importants avec *S. cook* qu'avec *S. hamata*, une situation semble-t-il plus marquée sur ce dernier site.

Sur parcelles fertilisées, les rendements obtenus étaient plus élevés que ceux enregistrés après les précédents culturaux non fertilisés. On note une relative supériorité des rendements après *S. hamata* par rapport à *S. cook* aussi bien à Bouaké qu'à Korhogo. Les rendements moyens étaient plus élevés à Bouaké qu'à Korhogo.

Figure 2. *Rendement en grains secs de maïs, après des légumineuses non fertilisées (A) et fertilisées (B)*





Discussion et conclusion

A Korhogo, les résultats enregistrés étaient médiocres tant sur le plan de la croissance en hauteur que du rendement en grains du maïs. Il convient de signaler que sur ce site, la saison sèche a été particulièrement longue au cours de la première année d'essai, avec un déficit hydrique relativement important (Messager, 1983). Un manque ou un excès d'eau peuvent avoir des effets néfastes sur la nodulation et la fixation d'azote des légumineuses fourragères (Gibson, 1977; Gibson *et al*., 1982).

A Bouaké, les résultats étaient bien meilleurs, notamment pour les précédents culturaux fertilisés. Cette constatation confirme les résultats obtenus par Messager (1983) sur la réponse des légumineuses fourragères tropicales aux fertilisants (P et K).

Malgré l'augmentation sensible des rendements de maïs après des précédents culturaux fertilisés, les chiffres obtenus n'atteignent pas les valeurs de 2 500 à 3 000 kg/ha obtenues en culture paysanne (Marchand et Hainzelin, 1982). Les résultats enregistrés à Korhogo comme à Bouaké sont cependant loin de ceux rapportés à Tombokro (Messager et Haas, 1977) et au nord du Nigéria (Haque et Jutzi, 1984) sur l'effet résiduel des légumineuses fourragères fertilisées. Cette situation pourrait s'expliquer par l'exploitation (3 au total) des précédents culturaux. Talineau *et al*. (1976) ont observé qu'en l'absence d'un apport d'engrais, un rythme rapide d'exploitation des légumineuses entraînait une baisse du rendement du maïs. Messager et Haas (1977) estiment que l'azote fixé par les légumineuses fourragères est restitué au sol dans des proportions plus ou moins importantes selon leur mode d'exploitation. Cet azote reste dans le sol à concurrence de la moitié ou des deux tiers lorsque les légumineuses sont pâturées sur place. Roberge et Raffin (1974) indiquent que toute culture fourragère fauchée et exportée doit être considérée comme une culture à part entière et non comme une période de repos (jachère) du sol; elle est épuisante en fonction de l'intensité des prélèvements en éléments minéraux.

Les résultats de cette étude ne permettent de tirer aucune conclusion définitive quant à l'effet résiduel des légumineuses fertilisées sur une culture de maïs. Néanmoins, ils permettent de mieux orienter les recherches futures dans ce domaine car d'une part, l'importance de la fertilisation des précédents culturaux (légumineuses) est démontrée et d'autre part, l'intérêt de la sole fourragère dans le cadre de l'intensification de l'agriculture en vue d'un meilleur rendement des productions végétales et animales semble indéniable.

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Annexe

Résultats de l'analyse des sols en 1982

	Facteur	Korhogo	Bouaké
pH	pH eau	6,1	6,4
Granulométrie	Argile %	5,63	8,25
	Limon %	5,38	6,60
	Sable très fin %	4,28	5,63
	Sable grossier %	51,19	41,82
	Humidité à 105 %	1,94	1,77
Matière organique	Matière organique %	1,13	1,55
	Carbone %	0,66	0,90
	Azote total %	0,40	0,59
	Rapport C/N	16,50	15,20
Phosphore	Total ppm	240	160
	P	10	7
	P résine ppm	3,7	4,1
Complexe absorbant	Ca me pour 100 g	0,94	1,50
	Mg me pour 100 g	0,68	1,05
	K me pour 100 g	0,10	0,18
	Na me pour 100 g	0,02	0,01
	S des bases S me/100 g	1,74	2,74
	Capac. d'échange T me/100 g	4,40	7,20
	Saturation V = 100 S/T	39,55	38,06

Tests d'introduction des soles fourragères dans les exploitations agricoles du Sud-Mali

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Résumé

Le principal obstacle au développement de la production agricole dans le Sud-Mali est la baisse de la fertilité des sols. C'est pourquoi, dans l'objectif d'améliorer la jachère, des essais ont été effectués pour tester des soles fourragères pluriannuelles. Entre 1988 et 1992, une expérience split-plot a été effectuée pour tester trois facteurs, à savoir la clôture, le phosphate naturel de Tilemsi (PNT) et diverses espèces fourragères.

Il ressort des résultats enregistrés que *Stylosanthes hamata* en culture pure était supérieur aux autres espèces testées et à leurs associations et ce, en raison de son meilleur recouvrement aussi bien à l'intérieur qu'à l'extérieur de la clôture. L'apport de 600 kg de PNT avait un effet favorable sur la production de fourrage et sa teneur en phosphate.

Après trois ans, l'amélioration de la fertilité du sol se manifestait surtout par un meilleur rapport C/N, un niveau plus élevé d'azote et de phosphate et une productivité supérieure après la mise en culture.

Cependant, compte tenu du climat, des conditions économiques et de l'attitude des populations de la région, les chances d'adoption des jachères améliorées sont plutôt restreintes.

Trials on the introduction of fodder plots on agricultural farms in Southern Mali

Abstract

The main constraint to increased agricultural production in southern Mali is decreasing soil fertility. This led to trials to assess long-term fodder plots designed to improve fallows. Between 1988 and 1992, a split-plot design experiment was carried out to study the effect of three factors, namely fence, Tilemsi natural phosphate (PNT) and various fodder species.

The results show that when grown alone, Stylosanthes hamata *outperformed other species or their combinations, due to better cover both inside and outside the fence. Applying 600 kg of PNT/ha had a positive effect on fodder production and phosphate content.*

Three years after establishment, soil fertility improved as evidenced by better C:N ratios, higher nitrogen and phosphate levels and increased yields of subsequent crops. However, given the climatic and economic conditions in the region and people's attitude towards fodder plots, prospects for adoption of this innovation are rather bleak.

Introduction

La Division de recherches sur les systèmes de production rurale à Sikasso (DRSPR/ Sikasso) travaille dans le Sud-Mali depuis 1977 avec une équipe pluridisciplinaire. Sa zone d'intervention couvre aujourd'hui trois zones agro-écologiques identifiées sur la base de la pluviométrie, de la date des semis et de la durée de la saison agricole (PIRT, 1986). La population, sans cesse croissante, est essentiellement composée d'agriculteurs purs d'origine, ce qui entraîne une lourde pression sur la terre.

L'introduction de la culture de rente et le souci de rentabiliser le matériel agricole ont provoqué d'une part des problèmes d'autosuffisance alimentaire et d'autre part une extension des superficies cultivées (Berckmoes *et al.*, 1990). Les apports d'engrais, toujours insuffisants, sont constitués de fumier organique et de fumure minérale. Le système d'exploitation se résume en une succession de cultures avec des temps de jachères de plus en plus courts, ce qui a entraîné une baisse progressive de la fertilité.

La conduite du troupeau est traditionnellement caractérisée par une longue période de divagation de décembre à juin. Pendant la saison sèche, l'herbe est de qualité médiocre lorsqu'elle n'est pas tout simplement inexistante, d'où une faible productivité du secteur de l'élevage.

Tout cela a conduit à une détérioration des ressources naturelles, favorisant l'érosion hydrique et éolienne dans un milieu où les feux de brousse sont courants dès la fin des récoltes. Face à ces problèmes, la DRSPR a lancé avec des agriculteurs des tests de soles fourragères pluriannuelles. Ces essais visent un triple objectif, à savoir améliorer la fertilité des sols, produire du fourrage de qualité afin de réduire la dépendance des paysans vis-à-vis des aliments de l'extérieur et couvrir les sols afin de les protéger contre les eaux de pluie, le soleil et le ruissellement.

Un programme de prévulgarisation est déjà en cours d'exécution avec la Compagnie malienne de développement des textiles (CMDT).

Méthodologie

Des parcelles de 1 ha à mettre en jachère ont été identifiées chez trois paysans par zone agro-écologique en 1988. Un schéma expérimental split-plot a été mis en place afin de déterminer l'influence de trois facteurs, à savoir la clôture, le phosphate naturel de Tilemsi (PNT) et l'espèce fourragère. Le PNT était appliqué à trois niveaux: 0 kg, 300 kg et 600 kg. Dans chaque zone, *Stylosanthes hamata* était semé en culture pure et comparé avec la jachère naturelle (témoin). A Tominian (700 mm de pluies/an) en zone semi-aride, il y avait en plus l'association de *Stylosanthes* et de *Cenchrus ciliaris* d'une part et de l'autre celle de *Macroptilium atropurpureum* et de *Clitoria ternatea*. A Koutiala (900 mm de pluies/an) en zone humide, la première association a été remplacée par celle de *Stylosanthes* et de *Panicum maximum*. A Fonsébougou (1 100 mm de pluies/an) en zone très humide, en dehors du témoin, la culte pure de *Stylosanthes* a été comparée à son association avec *Brachiaria ruziziensis* et avec *Panicum maximum*.

Des prélèvements d'échantillons de sol ont été effectués en début de test et sur les différents traitements en fin de cycle. En outre, les résultats des analyses de sol ont été comparés aux observations effectuées sur chaque traitement auprès des paysans. Le recouvrement du sol et la contribution spécifique des espèces ont été déterminés deux fois par an par la méthode des points quadrants alignés (100 points le long de deux lignes de 20 m). La production de fourrage a été estimée par le jet de placeau (1 m^2) deux fois par an. Les teneurs en azote et en phosphore ont été déterminées par traitement et par zone (cinq fois pendant les trois années d'observation). Après trois années, les soles ont été labourées en début de campagne et semées avec *Sorghum bicolor* afin de déterminer les conséquences agronomiques des tests effectués.

Résultats

Recouvrement du sol

Le recouvrement du sol par les espèces indique une protection efficace contre les eaux de pluie, le soleil et le vent et une bonne production de biomasse. Il donne une indication sur la résistance des espèces au pâturage. Les résultats indiquent que *Stylosanthes* pur donne partout la meilleure couverture et se maintient mieux par rapport aux associations et à la combinaison *Macroptilium atropurpureum – Clitoria ternatea*. En zone humide, son recouvrement approche 100% et il se maintient assez bien hors de la clôture. En zone semi-aride le recouvrement est moins élevé et *Stylosanthes* a du mal à se maintenir hors de la clôture. Aucun effet du PNT n'a été clairement observé sur le recouvrement dans aucune des trois zones d'observation.

Production de fourrage

En zone semi-aride en 1988, et dans les trois zones pour les deux dates d'observation de 1989, une différence significative a été enregistrée entre les espèces pour la production de fourrage. D'une manière générale, la production des parcelles semées en *Cenchrus ciliaris* était relativement faible en 1988, tandis que celles des parcelles semées en *Brachiaria ruziziensis* et des témoins étaient relativement élevées (tableau 1). Au cours de la première année, l'apport de 600 kg de PNT se traduisait par un accroissement significatif de la production de fourrage dans les zones humide et très humide (tableau 2).

Tableau 1. *Production de fourrage (MS/ha) des diverses espèces fourragères dans les différentes zones agro-écologiques en 1988*

	Zone semi-aride	Zone humide	Zone très humide
Témoin	1,79c	3,29b	5,75b
Stylosanthes	1,27b	2,92b	4,34a
Cenchrus + *Stylosanthes*	0,53a	0,88a	–
Brachiaria + *Stylosanthes*	–	3,61b	7,12c
Panicum + *Stylosanthes*	–	–	4,87ab

Dans une même colonne, les chiffres suivis de la même lettre ne sont pas significativement différents au seuil de 10%.

Tableau 2. *Effet du PNT sur la production de fourrage en zones humide et très humide*

PNT	Zone humide	Zone très humide
0	2,14a	4,47a
300	2,31ab	5,34a
600	3,58b	6,75b

Dans une même colonne, les chiffres suivis de la même lettre ne sont pas significativement différents au seuil de 10%.

Les parcelles clôturées étaient plus productives que celles non clôturées. En réalité, la production de ces dernières était plus élevée que celles présentées au tableau 3, dans la mesure où il est impossible de quantifier la consommation totale des animaux. Les résultats enregistrés en zone très humide indiquent qu'après une période de surpâturage pendant la saison sèche, la productivité des soles fourragères pendant la saison pluvieuse suivante était inférieure à son niveau de l'hivernage précédent. Dans les zones humides, la productivité de *Stylosanthes* était généralement supérieure à celles des associations et du témoin.

Tableau 3. *Effet de la clôture sur la production de fourrage (t de MS/ha)*

	Zone semi-aride		Zone humide		Zone très humide	
	1988	1989	1988	1989	1988	1989
Témoin	0,87a	1,33a	2,30a	1,65a	5,51a	1,0a
Clôture	1,34b	4,01b	3,05a	5,49b	5,53a	8,62b

Au sein d'une même colonne, les chiffres suivis de la même lettre ne sont pas significativement différents au seuil de 10%.

Qualité du fourrage

En 1989, l'effet de la clôture sur la qualité du fourrage dans les zones humide et semi-aride était exactement opposé en ce qui concerne la teneur en phosphore. En zone semi-aride, la teneur en phosphore du fourrage était significativement plus élevée à l'intérieur qu'à l'extérieur de la clôture, ce qui pourrait être dû à la contribution limitée des légumineuses au fourrage à l'extérieur. Ce schéma était inversé en zone humide. Cela est peut-être dû au fait que sous l'effet de la pâture, la végétation à l'extérieur de la clôture continuait pendant toute la saison à former de nouvelles feuilles riches en phosphore, tandis que dans la partie clôturée, elle était dominée par des feuilles moins fraîches et plus pauvres en phosphore.

L'effet du PNT n'était significatif qu'en zone très humide (tableau 4), ce qui pourrait s'expliquer par la faible teneur initiale en phosphore des sols de cette zone. La teneur en azote du fourrage dépendait de la zone considérée et était liée à la productivité (tableau 5).

Tableau 4. *Effets du PNT sur la teneur en P (%) du fourrage, zone très humide.*

PNT	Août 1989	Oct. 1989	Août 1990
0	0,076a	0,055a	0,093a
300	0,121b	0,094b	0,120a
600	0,168c	0,120b	0,170b

Au sein d'une même colonne, les chiffres suivis de la même lettre ne sont pas significativement différents au seuil de 10%.

Tableau 5. *Teneur en azote du fourrage par espèce fourragère en 1988*

	Zone semi-aride	Zone humide	Zone très humide
Témoin	1,39a	1,23b	0,96a
Cenchrus + *Stylosanthes*	1,17a	1,66ab	–
Stylosanthes	2,26b	2,086	–
Macroptilium + *Clitoria*	2,53b	–	–
Panicum + *Stylosanthes*	–	–	0,78a
Brachiaria + *Stylosanthes*	–	0,95a	0,95a

Dans une même colonne, les chiffres suivis de la même lettre ne sont pas significativement différents au seuil de 10%.

Fertilité du sol

Les jachères améliorent les variables physico-chimiques du sol. D'une manière générale, les sols des trois zones étaient très acides, et à Koutiala la capacité d'échange cationique (CEC) ne s'améliorait pas, quoique son niveau soit médiocre. Le taux de phosphore assimilable augmentait nettement en zone très humide, alors qu'il était très faible au départ (normes FAO). Après trois années de jachère améliorée, le rapport C/N se situait entre 8 et 12 (le niveau souhaitable), ce qui est une nette amélioration en comparaison du rapport initial de 21 à 30. L'effet de la clôture sur les caractéristiques des sols n'a pas fait l'objet d'analyse statistique. Le pH-eau apparaît légèrement plus élevé dans les parcelles clôturées dans les zones semi-aride et humide (tableau 6).

Tableau 6. *Effet de la clôture sur quelques variables chimiques du sol*

	pH-eau	Carbone	Azote	Pa	Pt	CEC	Ca-éch.
Semi-aride	(5,51)	(0,47)	(0,021)	(8,9)	(69,5)	(2,46)	–
Témoin	5,8	0,28	0,039	11,6	124	4,0	2,31
Clôture	6,1	0,34	0,040	14,2	114	4,0	2,31
Humide	(5,05)	(0,41)	(0,016)	(11,2)	(50,6)	(2,3)	–
Témoin	5,4	0,27	0,031	13,1	114	2,4	1,33
Clôture	5,7	0,26	0,033	14,5	122	2,2	1,25
Très humide	(4,59)	(0,54)	(0,025)	(2,01)	(72,6)	(4)	–
Témoin	5,1	0,49	0,050	8,2	174	5,0	1,98
Clôture	5,1	0,92	0,057	8,0	142	4,6	1,76

( ) = Niveau initial.

Pa = P assimilable; Pt = P total.

L'effet du PNT sur le P assimilable et le P total en zone semi-aride et sur le P assimilable en zone humide était significatif. Une dose de 600 kg PNT/ha contient environ 79 kg de phosphore. En supposant que ce phosphore a été fixé dans le sol jusqu'à une profondeur de 30 cm, cela représente 19 ppm de P total. La différence en P total entre les parcelles avec et sans fumure était négligeable en zone très humide et égale à 13 ppm en zone semi-aride, et à 7 ppm en zone humide (tableau 7).

Tableau 7. *Effet du PNT sur la teneur en phosphore total (Pt) et assimilable (Pa) des sols*

	Zone semi-aride				Zone humide				Zone très humide			
	Taux initial	0	1	2	Taux initial	0	1	2	Taux initial	0	1	2
Pt	69,5	105	115	136	50,6	113	122	119	72,6	155	162	156
Pa	8,9	6,6	13,5	19,6	11,2	11,0	12,5	17,9	2,01	6,9	9,4	7,9

0, 1 et 2 sont les niveaux 0, 300 et 600 kg de PNT/ha.

Mise en culture

La réponse du sorgho, lors de la mise en culture, a été meilleure dans toutes les soles (sur tous les sites) par rapport aux jachères avoisinantes mises en culture par les paysans et ayant subi le même régime de fumure. L'analyse des résultats montre que seuls le site et la clôture ont un effet significatif positif (tableau 8). L'effet du PNT n'était significatif qu'en zone très humide. Les autres facteurs avaient des effets arithmétiquement différents mais attribuables à d'autres facteurs comme les pluies, l'état initial du sol, la résistance des espèces etc.

Tableau 8. *Effet de la clôture de la jachère améliorée sur la production de sorgho (kg/ha)*

	Zone semi-aride	Zone humide	Zone très humide
Témoin	688	769	401
Clôture	903	1096	603

Il ressort des résultats de l'évaluation effectuée avec les paysans que la sole fourragère permet de restaurer la fertilité des sols et de raccourcir la durée des jachères. Le grillage constitue incontestablement le meilleur moyen de protéger la sole contre la pâture par les animaux.

Discussion

Compte tenu du coût élevé du grillage, on a tenté, dans le cadre des actions de prévulgarisation, de le remplacer par la haie vive et des espèces protectrices, notamment *Bauhinia rufescens* et *Zizipus mauritiana*.

Le fourrage de qualité ne peut être obtenu qu'à une période où les paysans sont trop occupés, de sorte que la détermination d'une période optimale permettra de favoriser l'adoption des soles fourragères.

La prévulgarisation et la vulgarisation des soles fourragères de *Stylosanthes hamata* et d'*Aechynomene hystrix* sont en cours sur la base d'une fiche technique dans divers programmes de gestion du terroir et de gestion de l'élevage. La fertilité des sols est le paramètre majeur de la production agricole. Toutefois, des actions appropriées doivent être entreprises pour faciliter l'installation de clôtures métalliques et encourager les populations à lutter contre la divagation.

Conclusion

Lorsqu'elle est clôturée, la sole fourragère c'est-à-dire jachère améliorée, a une influence positive sur certaines variables physico-chimiques du sol et sur leur productivité après la mise en culture. La principale amélioration se situe au niveau du rapport C/N et de la teneur en phosphore. Un apport de 600 kg de phosphate naturel a un effet significatif, non seulement sur la production du fourrage et sa teneur en phosphore, mais également sur la productivité du sorgho lorsque la teneur initiale en P assimilable est faible.

Les paysans, qui accordent une grande importance à la production de fourrage, ont identifié diverses contraintes à l'adoption des soles fourragères, y compris l'acquisition des semences, l'application du PNT et la protection de la jachère.

Les haies vives ne peuvent permettre de séparer efficacement les parcelles individuelles que si l'on arrive à combattre efficacement la divagation. Les chances de réussite de la jachère améliorée en zone semi-aride sont restreintes. La recherche de solutions a amené la DRSPR à tester d'autres associations comme par exemple le pois d'angole (*Cajanus cajan)*, le niébé en lignes alternées avec les céréales et d'autres espèces (*Bauhinia rufescens* et *Ziziphus mauritiana*) dans ces zones.

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Introduction des soles fourragères de *Stylosanthes hamata* dans les exploitations agricoles du Sud-Mali

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Résumé

La Division de recherches sur les systèmes de production rurale (DRSPR/Sikasso) a commencé en 1989 au Sud-Mali la prévulgarisation de la sole fourragère/jachère améliorée avec utilisation de haies vives. Les objectifs de la sole sont la production de fourrage et la restauration de la fertilité des sols. Les paysans apprécient ce double objectif mais sont surtout motivés par la production de fourrage précédant la mise en culture. Etant donné que les excédents de céréales produits par suite de la jachère améliorée ne permettent pas de rentabiliser la sole, la vulgarisation devrait surtout viser à promouvoir l'utilisation optimale du fourrage produit.

L'adoption des soles fourragères est difficile pour les exploitations agricoles disposant de peu de main-d'oeuvre. La nécessité de protéger les soles contre les animaux en vue de favoriser l'accumulation de matière organique et la production des semences est un facteur limitant de sa vulgarisation. Les haies vives ne permettent pas de protéger efficacement les soles alors que la clôture en matériel durable n'est pas toujours facile à construire. La recherche de solutions possibles en matière d'exploitation optimale du fourrage et de protection se poursuit sur la base d'autres modes de conduite des animaux.

Introduction of *Stylosanthes hamata* fodder fallows agricultural farms in Southern Mali

Abstract

The Division de recherches sur les systèmes de production rurale (DRSPR/Sikasso) in Mali started a pre-extension programme on improved fodder fallows protected by live fences in southern Mali in 1989. The programme was designed to produce fodder and restore soil fertility. While appreciating these two objectives, farmers were primarily interested in fodder production preceding cropping. Since the surplus cereal produced as a result of the improved fallow does not guarantee the financial attractiveness of the system, extension schemes should focus on optimal use of the fodder produced.

Adoption of these fallows is difficult on farms with inadequate labour supply. The need to protect fallows against unregulated grazing in order to achieve organic matter accumulation and seed production is a limiting factor to adoption. While live fences are inappropriate for effective protection, durable material fences are not always easy to build. Research continues however, on alternative solutions to optimum fodder utilisation and fallow protection, based on alternative livestock management techniques.

Introduction

Le Sud-Mali est une des principales zones d'agriculture et d'élevage du Mali où la dégradation des sols est un problème de plus en plus alarmant. Des institutions de recherche et de vulgarisation collaborent dans cette zone en vue de mettre au point des systèmes de production plus durables et plus productifs.

Organisation

La Division de recherches sur les systèmes de production rurale à Sikasso (DRSPR/Sikasso) travaille dans la zone Sud-Mali depuis 1978/79 en collaboration avec le principal organisme de vulgarisation de la zone, à savoir la Compagnie malienne pour le développement des textiles (CMDT).

La démarche recherche système comprend quatre phases: le diagnostic, la planification, l'expérimentation et le transfert dont la prévulgarisation des résultats de recherche est une sous-étape (Joldersma *et al*., 1991). L'élaboration du programme de la DRSPR comprend entre autres une restitution des résultats auprès des paysans, des rencontres avec les organismes de développement et la recherche thématique, tout en tenant compte des orientations du plan national des ressources humaines et financières disponibles. La DRSPR/Sikasso travaille essentiellement avec les agriculteurs sédentaires et n'a développé aucun test en milieu pastoral semi-sédentaire.

Géographie

La zone d'intervention actuelle de la DRSPR comprend trois zones agro-écologiques (PIRT, 1986), identifiées sur la base de la pluviométrie, de la date de semis et de la durée de la saison agricole (mai à décembre). Il s'agit de la zone nord-soudanienne, semi-aride avec 500 à 900 mm de pluies, de la zone nord-guinéenne, humide avec 900 à 1 100 mm de pluies et de la zone guinéenne, très humide, avec plus de 1 100 mm. La saison sèche dure de cinq à neuf mois et comprend une partie froide et une autre plus chaude. La zone d'intervention a une superficie d'environ 48 000 km^2. La DRSPR entreprend des activités de recherche dans au moins trois villages représentatifs par zone agro-écologique ainsi que des actions de prévulgarisation dans plusieurs villages.

Hormis le caractère aléatoire de la pluviométrie, le problème clé de la zone d'intervention est la baisse de la fertilité des sols par suite du raccourcissement voire l'absence des périodes de jachère, des pratiques culturales non adéquates, d'une utilisation insuffisante et déséquilibrée des fertilisants et du fumier et de la réalisation, voire du dépassement, de la capacité de charge maximum des parcours.

Tout cela entraîne une détérioration des ressources naturelles, favorisant l'érosion hydrique et éolienne. A cela, il convient d'ajouter les feux de brousse fréquents et le débroussaillement. En raison de l'appauvrissement des pâturages, la quantité et la qualité des fourrages de saison sèche laissent beaucoup à désirer, d'où une productivité médiocre ou très faible du système d'élevage et du système de culture. Dans certaines zones, on signale un cycle biennal de reproduction bovine et des taux de reproduction annuelle proche de 40% (Bosma *et al*., 1992). En outre, l'élevage extensif ne peut permettre de satisfaire les besoins en fumure du sol dans un système continu de culture où plus de 20% des terres sont cultivées (Pieri, 1989).

Systèmes de production

Les systèmes de production dominants au Sud-Mali sont des systèmes familiaux à caractère agropastoral privilégiant l'agriculture. L'exploitation agricole moyenne compte 13 personnes et occupe une superficie d'environ 10 ha. Le système de culture comprend des cultures céréalières (mil, sorgho, maïs et fonio) généralement associées au niébé et à l'oseille (dah). Les principales cultures de rente par ordre d'importance sont le coton, le maïs, l'arachide, le dah-fibre et le sésame. Les rendements agricoles sont variables et ont tendance à diminuer, ce qui fait obstacle à l'objectif d'autosuffisance alimentaire et oblige à augmenter les superficies cultivées à l'aide de la traction animale. L'introduction de cette technologie n'a pas conduit à une intensification des systèmes de culture (Berckmoes *et al.*, 1990).

Traditionnellement, l'élevage n'était pas une activité importante dans cette région. Par la culture attelée et comme épargne de précaution, les bovins constituent actuellement un élément clé du système de production rurale (Bengaly *et al.*, 1992). En plus, les petits ruminants en particulier contribuent à la satisfaction des besoins pécuniaires, sociaux et religieux de la population. La conduite des ruminants est traditionnellement caractérisée par une longue période de divagation des animaux de décembre à juin. Après les récoltes, ils pâturent librement les résidus de récolte et les parcours naturels. Les petits ruminants passent la nuit habituellement au sein d'un enclos dans la cour de la ferme. Après l'installation des cultures, les animaux sont gardés pour éviter les dégâts dans les champs (Bagayogo *et al.*, 1992).

Pour cibler la recherche de solutions et les messages à vulgariser, on distingue en zone Mali-Sud quatre types d'exploitation agricole sur la base de l'équipement et du cheptel bovin. Le type A dispose de beaucoup de bovins et de main-d'oeuvre, tandis que le type B est souvent confronté à un problème de capital (bovins) et de main-d'oeuvre. Par ailleurs, le type C ne dispose que d'une partie de l'équipement nécessaire, tandis que les exploitations de type D sont généralement démunies. Dans la zone semi-aride on rencontre aussi la traction asine et équine.

Historique

Face aux contraintes du maintien de la productivité, la DRSPR a entamé des tests de soles fourragères pluriannuelles. Avant que les résultats de ces tests ne soient disponibles et vu l'importance qu'elle accorde à ce thème, la CMDT a démarré un programme d'introduction de soles de *Stylosanthes hamata* dans sa zone d'intervention. C'est ainsi que la prévulgarisation a démarré en 1989/90 dans quatre villages des régions CMDT de Sikasso et de Koutiala dans l'objectif d'améliorer la jachère et de produire du fourrage de qualité afin de diminuer la dépendance des paysans vis-à-vis des aliments venus de l'extérieur. Faute de semences de *Stylosanthes* en 1990/91, certaines soles ont été semées avec *Aeschynomene hystrix*, qui est également une légumineuse pérenne produite à la ferme semencière de la SODEPRA à Korhogo (Côte d'Ivoire).

Programme de prévulgarisation des soles fourragères

Objectifs

Le programme de prévulgarisation visait trois objectifs principaux, à savoir évaluer les résultats techniques de l'introduction de soles fourragères dans les conditions de gestion technique des paysans, déterminer le degré d'adoption des soles par les paysans et déterminer le fonctionnement des services d'appui (CMDT) pour le transfert du message et les conditions à remplir (approvisionnement en semences, etc.).

Justification

La sole fourragère pluriannuelle est une parcelle de légumineuses pérennes permettant de raccourcir la durée de la jachère grâce à l'amélioration de la fertilité du sol. Elle produit en même temps du fourrage de qualité et protège la parcelle contre l'érosion. Après trois années, cette sole aura atteint un niveau de fertilité suffisant pour être mise en culture (DRSPR, 1992a).

Compte tenu de la nécessité de protéger les soles fourragères et étant donné que le grillage est trop cher pour la plupart des paysans, on a dû recourir aux clôtures de haies vives. Les espèces utilisées sont *Euphorbia balsamifera* et *Jatropha curcas*, lesquelles avaient donné de bons résultats dans un précédent programme de lutte anti-érosive (DRSPR, 1986). Cinq champs ont été retenus par village et dans chacun d'entre eux, une parcelle de 10 m sur 10 a été clôturée avec du grillage à titre de démonstration. Comme fumure de fond, le phosphate naturel de Tilemsi a été épandu à la dose de 300 kg/ha et enfoui au moment du labour.

Méthodologie d'introduction

La méthodologie d'introduction des soles fourragères commence par une réunion de sensibilisation des paysans et le choix des paysans volontaires par le village. Puis une séance de démonstration de l'implantation des soles et des haies vives est organisée par les agents d'encadrement. Elle est suivie de visites inter-paysannes au sein des villages, puis de l'évaluation intermédiaire collective et individuelle avec des paysans impliqués, en collaboration avec l'équipe technique villageoise. Enfin, on procède à l'évaluation finale par la restitution et la discussion des résultats en assemblée villageoise avec les trois acteurs concernés (DRSPR, CMDT, paysans).

Quatre villages ont été choisis de commun accord par la CMDT et la DRSPR parmi les villages ayant déjà bénéficié d'un programme antérieur de prévulgarisation. Ce critère ne reflète pas clairement le degré de gravité des problèmes (fertilité, fourrage, érosion) auxquels les soles fourragères sont destinées à apporter des solutions.

Exécution

L'approvisionnement en semences a été pris en charge par la CMDT, étant donné que les semences sont difficiles à acquérir et chères au Mali. Elles ont été achetées en Côte d'Ivoire au prix de 4 000 FCFA/kg. Les boutures d'euphorbe et les semences de pourghère ont également été fournies gratuitement par le même organisme.

Un protocole définissant les tâches des différents partenaires dans la préparation, l'exécution et l'évaluation du programme de prévulgarisation a été élaboré. La DRSPR assurait la formation technique de l'encadrement CMDT, lequel était chargé du suivi quotidien. Par des visites ponctuelles sur le terrain, la DRSPR apportait son appui à diverses étapes du programme. Une fiche technique provisoire avait été élaborée à l'intention de l'encadrement CMDT afin de faciliter la mise en place et le suivi des activités.

Résultats

Après trois années de fonctionnement, le programme de prévulgarisation des soles fourragères a rassemblé 59 paysans et porté sur un total de 49 ha (tableau 1). Les soles ont surtout été réalisées au niveau des exploitations agricoles de type A (33) et B (19). Celles de type C (2) et D (5) sont localisées à Touroumadié.

Tableau 1. *Caractéristiques des soles fourragères de* Stylosanthes hamata *et d'*Aeschynomene hystrix *mises en place au Sud-Mali entre 1989 et 1991*

Village	Nombre total d'exploitations	Nombre d'exploitations suivies	Superficie réalisée (ha)	
			Totale	Moyenne/ exploitation
Kola	84	13	10,7	0,8
Karangana	120	17	12,7	0,7
Segain	58	11	15,5	1,4
Touroumadié	18	18	10,4	0,5
Total		59	49,3	

Pour ce qui concerne la période et les techniques d'installation des soles, les semis de juillet donnent des meilleurs résultats. On constate parfois que les paysans ont des difficultés à bien répartir les semences sur la parcelle. Ils avaient tendance à comparer la semence de *Stylosanthes* à celle du fonio à cause de la taille des graines, alors que les doses recommandées étaient très différentes, à savoir 6 kg/ha pour *Stylosanthes* contre 25 à 30 kg/ha pour le fonio. Pour permettre un semis homogène, on peut conseiller de faire un quadrillage de la surface et de répartir la semence entre les différents blocs avant le semis.

Lors de l'évaluation intermédiaire, avant la mise en culture, il a été demandé aux participants de choisir parmi les trois objectifs celui qu'ils jugeaient le plus important (tableau 2). L'importance accordée aux objectifs dépendait de la situation particulière du village. D'une manière générale l'importance de la restauration de la fertilité était bien perçue, sauf à Touroumadié où il existait encore des terres disponibles. A Ségain, des exploitants ont installé des soles sur des terres très pauvres et ont pu constater que les espèces utilisées poussaient là où d'autres espèces d'herbe ne pouvaient germer. La production de fourrage était généralement considérée comme un objectif important, sauf à Kola où les paysans semblaient beaucoup plus préoccupés par le problème de l'érosion. A Touroumadié, où il existe une plaine rizicole et davantage d'exploitations des types C et D, le problème de fourrage ne se pose pas avec la même acuité, mais le fait que les animaux apprécient beaucoup *Stylosanthes* peut expliquer l'importance accordée à sa production.

Tableau 2. *Opinions des participants à l'évaluation intermédiaire sur l'importance des objectifs des soles fourragères*

Village	Nombre de participants	Importance de l'objectif (%)		
		Fertilité	Lutte anti-érosive	Production de fourrage
Kola	23	30	56	14
Karangana	32	47	0	53
Ségain	44	45	5	50
Touroumadié	22	9	45	45

Dans la même année, une enquête a été menée auprès d'un échantillon d'exploitations agricoles non impliquées en vue d'évaluer leur intérêt pour ce programme et leur opinion sur l'efficacité de la démarche suivie. 24 des 27 exploitants interviewés ont déclaré avoir visité au moins une sole fourragère tandis que 26 souhaitaient en installer. Outre les objectifs mentionnés, les personnes interrogées étaient séduites par la délimitation des parcelles et la possibilité de vendre des semences de *Stylosanthes*. Le seul interviewé pour qui cette technologie ne présentait aucun intérêt se trouvait sur de nouvelles défriches.

Il ressort des résultats de l'évaluation intermédiaire que de nombreux paysans, participants ou non, aimeraient voir ce programme se poursuivre. La non-disponibilité des semences et boutures constituerait un obstacle majeur à franchir en la matière. Quelques-uns estiment que l'installation des soles est contraignante pour les exploitations possédant peu de personnes actives. La même raison a été évoquée pour expliquer le faible nombre de participants. La majorité des interviewés estiment que tous les types d'exploitation peuvent être intéressés, et plus particulièrement ceux qui possèdent des bovins.

La croissance végétative des plantes des soles fourragères a été assez bonne, mais jusqu'à la troisième année, les haies vives n'arrivaient toujours pas à les protéger efficacement. En quatrième année, après la mise en culture des premières soles (1992/93), certains paysans se disaient convaincus que cette technique permettait effectivement de restaurer la fertilité des sols. Il est vrai que les cultures installées sur ces soles présentaient un meilleur développement et un meilleur comportement végétatif que celles installées sur les parcelles témoins.

Vu l'intérêt des paysans pour ce programme, celui-ci se poursuit pendant que continue la recherche de solutions aux problèmes identifiés. Actuellement, la prévulgarisation concerne aussi 49 villages du programme pilote "Elevage et gestion de terroir" de la CMDT. Afin d'informer et d'associer davantage les vulgarisateurs, une nouvelle fiche technique (DRSPR, 1992b) a été élaborée. En ce qui concerne la production de semences par les paysans eux-mêmes, une fiche provisoire définissant les techniques de récolte des semences a été élaborée, ainsi qu'un module destiné à la formation des exploitants.

Discussion

Les objectifs prioritaires des soles fourragères sont l'amélioration et le maintien de la fertilité des sols et la production de fourrage de qualité. La situation actuelle permet-elle de réaliser tous ces objectifs? Sont-ils conciliables? L'introduction de soles est-elle une opération rentable?

Un développement abondant de la végétation favorise l'accumulation de matière racinaire, facteur déterminant pour la qualité de la jachère améliorée. Pour la réussite de la jachère, elle doit donc être protégée contre l'exploitation intensive par les animaux. Cette protection est imposée par le système actuel de conduite des animaux et l'attitude des paysans vis-à-vis des cultures fourragères. Celles-ci ne sont jusqu'ici pas considérées comme fermées aux animaux dans la mesure où elles ne sont pas encore reconnues par les paysans comme une culture à part entière du système. Qui plus est, tout fourrage sur pied après les récoltes de céréales est considéré comme pâturage à accès libre et, étant donné qu'une grande partie des animaux n'est pas surveillée, ils se livrent à la divagation.

La non-protection des soles pose également problème en ce qui concerne la production semencière. Les petites parcelles de 10 m sur 10 clôturées de grillage pourront servir à la multiplication des semences. Les paysans produiront ces semences beaucoup moins cher que les fermes semencières.

Le remplacement de la clôture en matériau durable par des haies vives sera un travail de très longue haleine, qui en plus sera rarement efficace dans la mesure où les ovins et caprins des zones humides sont de très petite taille et peuvent se faufiler aisément à travers des ouvertures à peine visibles. Pour l'instant, les haies vives serviront plutôt à délimiter les parcelles individuelles. La clôture en fil de fer constitue le plus important poste de dépense dans le budget d'exploitation de la sole (tableau 3), et seules les exploitations agricoles dotées d'un capital de réserve important (bovins) pourront se l'offrir. Si toutes pouvaient se convaincre de la nécessité de protéger les jachères améliorées, les pénalités pour divagation d'animaux pourraient être étendues à la saison sèche et l'accès aux soles pourrait être réglementé.

L'adoption d'une innovation par le paysan est surtout fonction de l'avantage qu'il peut en tirer à court terme. La sole bénéficiera à court terme aux exploitations agricoles à travers l'exploitation du fourrage pour l'alimentation des animaux, autrement dit l'amélioration de la force et l'endurance des animaux de trait au début de la campagne agricole, l'augmentation du taux de survie des reproductrices suitées et de leurs produits et la commercialisation du lait. En mettant l'accent sur ces aspects de la production animale, on pourra mieux rentabiliser l'utilisation du fourrage. Et cela d'autant plus que le surplus de production céréalière qu'engendre la jachère améliorée protégée équivaut à peine aux investissements en semences et engrais.

Tableau 3. *Budget d'exploitation (en FCFA) d'une sole fourragère dans la zone humide, avec clôture en barbelé et utilisation du fourrage après la coupe*

Dépenses	Montant
Clôture	60 720
Semences 12 kg	18 000
PNT 600 kg	18 000
Préparation du sol	10 000
Semis 1 j/h	600
Désherbage 2 j/h	1 200
Coupe, transport et stockage	40 000
Dépenses totales	**148 520**
Recettes	
Fourrage sur 3 ans: 11,2 t/ha (pertes 20%)	168 000
Production de céréales supplémentaires par rapport au 300 kg/ha = 600 kg/ha	36 000
Recettes totales	204 000
Bilan (dépenses-recettes)	**+ 55 480**

Pour l'évaluation économique, les prix suivants ont été retenus: foin de *Stylosanthes* (= prix aliment bétail): 15 FCFA/kg. Coupe, transport et stockage: 5 FCFA/kg. Céréales: 60 FCFA/kg. Clôture en fil de fer barbelé: 6x60 = 360 FCFA/m; coût poteaux en bois local et fixation (y compris tendeurs) = 100 FCFA/m; coût total 184 000 FCFA/ha, amortissement et perte de valeur sur 20 ans (11%): 20 240 FCFA/an. Coût total sur 3 ans: 60 720 FCFA/ha (clôture en grillage: 188 400 FCFA/ha).
Entretien clôture: 10 000 FCFA/an.

L'importance du fourrage produit pour l'adoption de l'innovation justifie l'utilisation de *Stylosanthes*, espèce qui garantit une certaine qualité fourragère. Son exploitation peut se faire sous forme de fauche ou de pâture comme par exemple dans les banques fourragères (CIPEA, 1989). Une pâture brève et intensive pendant la première saison des pluies réduira la vigueur des adventices en faveur de *Stylosanthes*. Le budget d'exploitation indique que la coupe donne un meilleur résultat que la pâture, mais le coût d'un dispositif efficace de stockage (grange) n'a pas encore été pris en compte. L'utilisation par fauche entraîne la perte des feuilles (partie la plus nutritive de la plante), encore qu'elles contribuent à restaurer la fertilité du sol. Le fourrage de meilleure qualité s'obtiendrait en août/septembre, mais cette période, qui coïncide avec les opérations de désherbage et de buttage de certaines cultures et la récolte du maïs et de l'arachide, est donc une période bien remplie dans le calendrier agricole des paysans. Aussi pendant cette période il continue de pleuvoir, ce qui affecterait la qualité du fourrage si les récoltes se faisaient sans que des dispositions de protection ne soient prises (grange). Les conditions d'exploitation optimale de ce fourrage méritent encore d'être étudiées.

Le bilan du budget d'exploitation n'est pas forcément positif pour toutes les zones agro-écologiques lorsque la protection des soles est assurée avec des matériaux durables (tableau 4). La DRSPR cherche actuellement d'autres alternatives (pois d'angole en lignes alternées avec quelques lignes de céréales) pour les zones semi-arides. La recherche de dispositifs de protection plus performants (espèces épineuses), économiquement supportables pour les paysans est également en cours en collaboration avec la recherche forestière. La recherche sur les systèmes exploitera les solutions paysannes au problème de la protection, à savoir l'installation de soles au sein des cultures.

Tableau 4. *Bilan d'exploitation (en FCFA) des soles fourragères dans les trois zones agro-écologiques du Sud-Mali pour trois ans de culture de* Stylosanthes, *suivis d'une année de culture de sorgho*

		TYPE DE GESTION			
		Coupe[b]		Pâture[c]	
Zone	Sans[a] clôture	Barbelé	Grillage	Barbelé	Grillage
Semi-aride	+ 56 200	–4 520	–132 200	+ 680	–127 000
Humide	+ 128 200	+ 67 480	–60 280	+ 45 680	–82 000
Très humide	+ 200 200	+ 139 480	+ 11 800	+ 90 680	–37 000

a Cas hypothétique, puisque dans les conditions actuelles, la production des soles diminuera fortement lorsqu'elles ne sont pas clôturées.

b En coupe on considère 20% de pertes.

c En pâture, le désherbage est remplacé par une pâture intensive pendant une journée. On suppose que les animaux n'exploitent que la moitié du fourrage total produit, ce qui mérite d'être vérifié notamment dans la mesure où *Stylosanthes* produit des repousses.

Conclusion

Bien qu'ils comprennent les avantages des soles fourragères avant la mise en culture, les paysans privilégient surtout l'aspect production de fourrage, dont l'importance est confirmée par le budget d'exploitation.

Les programmes de vulgarisation doivent viser en priorité à tirer le meilleur parti possible de *Stylosanthes* à travers les productions animales rémunératrices à court terme, sans pour autant négliger les autres avantages (restauration de la fertilité du sol et lutte contre l'érosion). Des travaux de recherche doivent être effectués sur la pâture et/ou la fauche pour déterminer lequel des deux est le mode d'exploitation le plus efficace du fourrage.

L'insertion des soles fourragères dans le calendrier agricole des paysans n'est pas encore bien maîtrisée. Elle est surtout difficile pour les exploitations agricoles possédant peu de main-d'oeuvre. Les autres contraintes à l'adoption de ces soles (l'utilisation trop intensive par les animaux et l'autoproduction de semences) sont liées à une protection efficace, impossible pour l'instant à assurer avec les haies vives. Les grandes exploitations agricoles pourraient supporter la clôture en matériau durable, mais dans la zone semi-aride, son installation n'est pas rentable. Les obstacles identifiés pourraient être aplanis lorsque les paysans comprendront mieux l'importance des soles fourragères/jachères améliorées et arriveront à lutter efficacement contre la divagation en saison sèche et à réglementer l'accès auxdites parcelles.

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Research approach and methodologies of the project “Production Soudano-Sahélienne”: Towards the optimal utilisation of plant nutrients by livestock

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Abstract

Current agricultural production systems in the Sudano-Sahelian region impose over-exploitation and consequently lead to degradation of natural resources and food shortages. Despite many efforts towards rural development, degradation of natural resources still occurs on a large scale and production does not cover needs of the population. The limited impact of rural development is mainly due to the lack of quantitative knowledge on the processes governing the stability of the soil–plant–animal production system. The main objective of the present project is to contribute to the development of sustainable production systems in the Sudano-Sahelian zone of sub-Saharan countries.

Results obtained between 1976 and 1980 by the PPS Project (Production Primaire au Sahel) and studies undertaken by the Center for Agrobiological Research in The Netherlands have shown that the major constraint on agriculture in the Sudano-Sahelian region is the lack of such nutrients as nitrogen and phosphorus. Thus livestock production is constrained not only by shortage of fodder but also by the poor quality of the forage available. To improve this situation two solutions are possible:

1. To increase productivity of crop residues.
2. To increase forage production on farm lands.

Intensification of production should be done through innovations oriented towards efficient use of nitrogen and phosphorus to ensure the stability of the agro-ecosystem.

Before application of nitrogen and phosphorus fertilizers can be recommended, the processes underlying N and P availability and exploitation within soil–plant–animal systems must be fully understood.

The present approach aims at providing a thorough understanding of plant production as a function of nutrient availability, soil organic matter and chemical and organic fertiliser use. Another objective is to evaluate the nutritive value of different forages by studying the effects of supplementary feeding on the performance of ruminants. Finally, system simulation is being used to determine the economic viability and sustainability of different agropastoral production systems.

Stratégies et méthodologies de recherche du projet Production soudano-sahélienne: vers une utilisation optimale des éléments nutritifs des plantes par les animaux d'élevage

Résumé

Les systèmes actuels de production agricole de la région soudano-sahélienne rendent inévitable la surexploitation des ressources et conduisent à la dégradation des ressources naturelles et aux pénuries alimentaires. En dépit des nombreux efforts de développement rural, les ressources naturelles sont encore régulièrement dégradées tandis que la production est insuffisante pour couvrir les besoins de la population. L'impact des actions de développement rural demeure limité en raison essentiellement d'une connaissance quantitative insuffisante des mécanismes régissant la stabilité du système de production sol-plante-animal. Le principal objectif de ce projet est de promouvoir des systèmes de production durables dans les pays de la zone soudano-sahélienne de l'Afrique subsaharienne.

Il ressort des résultats obtenus entre 1976 et 1980 par le projet Production primaire au Sahel (PPS) et le Centre de recherche agrobiologique aux Pays-Bas que la carence en éléments comme l'azote et le phosphore constitue le principal problème de l'agriculture dans la région soudano-sahélienne.

Par ailleurs, les pénuries d'aliments du bétail et la qualité médiocre des aliments disponibles constituent les principaux obstacles au développement de l'élevage dans cette région. Deux solutions sont possibles , à savoir:

1. *Augmenter la productivité des résidus de récoltes, et*
2. *Accroître la production fourragère des terres agricoles.*

La production devrait être intensifiée grâce à des innovations visant à promouvoir une utilisation plus efficace de l'azote et du phosphore en vue d'améliorer la stabilité de l'écosystème agricole.

L'application d'engrais azotés et phosphoreux ne peut être recommandée sans une bonne connaissance des mécanismes déterminant la quantité et le mode d'utilisation de l'azote et du phosphore assimilable disponible dans les systèmes sol–plante–animal.

La présente stratégie vise à permettre une connaissance approfondie du processus de production végétale en tant que fonction de la quantité d'éléments nutritifs disponibles, des caractéristiques de la matière organique du sol et de l'utilisation des engrais organiques. Un autre objectif consiste à déterminer la valeur nutritive des différents fourrages grâce à l'étude des effets de la complémentation alimentaire sur les performances des ruminants. Enfin, la simulation a été utilisée pour évaluer la rentabilité économique et la durabilité de différents systèmes de production agropastorale.

Section 6

Seed production of *Stylosanthes*

The production of seeds of *Stylosanthes* cultivars in Nigeria

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Abstract

Three *Stylosanthes* species, *S. guianensis* cvs Cook and Schofield, *S. hamata* cv Verano and *S. humilis*, are most adapted to a wide range of climatic conditions and soil types. Although a great deal of work was carried out on the agronomic characteristics, nutritive value and conservation of the species, investigations into their seed-yield potential commenced only as late as 1976. The guinea savannah or subhumid zone provides the best climatic and soil conditions for large-scale seed production in *Stylosanthes*. Currently, seed production of Verano stylo is the only one being encouraged in Nigeria because of the susceptibility of Cook, Schofield and Townsville stylos to the disease, anthracnose. Between 1980 and 1990, over 200 tonnes of Verano stylo seed were produced.

The agronomy of stylo seed production is described in this paper. Four harvesting methods have been identified which do not involve the use of combine harvesters and pneumatic harvesters. Seed cleaning is done manually, which is slow and expensive and quality control is non-existent so the seeds being marketed usually have many impurities.

The advantages of and constraints to stylo seed production are listed. To improve stylo seed production in Nigeria, there is need, not only to remove the constraints, but also to carry out more research on seed production of the adapted new lines of *Stylosanthes*. Private-sector participation is also necessary if large-scale and efficient production is to be achieved.

Production de semences de cultivars de *Stylosanthes* au Nigéria

Résumé

Trois espèces de Stylosanthes*, à savoir* S. guianensis *(cv. Cook et Schofield),* S. hamata *cv. Verano et* S. humilis *sont connues pour être adaptées à un large éventail de climats et de sols. Alors que les caractéristiques agronomiques, la valeur nutritive et la conservation de ces espèces ont fait l'objet de nombreux travaux, leurs capacités de production semencière n'ont commencé à être étudiées qu'en 1976. Les climats et les sols de la savane guinéenne et de la zone subhumide sont les plus adaptés à la production à grande échelle de semences de* Stylosanthes*. A l'heure actuelle, seule la production de semences du Verano est encouragée au Nigéria dans la mesure où les cultivars Cook, Schofield et Townsville sont trop sensibles à l'anthracnose. Ainsi, entre 1980 et 1990, plus de 200 tonnes de semences de Verano ont été produites dans le pays.*

Cet article expose les aspects agronomiques de la production de semences de Stylosanthes *ainsi que quatre méthodes de récolte ne nécessitant ni moissonneuse-batteuse, ni moissonneuse pneumatique. Au Nigéria, les semences sont nettoyées manuellement, ce qui*

est un exercice lent et coûteux. Par ailleurs, le contrôle de la qualité est inexistant, ce qui fait que le produit commercialisé contient généralement beaucoup d'impuretés.

Cet article passe également en revue les avantages et les problèmes de la production de semences de Stylosanthes. *Pour développer ce secteur d'activité, il importe, non seulement d'aplanir les obstacles identifiés, mais également de promouvoir la recherche sur la production de semences des nouvelles lignées mieux adaptées déjà identifiées. Enfin, seule une participation active du secteur privé au processus permettra de produire efficacement de grandes quantités de semences.*

Introduction

The recommendation for the introduction of forage legumes into Nigeria for sown-pasture research was first made in 1944. During the 1950s many indigenous and exotic grasses and legumes were evaluated for their adaptability and agronomic characteristics (Foster and Mundy, 1961; Blair Rains, 1963), nutritive value and their suitability for conservation as hay or silage (Miller et al, 1963), green manure, soil cover and forage (Nwosu, 1960).

Stylosanthes guianensis was the most outstanding out of the numerous forage legumes that were evaluated. It was easy to establish either from cuttings or seed, and was suitable for green manuring (to improve soil fertility), soil cover against erosion and for forage. Its ability to remain green for a large part of the dry season means that cattle could benefit from increased intake of protein-rich feed. This made it a prime candidate for pasture improvement in the subhumid and semi-arid areas of the country. A great deal of the research on forage legumes in Nigeria has therefore concentrated more on the cultivars in the genus *Stylosanthes*. Three species *S. guianensis* cvs Cook and Schofield, *S. hamata* cv Verano and *S. humilis*, have received most research attention in Nigeria. Although some seeds were being harvested from these species, investigations into their seed-yield potential started only in 1976. This is some 20 and 10 years after similar investigations were undertaken, respectively, on *Chloris gayana* (Foster, 1956) and *Andropogon gayana* (Haggar, 1966). However, Between 1977 and 1991, over 200 tonnes of stylo seeds were produced in Nigeria. This paper reports on the agronomy of seed production in *Stylosanthes* cultivars in Nigeria. Some of the problems affecting stylo seed production in the country are also mentioned.

History

There are only two indigenous *Stylosanthes* species in Nigeria, namely *S. erecta* and *S. fruticosa*. *S. erecta* is a slightly woody, herbaceous, and almost glabrous perennial legume prevalent in sandy wastes along beaches near the sea. *S. fruticosa* is an erect, woody, bushy and densely pubescent herbaceous perennial found on poor and eroded soils of the savannah zone. Both these species have limited use either as cover for crops or forage. The exotic *Stylosanthes* species that have been used widely in Nigeria are *S. guianensis* cvs Cook and Schofield, *S. hamata* cv Verano and *S. humilis*.

Stylosanthes guianensis cv Schofield (stylo)

Stylo was first introduced into Nigeria on 19 December 1947 from Queensland, Australia, by the Department of Agriculture (Agishi, 1977). Subsequent introductions into Shika Agricultural Research Station were made from Queensland and Kenya between the mid-1950s and 1975. Stylo was found to be well adapted to a wide range of soil types in the humid and subhumid zones of the country.

Between 1950 and 1970 almost all the stylo pastures were found on government farms and research stations. Limited quantities of seed were collected from these crops each year.

The two main sources of stylo seed in the country were Shika Agricultural Research Station and the Ministry of Agriculture and Natural Resources (MANR), Plateau State. Seed production during the period 1965–75 was estimated at 1.5 t and 2.5 t by Shika and MANR Plateau State, respectively, while the 1976–87 total production was about 3 t. Stylo is susceptible to anthracnose, and so its production is not presently encouraged.

Stylosanthes guianensis cv Cook (Cook stylo)

Cook stylo was released in Australia in 1971 and was first introduced into Nigeria in 1975. Cook stylo has the same range of soil adaptation and climatic requirements as Schofield stylo, but it is less leafy and is earlier flowering. Between 1977 and 1987, about 15 t of Cook stylo seed were produced in and around Shika near Zaria. During this period Cook stylo seed production from other sources (private and government farms) was estimated at 5 t.

As from 1984 when anthracnose was first observed on Cook stylo pasture at Shika, less emphasis was laid on its seed production even though the demand for seed was high until 1988. It is no longer on the list of recommended forage legumes in Nigeria.

Stylosanthes humilis (Townsville stylo)

Townsville stylo was first introduced into Nigeria in 1953 by the botanist at the Institute for Agricultural Research (IAR), Samaru, Zaria. Later introductions were made in 1967–69 and in 1975 (cvs Gordon, Lanson and Paterson).

Townsville stylo was rejected in earlier evaluations because of its relatively low dry-matter yields compared with stylo. It was also found to be highly susceptible to anthracnose. In the 1970s Townsville stylo was revived in Nigeria because of the possibility of using it for large-scale range seeding as was being practised in Australia (de Leeuw, 1974); between 1970 and 1975 about 1.5 t of Townsville stylo seed was produced in Shika alone. Verano stylo was introduced in 1975 and proved superior to Townsville stylo in many respects. This was one of the factors that led to a reduced tempo of research on Townsville stylo.

Stylosanthes hamata cv Verano (Caribbean stylo, Verano)

Verano stylo was released in Australia in 1973, and was imported into Nigeria in 1974 by the Pasture Unit of the Federal Livestock Department, Kaduna. Over 95% of the Verano stylo grown in Nigeria came originally from 1 kg of seed introduced from Queensland, Australia, in 1975.

The annual Verano seed production between 1977 and 1980 from a farm near Shika was 15 t. Between 1980 and 1990, an estimated 200 t of Verano stylo seed was produced in Nigeria.

Selecting sites for seed production

Climate

The three main ecological zones in Nigeria are the humid (Forest), subhumid (southern and northern Guinea Savannah) and semi-arid (Sudan Savannah and Sahel). The humid zone has a rainfall range of 1500–4000 mm/year which falls between February and early December. The subhumid zone covers a large proportion of the country and has a rainfall range of 1000 to 1500 mm/year that occurs from April to October. The annual rainfall in the semi-arid zone is below 1000 mm, and falls within 3–5 months of the year (May to September).

In all the three zones, temperature and sunlight hours favour seed production of perennial and annual stylos. Although high temperatures inhibit Schofield flower development and preclude large spike populations (Okigbo, 1972), the flowering time for Schofield in Nigeria which is in January coincides with the harmattan when air temperatures are most favourable. In the humid zone, the time of seed ripening in perennial stylo coincides with the onset of the rains, and this makes seed harvesting different. Verano stylo continues growth during reproductive development provided there is sufficient moisture. This means that seed that ripen during the rains may get mouldy or germinate while those that mature during the short dry spell cannot be fully harvested before the onset of the rains.

In the semi-arid zone, except in the low-lying areas (*fadama*) the wet season is too short for good seed production in perennial stylos. For example, at Shika (subhumid zone) Cook, Endeavour and Schofield only flower at about five months after seeding (Abdullahi et al, 1982); in the humid zone 183 days are required for Schofield stylo to achieve 50% flowering from sowing (Okigbo, 1972). The semi-arid zone is favourable to Verano seed production. The best combination of climatic factors for producing seeds from perennial and annual stylos occurs in the subhumid zone. Here the temperature, sunshine and rainfall (growing period) are most favourable for good plant growth and flowering. The long dry season with the accompanying low relative humidity favour seed harvesting.

Soils

Schofield, Cook and Verano stylos grow satisfactorily on a wide range of soils. For seed production however, soils that allow for easy recovery of fallen seeds are preferred. In this respect, poorly drained soils, cracking clays, very sandy soils and stony or rocky soils are to be avoided. In Nigeria, good recovery of fallen stylo seeds has been achieved on clay loams and sandy loam soils.

Establishment

Perennial and annual stylos can be established by broadcasting seed on fallow land or on natural pasture usually after partial defoliation with herbicides or burning (de Leeuw, 1974) and by feeding seed to cattle (Foster, 1961). However, pastures established using the above techniques are subject to severe competition from the existing vegetation (Haggar et al, 1971). The most successful stylo establishment has been on well-prepared seedbeds on which phosphatic fertilisers have been applied (de Leeuw, 1974; Agishi, 1982a; 1982b). With seed crops the main objective is to produce a clean dense crop of the sown species in the year of establishment. Mechanical scarification or hot-water treatment of seed at 70^{o}C for 10 minutes removes hardseededness, resulting in early and uniform establishment. This is applicable only where the rains are well-established since any dry spells after establishment may result in the death of most seedling.

Schofield and Cook stylo seeds may not germinate if sown deeper than 2.5 cm; for Verano a depth of 1 cm is optimal (Agishi, 1979). Seed rates of 15 kg/ha are recommended for Cook and Schofield stylos but for Verano and Townsville stylo 30–40 kg of clean seed (pods) are necessary for early ground cover.

Fertiliser application

Single superphosphate (ssp) is the commonest fertiliser used on legumes in Nigeria. It is applied at seeding for the first-year crop, at the onset of the rains for the second and subsequent years crops and soon after closing the field to grazing by cattle. On the savannah the recommended rate for legume establishment is 8–26 kg P/ha (Agishi and Asare, 1980). For stylo seed crops higher rates may be required. For example, mean seed yield for first year Verano crop fertilised at 31 kg P/ha was 1404 kg/ha with a range of 1192 to 1775 kg/ha. In a detailed study at Shika single superphosphate applied to two-year old Verano seed crop at 0, 13, 26, 39 and 52 kg P/ha gave corresponding seed yields of 480.6, 552.8, 961.3 1266.0 and 1280.5 kg/ha (Agishi, 1982a). This shows that for Verano stylo seed production, approximately 40 kg P/ha is required for optimum seed yield.

At Shika, maximum seed yields of Cook and Endeavour stylos were achieved at about 17 kg P/ha (Abdullahi et al, 1982). At Kurmin Biri, some 120 km south-east of Kaduna, an application of 0, 13, 26, 39 and 52 kg P/ha on a first year seed crop of Schofield stylo gave maximum standing seed yields of 298, 393, 434 and 307 kg/ha, respectively. The corresponding maximum standing seed yields for the residual levels were 208, 321, 283, 346 and 427 kg/ha (Ezeaku, 1982). When these responses from the southern Guinea Savannah zone are compared with those from the northern Guinea Savannah zone (Shika), it becomes clear that the level of P required for optimum seed production in the Nigerian savannah is 13–26 kg P/ha for perennial stylo and 40 kg P/ha for Verano stylo. When the effect of residual P is taken into consideration, then a lower level of 13 kg P/ha may be recommended.

Management of stylo seed crops

Defoliation

Defoliation can be carried out either by cutting or by grazing animals. For seed crops, defoliation is important in bringing about the greatest density of inflorescences and a synchronisation of their development and maturation. Timing of defoliation is important in this respect. In Schofield stylo, early defoliation was found to be useful in synchronising inflorescence development (Loch et al, 1976). In Townsville stylo and Verano the effects of defoliation have been variable though sometimes beneficial (Humphreys, 1979; Wilaipon et al, 1979). Verano stylo has an indeterminate pattern of growth and as such when defoliated early enough to allow for more growth, seed production may not be affected. In the determinate *S. humilis* cv Townsville where time of flowering and seed set are closely linked, to the normal end of growing season, late defoliation can significantly reduce seed yields.

At Kurmin Biri, Ezeaku (1982) also found that defoliation could be beneficial to seed production in Schofield stylo provided it was done before the first floral initiation stage (Table 1).

Table 1. *The effect of defoliation and harvest date on seed yields of Schofield stylo (kg/ha).*

Harvest date	Defoliation treatment					
	D0	D1	D2	D3	D4	Means
31/1/80	348	472	346	239	87	305 b
14/2/80	335	396	442	410	250	367 a
01/3/80	248	321	356	319	202	289 c
15/3/80	181	260	265	231	194	226 d
29/3/80	173	183	186	182	180	181 e

D0 = Uncut (control).
D1 = Cut on 25th July 1979.
D2 = Cut on 25th August 1979.
D3 = Cut on 25th September 1979.
D4 = Cut on 25th October 1979.
Cleaning cut was in April 1979.

Maximum seed yield was achieved in the late July cut. Defoliation after July delayed seed maturation time by about two weeks and delaying cutting to late October resulted in a 31% seed-yield reduction from the control.

At Shika, it was found that when cattle stopped grazing Verano seed crops by the middle of July it was possible to harvest between 1000 and 1100 kg/ha of seed. When the crops were grazed up to early to mid-August, i.e. six to seven weeks to the end of the rains, only 500 to 600 kg/ha of seed could be harvested (Agishi, 1982b). The marked reduction in seed yields in the August grazed seed crops is to be expected since by August, there are many flowers on the old seed crops.

Weed control

Weeds are a problem in stylo seed crops as they compete with the legumes for nutrients, water and light thus interfering with their early establishment. Regrowths from stumps, lignotubers and root stocks should be regularly slashed. For, small plots of seed crops, the grass and other herbaceous weeds may be hand-weeded. For large seed farms, hand-weeding is too expensive to contemplate.

Stylos are said to be tolerant to a wide range of herbicides, which allows for strategic selective weed control to be practised (Hawton and Johnson, 1980). In Australia, a pre-emergent herbicide such as trifluralin is used at establishment to control annual grasses. This is followed by 2, 4-D during the vegetative growth stage to control dicotyledonous weeds (Hopkinson and Walker, 1984). In Nigeria, herbicides are not generally used to control weeds in stylo seed crops. However, a recent study at ILCA, Kaduna (Kachelriess and Tarawali, pp. 287–297), on the effect of types and rates of herbicides application on forage legume seed yields has shown the positive role of herbicides in pasture legume seed production.

An alternative to hand-weeding and herbicide use is to graze the seed crops with cattle as from four to five weeks after the onset of the rains up to 9–10 weeks before the expected termination of the rains. During the early part of the wet season, grass is preferred to stylo, and with heavy grazing the photosynthetic tissues and nutrient reserves are continually removed while stylo growth proceeds with minimum checks (Gardener, 1980). In general, weed infestation can be greatly reduced by using high seeding rates, preparation of clean seedbeds, choosing an appropriate time to sow, applying an adequate amount of fertiliser at sowing and selecting the right time to cut or graze the crop.

Disease control

The most common disease of *Stylosanthes* species is anthracnose. This is a fungal disease caused by *Colletotrichum gloeosporoides*. Verano stylo is tolerant to anthracnose attack. Since transmission of the disease is by seed, seed treatment with a fungicide such as binomial has been used to check the threat of anthracnose in stylo seeds (Hopkinson and Walker, 1984). Although Cook and Schofield stylos are affected by anthracnose, these cultivars can still be seen growing luxuriantly in some anthracnose-free areas. Townsville stylo is also susceptible to anthracnose, but presently in Nigeria it can be seen growing luxuriantly in many areas, particularly in grazing reserves, cattle tracks, fallow lands and playgrounds. Seed production from these susceptible species could be restricted to areas where anthracnose has not yet been observed.

Seed harvesting methods

Stylo seed can be harvested by direct heading using combine harvesters or pneumatic pick-up of fallen seeds using suction harvesters. These machines are not in use in Nigeria for stylo seed production and as a result other harvesting methods have been tried.

Hand picking

This method though best suited to legumes that produce large pods, e.g. *Leucaena*, *Gliricidia*, *Centro*, *Siratro*, lablab and phasey bean, is also used in perennial stylo-seed harvesting. Ripe seed heads of stylo are hand-picked from the field and dried on concrete floors or any hard, smooth surface. When dry, the heads are threshed with sticks and cleaned by repeated winnowing. This gives clean seeds but the method is slow and expensive. For example, at Shika it has been found that one woman could harvest only 20 kg of seed heads per day (Agishi, 1982b). Harvested seed heads of Schofield and Cook stylo were found to contain only 1.1 and 2.6% seed, respectively, corresponding to 0.22 kg and 0.52 kg of seed per day's harvest. In a detailed study carried out at Shika, it was found that from hand-picking Cook stylo seed heads to seed recovery or seed cleaning required 250 and 360 man-days per hectare for the first- and second-year seed crops, respectively (Agishi, 1982b).

Cut, dry and thresh method

The seed crop is harvested by hand-held sickles, spread on a hard floor and threshed after some days of drying. This method is normally used in grass seed harvesting, but has also been used at Shika to harvest Verano stylo seed. This method is also slow and expensive. For example, it took 10 man-days to harvest one hectare of first year crop of Verano stylo, and about 12 man-days for the second and subsequent years' crops. It took 120 and 160 man-days to sweep and clean Verano seed from first and second year seed crops, respectively (Agishi, 1982b).

An alternative method is to harvest the seed crop using a forage harvester and deliver the harvested crop into an accompanying trailer. The crop is emptied on to a hard, smooth and flat surface each time the trailer is full. Since harvesting has to be done when not much seed has dropped, some unripe seeds are also harvested along with the ripe ones. Although this is a faster method of harvesting Verano seed, the recovery of seed is difficult and inefficient because of the large amount of herbage involved. It also requires at least two tractors to operate effectively.

Cut, sweep or suck

The crop is first brushcut, raked and baled. The operation requires about one tractor work day for Verano and 1.5 work days for Cook stylo. The brush-cutter, through its violent shaking of the standing crop, removes most of the ripe seeds from the plant. The fallen seeds are swept by women and winnowed repeatedly to obtain about 80–90% clean seed.

Recovering fallen seed is time-consuming. For example, sweeping and cleaning of seeds from one hectare require 100 and 120 man-days for the first and second year Verano crops, respectively, with a corresponding 150 and 200 man-days for Cook stylo (Agishi, 1982b). Townsville stylo and Verano stylo sweepings contain about 20–26% and 20% seed, respectively. While it is possible for a woman to obtain 60–80 kg of sweepings from a Townsville stylo farm in a day, only about 30 to 50 kg can be swept from a Verano field.

Harvester ants method

This method is only applicable to perennial stylos. The mature seed crop is brushcut, raked and baled. About a week after baling, heaps of seeds can be collected from harvester ant (*Messor barbatus*) nests at intervals of three to seven days depending on the size of the field and the labour available. This method has been successfully used on Cook stylo seed production where seed harvests of 1000 to 1243 kg/ha have been achieved with 69 to 83 per cent seed retrieval (Agishi, 1980). Over 10 000 nests/ha with diameter ranges of 10–50 cm were observed.

Seed yields

Seed yields from the four main cultivars of *Stylosanthes* grown in Nigeria are presented in Table 2. The yields vary widely within cultivars, and this is expected because of the great differences in soil types and climatic conditions under which they are grown and variations in management practices. The potential or maximum seed yields have not been determined for most cultivars, however, it is most probable that inefficient seed harvesting contributes to the low seed yields obtained for Verano and Cook stylo.

Table 2. *Seed yields of* Stylosanthes *cultivars in Nigeria.*

Cultivars	Seed yield (kg/ha)	Comments
Cook stylo	272	First year crop (Abdullahi et al, 1982). Poor recovery of fallen seed.
Cook stylo	560	Second year crop (Agishi, 1977)
Cook stylo	1243	Harvester ants method (Agishi, 1980)
Cook stylo	500–600	Cut and sweep method (Agishi, 1982b)
Schofield stylo	406–507	First year crop (Ezeaku, 1982)
Schofield stylo	239–529	Residual P only (Ezeaku, 1982)
Schofield stylo	339	First year crop at Shika. Poor recovery of fallen seed (Abdullahi et al, 1982)
Schofield stylo	200–300	Federal Livestock Department (FLD) at Kurmin Biri (Ajileye, pers. comm.)
Townsville stylo	1143–1177	Second year crop (Agishi, 1977)
Verano stylo	1192–1775	First year crop (Agishi, 1982a)
Verano stylo	800–1100	13 year old crop at Shika, Zaria (Agishi, unpublished)
Verano stylo	500	Unweeded crop (Kachelriess and Tarawali, pp. 287–297)
Verano stylo	100	Unweeded crop (Kachelriess and Tarawali, pp. 287–297)
Verano stylo	400–600	National Livestock Projects Division (NLPD) (Ajileye, pers. comm.)

Seed quality

The three main elements of seed quality are physical purity of the seed sample, the physiological quality of the seed component and its genetic quality, i.e. whether it is true to type (Hopkinson and Walker, 1984). In terms of physiological quality, this is not a problem in the four cultivars of stylo being used in Nigeria because the seeds are normally harvested when mature. Stylo seeds are also commonly green as sole crops, and so the problem of crossing or outcrossing which affects trueness to type of the seed is not important.

The physical quality of the sample is the main factor controlling seed quality. Weed seeds are usually common in stylo seeds particularly in those seeds that come from sweepings. In Nigeria, seeds of *Sida* species are usually common among seeds of Verano, Cook and Schofield stylos obtained from old seed crops. These seeds are very difficult to separate from true seeds, and in the process of trying to do so losses of the true seeds usually occur. At present there is neither a body or centre in Nigeria that controls pasture-seed quality in terms of purity and germination, nor is there any cultivar certification.

Marketing

There are very few people involved in pasture- or stylo-seed production in Nigeria. For years, the Federal Livestock Department (FLD) produced Schofield stylo seeds that were distributed free of charge to interested farmers. FLD also supplemented its production by buying the seeds from individuals. The National Animal Production Research Institute (NAPRI) also produced a range of forage seeds for distribution to farmers.

The first time forage seeds were marketed in Nigeria was in 1977 when about 10 tonnes of Verano stylo seed were produced and sold to State and Federal government ministries, organisations and some individuals. Before 1977 most of the pasture seeds used in the country were imported; after the initial sales subsequent sales become easier. However, when middlemen entered the seed trade, the quality of seeds in the market dropped drastically; some Verano stylo seed samples in the market had as low as 30% purity instead of the 80–90% purity achievable through repeated winnowing. Since seed was being sold by weight sand or soil was being deliberately added to the seed samples from the field.

The popularisation of the fodder bank development concept, grazing reserves improvement and interest from institutions and companies have been responsible for a steady increase in demand for stylo seeds. One major problem in stylo-seed marketing in Nigeria is that there is no reliable method of forecasting future demand or requirements. Any stylo-seed producer decides how much land should be devoted to stylo-seed production. Despite this uncertainty, at least 90% of the seed produced in a year is usually sold, either within or outside Nigeria.

Advantages of stylo-seed production in Nigeria

There are many advantages to producing stylo seeds in Nigeria. Some of these advantages are:

- both soils and climatic conditions are favourable for producing high seed yields in the savannah zone of the country
- elimination of the importation of stylo seeds will conserve the country’s foreign exchange and minimise the chances of introducing diseases and noxious weeds
- generation of an additional income for farmers
- since seed production is usually combined with hay production, it is a way of conserving dry-season feed for livestock
- stylo, being a legume, improves the fertility of the soil where it is grown, and also provides cover against soil erosion
- seed production in the country provides training for many technicians and jobs for unskilled women.

Constraints to stylo-seed production

Some of the factors militating against large-scale stylo-pasture development in Nigeria have been fully documented (Lazier, 1984; Agishi and de Leeuw, 1986). These factors also affect seed production of *Stylosanthes* cultivars. Briefly, these problems can be listed as follows:

1. Seed collection by harvester ants at establishment and ripe seed phases, leads to poor establishment and low seed recovery (if harvesting is delayed), respectively.
2. Termite attacks cause death of stands.
3. Attack by anthracnose may destroy the entire field of stylo.

4. Perennial stylos have low persistence of beyond three years.
5. Fire outbreaks may destroy the whole seed crop.
6. Weeds–both cultural and herbicide weed control are expensive.
7. To prevent frequent grazing of seed crops by stray animals a guard and/or fence is needed which gives an added cost.
8. Lack of seed-harvesting equipment.
9. Lack of seed-cleaning machines. Even when they are available, they are too expensive to purchase. Inadequate seed cleaning therefore means that poor-quality seeds act as a vehicle for spreading weed seeds. Also poor-quality seeds cannot be marketed internationally.
10. No pasture certification and quality-control body in the country.
11. It is impossible to forecast seed requirements on a national basis.
12. There is generally very poor extension work on pasture development, and so due to some ignorance on the importance of pasture seeds, the demand for seeds by livestock farmers is low.
13. Many livestock farmers do not have title to land, and since pasture development is a long-term project, they are unwilling to invest in it particularly on a piece of land that does not belong to them.
14. There is a very narrow *Stylosanthes* germplasm base in Nigeria, and this is dangerous in case of future disease attack.
15. Few trained manpower in forage-seed technology.

The future of stylo seed production in Nigeria lies in providing answers to most of the above-listed constraints. More research on seed production is required on the new lines of *Stylosanthes* that have shown promise in Nigeria. There is need also for more private-sector involvement in forage seed production.

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The effects of row spacing and weed control on seed production of *Stylosanthes* in the subhumid zone of Nigeria

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Abstract

Small-scale seed production of five *Stylosanthes* species comprising 17 accessions was carried out in the subhumid zone of Nigeria during 1988–91 with varied success; only one *S. capitata,* two *S. hamata,* one *S. humilis* and one *S. scabra* accessions produced over 200 kg/ha of seed. Subsequently, field experiments were conducted during 1990–91 to determine the effect of row spacing, manual weeding, herbicide application, harvest dates and method on seed production of *Stylosanthes hamata* cv Verano. Seed yield and purity did not differ between row spacings of 25 or 50 cm. Manual weeding improved seed yield and quality and was efficient when done in the early growing season and two to four weeks later. Herbicide application could be feasible; Trifluralin, Imazethaphyr and a combined application of Bentazon/Cycloxidim controlled weeds depending on the botanical composition of the weed flora. Seed collection needs to be done early when seed heads are collected by hand, while sweeping of fallen seeds can be done later. Cleaning of seeds is easier and cheaper when harvested directly from the standing crop. With appropriate weed control and harvest methods, up to 500 kg/ha of pure Verano seed could be obtained.

Effet de l'espacement et de la lutte contre les adventices sur la production de semences de *Stylosanthes* dans la zone subhumide du Nigéria

Résumé

Au cours de la période 1988–1991, de petites quantités de semences de 17 acquisitions de Stylosanthes *appartenant à cinq espèces ont été produites avec des résultats variables dans la zone subhumide du Nigéria. Seules deux acquisitions de* S. hamata *et une seule de* S. capitata, *de* S. humilis *et de* S. scabra *ont franchi la barre des 200 kg de semences à l'hectare. Des essais au champ ont ensuite été réalisés en 1990–1991 pour évaluer l'effet de l'espacement, du désherbage manuel, de l'application d'herbicide, de la date et de la méthode de récolte sur la production de semences de* S. hamata *cv. Verano. Aucune différence n'a été observée entre les espacements de 25 et de 50 cm en ce qui concerne la production et la pureté des semences. Le désherbage manuel améliorait la production et la qualité des semences et donnait de meilleurs résultats au début de la saison de croissance et deux à quatre semaines plus tard. Le recours aux herbicides demeure cependant une option valable. Ainsi, l'application de*

trifluralin, d'imazethaphyr et de bentazon associé à du cycloxidim permettait d'éliminer efficacement les mauvaises herbes en fonction de la composition floristique. La collecte des graines doit se faire rapidement lorsque les épis sont récoltés manuellement; les graines tombées par terre peuvent être balayées plus tard. Le nettoyage des semences est plus facile et moins cher lorsqu'elles sont récoltées directement sur la plante sur pied. Avec des méthodes appropriées de récolte et de lutte contre les adventices, on peut obtenir jusqu'à 500 kg de semences pures de Verano par hectare.

Introduction

In West Africa, *Stylosanthes hamata* cv Verano is widely used for pasture, fodder banks and for undersowing crops. In addition, other *Stylosanthes* accessions are being tested by ILCA in order to identify material that could replace or complement Verano stylo (ILCA, 1990; 1991; Tarawali et al, pp. 81–95).

Stylosanthes seeds are needed firstly to allow further research and also in larger quantities for on-farm testing and ultimately for issue to farmers. Although seeds of recognised cultivars (Verano, Cook, Seca etc) are commercially available from abroad (e.g. from Australia, Thailand), in Nigeria there is a shortage of seeds, except for Verano (Agishi, pp. 275–285). Therefore seed multiplication techniques are required to produce seeds locally. This paper covers two aspects: firstly, the production of seed of new accessions for subsequent experiments and secondly, experiments involving Verano stylo seed production. The effects of row spacing, manual weeding, herbicide application, harvest dates and methods on legume seed yield, purity and contamination with weed seeds were investigated.

Materials and methods

Small-scale multiplication of selected accessions

Seventeen accessions, selected for multiplication (Table 4), were established in June 1988 on a commercial farm called "Abuja Road", 30 km from Kaduna (10° 10'N; 7° 25'E; 600 m asl); general soil features are given in Table 1.

Before sowing the land was subsoiled, ploughed, harrowed and 16 kg/ha of phosphorus (as single superphosphate) was incorporated into the soil. Seeds were scarified by rubbing with sandpaper and then sown by hand in 100 m long rows (at a rate of 0.6 g/m of row) with 2 m between rows, equivalent to 3 kg/ha. Accessions of the same species were separated by blocks of soyabeans (50 m) to reduce the risk of cross-contamination. During the four-year period, some plots were abandoned as the accessions were no longer required, whereas new accessions identified as promising were newly planted (Table 3). The plots were weeded by hand, while ripe seeds were collected by shaking the plants over plastic containers two or three times a week.

Seed production of *S. hamata* cv Verano

Trials were conducted in 1990 and 1991 at two sites, Kurmin Biri[1] and Abuja Road. *Stylosanthes hamata* cv Verano seeds were manually scarified and sown at a rate of 10 kg/ha. In all trials except in the row-spacing experiment, planting was done in rows 50 cm apart. In 1990 the effect of two-row spacings (25 and 50 cm) on seed yield and purity was tested in a separate experiment.

1. For a site description of Kurmin Biri see Tarawali et al (pp. 81–95) and Tening et al (pp. 113–122).

Table 1. *General soil features of the seed multiplication site at "Abuja Road".*

Parameter	Value	Parameter	Value
		Micronutrients (ppm)	
pH (H_20)	5.1	Zn	1.5
pH ($CaC1_2$)	4.8	B	0.85
Organic C (%)	0.64		
	0.05	Particle size	
Total N (%)		distribution (%)	
Available P	17	Sand	76
(ppm)		Silt	14
Exchangeable cations		Clay	10
(meq/100g soil)			
Ca	1.91	Texture: gravelly-sandy-loam	
Mg	0.42		
K	0.19		
Na	0.05		
A1	0.10		

Source: Esu (1989).

At Kurmin Biri the testing of manual weed control was continued in 1991 and re-established in 1991 in plots that regenerated from the previous year. At Abuja Road new experiments were established each year (for treatments see Table 2).

Table 2. *Manual weed control treatments at Kurmin Biri and Abuja Road.*

Treatment	Kurmin Biri	Abuja Road
1	Not weeded	Not weeded
2	'Weed-free'	'Weed-free'
3	3 and 6 WAS	4 and 6 WAS
4	6 and 9 WAS	4, 6 and 8 WAS
5	9 and 12 WAS	4 and 8 WAS
6	12 WAS	4, 8 and 12 WAS

Weed free = weekly weeding;

WAS: Time of weeding in weeks after sowing.

Weeds were removed from the plots by hand-pulling. Herbicides were applied with a manual knapsack sprayer at about 300 litres of water per hectare according to the treatments given in Figure 3. Each plot was sampled for seed yield at the beginning of the dry season and again two weeks later by cutting plants from 1 m^2 at 5 to 10 cm above ground level; fallen seeds were swept from the soil surface of each 1 $m.^2$ Harvested plants were sun-dried on separate plastic sheets, then threshed and cleaned by hand-winnowing. Subsamples of 2.5 g were taken for purity testing to calculate pure seed yield.

Results

Small-scale multiplication of selected accessions

Seed yields of the 17 accessions are shown in Table 3. In 1988, seed production in the first year was poor except for *S. humilis* ILCA 7363 and *S. scabra* ILCA 441 which produced 142 kg/ha and 136 kg/ha, respectively. Seed yield of most accessions increased in 1989, except for *S. humilis* which disappeared and was not resown; however, it later regenerated from seed and seed production in the spontaneous crop in 1990/91 and 1991/92 was

Table 3. *Seed yields*[1] *of selected* Stylosanthes *accessions at Abuja Road during 1988–92.*

Accessions	Seed yield (kg/ha)			
	88/89	89/90	90/91	91/92
Stylosanthes capitata				
CIAT 10280 (Capica)	np[2]	179	pa[2]	–
ILCA 9052	74	303	na	–
Stylosanthes guianensis				–
CIAT 11374	np	63	pa	–
CIAT 136 (ILCA 163)	53	133	132	pa
CIAT 184 (ILCA 164)	57	125	na	106
ILCA 4 (Cook)	50	85	pa	–
ILCA 15557	np	np	np	145
Stylosanthes hamata				–
CIAT 118	np	71	pa	–
CIAT 147	np	28	pa	–
CIAT 2770	np	172	pa	–
ILCA 75 (Verano)	66	197	pa	–
ILCA 15868	np	np	np	563
ILCA 15876	np	np	np	256
Stylosanthes humilis				–
ILCA 7363	142	0	430	313
Stylosanthes scabra				
ILCA 140 (Fitzrog)	41	47	35	26
ILCA 441 (Seca)	136	108	na	531
KNARDA[3]	21	54	54	pa

1. Yields in tables and figures are pure (net) seed yields.

2. np = not planted; pa = plot abandoned; na = not available.

3. Accession received from Kano Agricultural and Rural Development Authority.

excellent. The two *S. hamata* accessions planted in 1991 gave good seed yields in the first year, as did *S. scabra* ILCA 441, in contrast to *S. scabra* ILCA 140 which performed poorly throughout the four-year period.

Seed production of *S. hamata* cv *Verano*

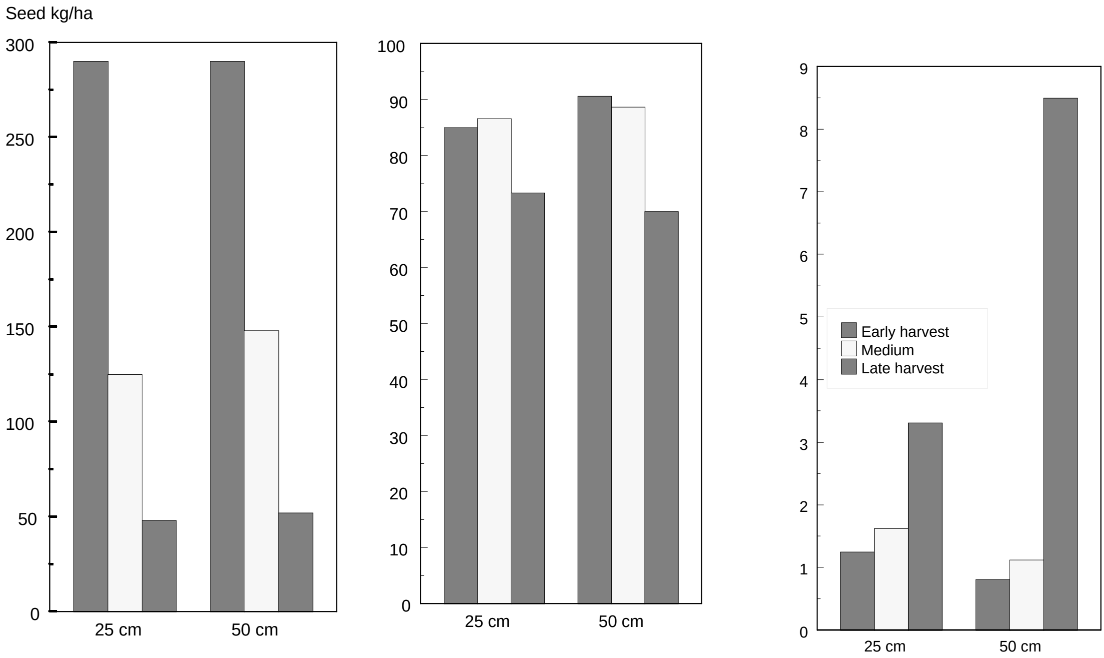
Both row spacings gave similar yields and purity (Figure 1). With a semi-erect cultivar of *Stylosanthes hamata,* row spacings greater than 50 cm were not suitable, because the rows would not close during vegetation growth thereby promoting weed infestation.

Manual weeding

In 1990 at Kurmin Biri, there were no significant differences in seed yield between the six weed control treatments (Figure 2a) although weeding generally enhanced seed yields as compared to the unweeded control. Early weeding (three and six weeks after sowing,) gave slightly lower seed yields. Seed yields on the second-year crop (in 1991) again were similar to those of first-season crops except than regrowth from the unweeded plots was low and hardly any seed was produced. The same experiment sown in 1991 gave slightly higher yields than in 1991, but with smaller differences between the treatments (Figure 2a).

At Abuja Road in 1990, high weed infestation reduced seed yield to only 4 kg/ha in the unweeded control. Weeding at 4 and 8, or 4, 8 and 12 WAS increased seed yield to about 75% of the weed-free treatment. Similar results were obtained in 1991 when no weeding again resulted in significant yield reductions; all weeding treatments gave yields similar to those of the weed-free treatment (Figure 2b).

Figure 1. *Effect of row spacing and time of harvest on seed-yield parameters of* Stylosanthes hamata *cv Verano.*



In all the weeding experiments, the purity of legume seeds generally improved, but it was higher in 1990 than in 1991 (Figure 2a). However, while in first-season crop purity of weeded crops ranged from 89–92% this level dropped to 69–84% in the second-season crop. Purity levels at Abuja Road were lower, varying from 65 to 81%; contamination with weed seed was low in all weeded crops in contrast to the unweeded crop with levels of 11–60% at Kurmin Biri and up to 34% in Abuja Road.

Herbicide application

At Kurmin Biri in 1990, applications of Trifluralin and Imazethapyr enhanced seed yields as compared to the unweeded treatment and reduced the contamination with weed seeds in some of the treatments in 1990 and in all the treatments in 1991. In 1991 yields of the treated plots were not significantly different ($P< 0.05$) from the unweeded control. Only the combined application of Bentazon (effective against broad-leaved weeds) and Cycloxidim (grass herbicide) improved seed yield and purity. Contamination with weed seeds was low in all treatments (Figure 3a). Imazethapyr applications at Abuja Road doubled seed yields compared with the control but yields were still less than in the weed-free treatment (Figure 3b).

Harvest date and harvest method

The highest seed yield was obtained by hand-harvesting early, before ripe seeds fell to the ground. Harvesting of fallen seeds by sweeping the soil surface gave the highest yield especially when done late (Figure 4). In Verano the hooked seeds dropped first, resulting in more unhooked seeds in later harvests. However, manual weeding did not affect the proportions of these two types of seeds (Figure 5).

Figure 2a. *The effect of weeding intensity on seed yield components of first and second year Verano stylo crops at Kurmin Biri.*

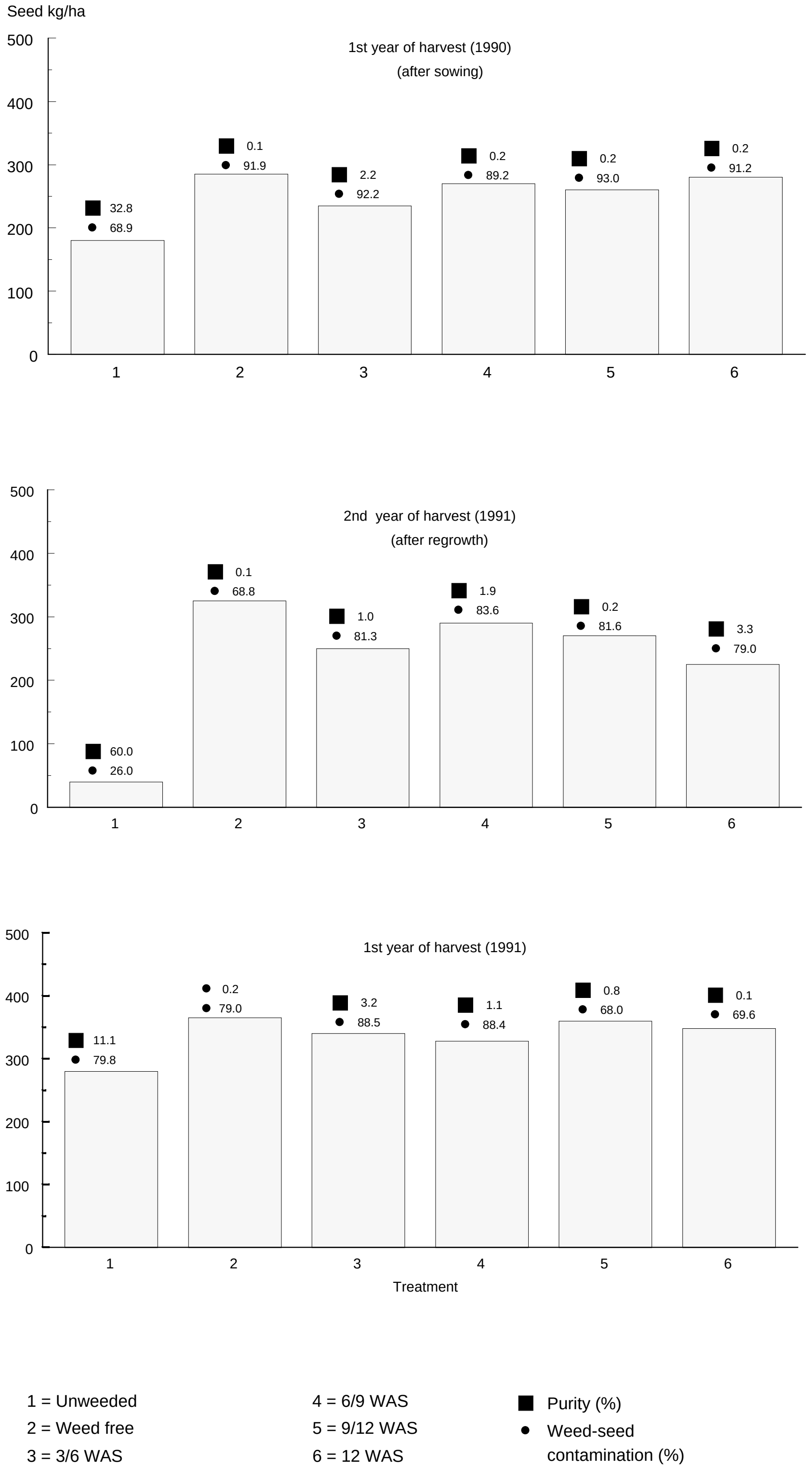
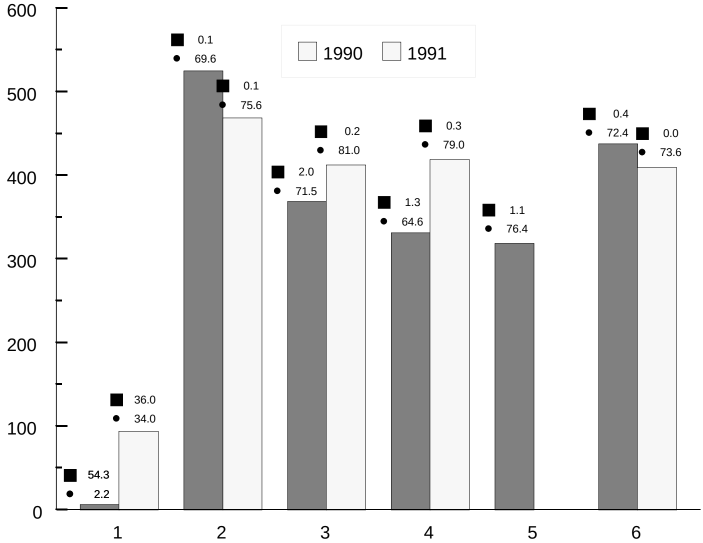


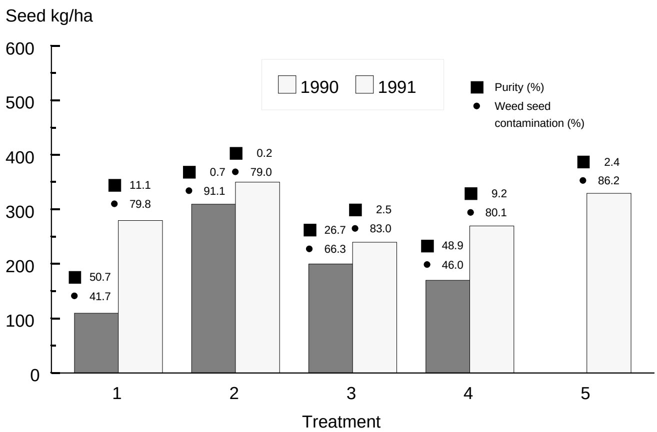
Figure 2b. *The effect of weeding intensity on seed yield components of first and second year Verano stylo crops at Abuja Road .*



1 = Unweeded | 2 = Weedfree | 3 = 4/6 WAS | ■ Weed-seed contamination (%)

4= 4/6 /8 WAS | 5 = 4/8 WAS (only 1990) | 6 = 4/8/12 WAS | • Purity (%)

Figure 3a. *Effect of chemical weed control with different herbicides (g active ingredient/ha) on net seed yield (kg/ha) of* Stylosanthes hamata *cv Verano at Kurmini Biri in 1990 and 1991.*



1 = Not weeded | 2 = Weedfree | 3 = Trifluralin 720 g al/ha

4= Imazethapyr 40 g al/ha | 5 = Bentazon 2x1080 g al/ha | + Cycloxidim 400 g al/ha

Figure 3b. *Effect of chemical weed control with different herbicides (g active ingredient/ha) on net seed yield (kg/ha) of* Stylosanthes hamata *cv Verano at Abuja Road in 1990 and 1991.*

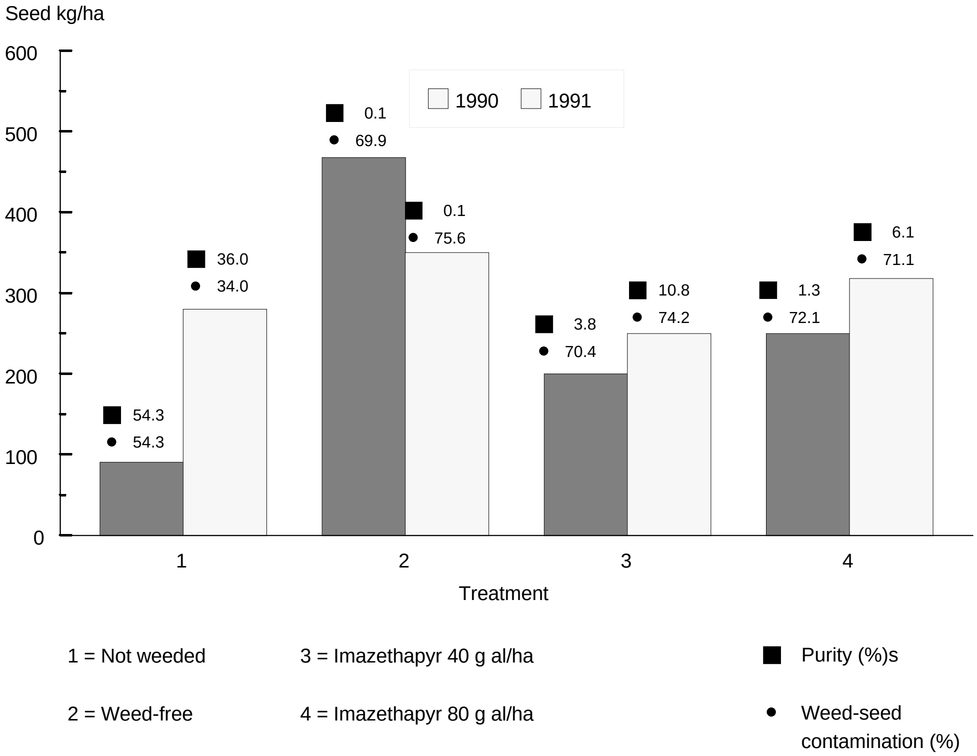
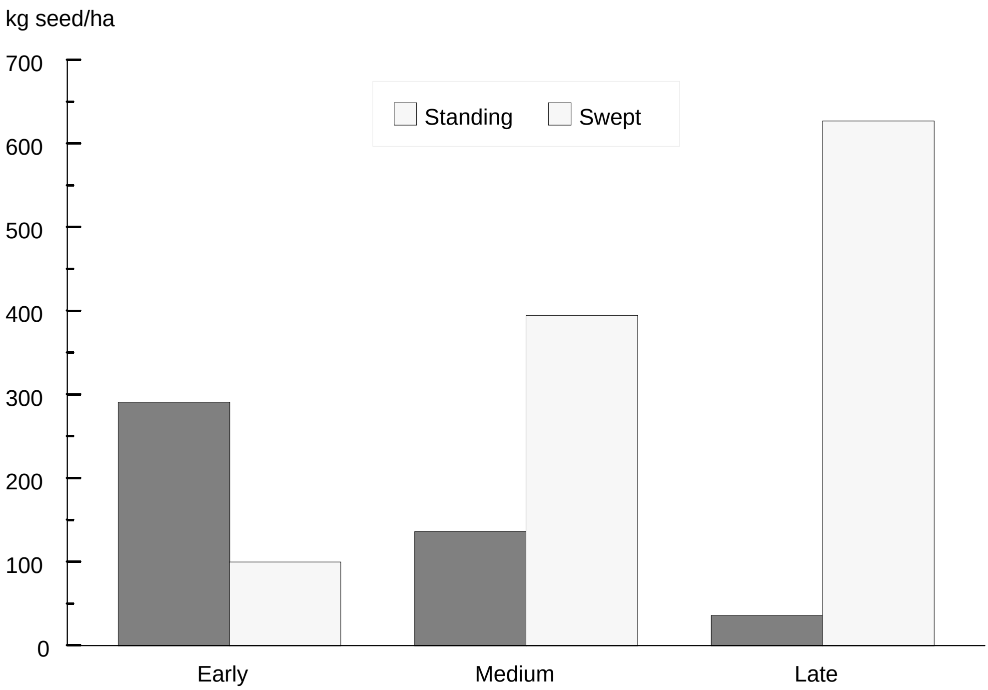


Figure 4. *Effect of harvest date and method on standing seed yield and seed recovered from swept material of* Stylosanthes hamata *cv Verano.*

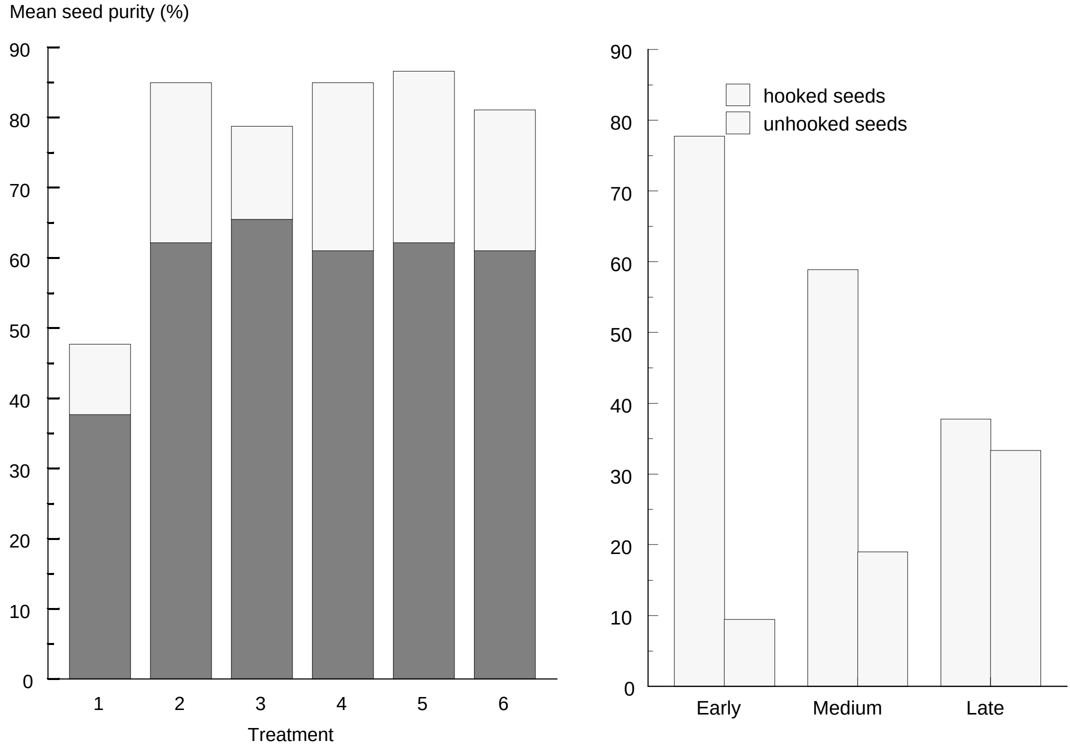


Discussion and conclusions

Seed yields of the *S. hamata* and *S. humilis* accessions and *S. scabra* ILCA 140 were below those reported in Australia, whilst yields of the other accessions were similar (Humphreys and Riveros, 1986). In Nigeria Agishi (1986) also reported higher yields for Verano stylo

(500–600 kg/ha) and Cook stylo (400–500 kg/ha). However, in more recent trials he reported much higher yields (Agishi, pp. 275–285). Yields of stylo (Table 3) are comparable to those reported by Youkeu et al (pp. 97–102) in the Cameroon.

Figure 5. *Effect of manual weeding and harvest date on proportions of hooked and unhooked seeds of* Stylosanthes hamata *cv Verano at Kurmin Biri in 1991.*



Manual weeding (at weeks after sowing (WAS))

1 = Unweeded   3 = 3/6 WAS   5 = 9/12 WAS

2 = Weed-free   4 = 6/9 WAS   12 = WAS

These poor yields can be explained by the wide row spacing (2 m) since subsequent experiments with Verano showed that a row spacing of 50 cm was optimal. Although the interrow spaces were kept weed-free, the low plant density accounted for the reduced yields. *S. scabra* ILCA 441 performed markedly better than ILCA 140, probably because the former showed little response to photoperiod (Thompson and Medeiros, 1981).

Weed control is essential to produce high yields of *Stylosanthes* seeds with low weed seed contamination. Under local conditions manual weeding may be most appropriate because the optimum timing and frequency can be changed and adapted to the level of weed infestation found in the field. One early weeding, when the weeds are just big enough for easy removal by hand, appears most effective. A second weeding before row closing may be necessary to remove the weeds that germinate later. Also, it seems necessary to remove the weeded material from the field to avoid re-establishment. Some contamination with weed seeds occurred in 'weed-free' plots because certain legume weeds were not easy to distinguish from *Stylosanthes* and therefore remained. However, manual weeding is labour-intensive and requires about 100 man-days per hectare (Agishi 1986).

Seed purity appears to be unaffected by weeding or herbicide treatments. Maximum purity of 85–90% was obtained in early harvests (Figure 1). In the weeding and herbicide trials mean purities ranged from 67 to 83% with no apparent treatment effects. Winnowing efficiency and the particle size and composition of the inert material may account for the differences. However, the low level of purity indicates that with manual seed clearing, quality standards are difficult to attain (see Agishi, pp. 275–285).

For weed control of larger areas, herbicide application may be feasible. In Côte d'Ivoire Trifluralin is used in commercial seed production of forage legumes. Hand weeding may still be needed to eradicate resistant weeds. The effectiveness of each herbicide depends on the botanical composition of the weed flora, which should be known before the selection of the appropriate single or combination of herbicides. The combination of Bentazon with Cycloxidim provided control of a wide range of weeds. Although re-emergence herbicides are easier to apply, post-emergence applications are also used for selective weed control. The time of application needs to be chosen carefully when weeds are most susceptible whilst avoiding damage to the legume (Hawton et al, 1990). This requirement, in addition to the possession and the expertise in handling the appropriate spraying equipment, implies that chemical weed control can only be recommended for the specialised seed producer.

Planting in rows facilitates both hand-weeding and herbicide application. On fertile soils, rows will close by the middle of the growing period so that weeds that emerge late are usually suppressed. Khara et al (1990) recommended row spacings of 40 cm for Verano which produced higher mean seed yield (950 kg/ha) than a 20-cm spacing (850 kg/ha).

In older Verano stands regenerating from seed-plant density is high and rows disappear. Older pastures should not be used for seed production when weed infestation and competition between legume plants has reached unacceptable levels. Agishi and de Leeuw (1986) stated that after four to five years fields become dominated by grasses and other nitrophilous weeds mainly due to the accumulation of nitrogen in the soil. In Côte d'Ivoire, after three years of seed production fields are usually cropped.

Provided weeds are controlled successfully, selecting the right time for seed harvest will be the main determinant for maximum yield. If seeds are harvested directly by cutting, the proper time to harvest is when the first seed fall occurs. Mechanised harvesting with combine harvesters is also possible at that time (Hopkinson and Loch, 1977). Specialised suction harvesters have also been used for mechanical collection of seeds (Hare, 1985). Sweeping fallen seeds can give additional yields and should be done when most seeds have dropped. As much as 44% of the total yield can be collected by sweeping between rows (Khara et al, 1990) and sweeping is also recommended by Wickham et al (1977). However, when seed collection is done later in the dry season precautions are needed to avoid yield loss by bush fires.

In Thailand and in Nigeria, cleaning swept material is very time-consuming since large quantities of soil and plant litter need to be removed (Agishi, 1986). The lack of appropriate equipment for seed cleaning is one of the limiting factors precluding the production of high-quality seeds. Adapted seed cleaners are available, or can be manufactured locally (Hare, 1985).

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Stylosanthes seed production management

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Abstract

Practical aspects of seed production from field multiplication through seed cleaning to storage and quality (based on work done at the Department of Primary Industries, Queensland, Australia, and ILCA) are presented in this paper.

Gestion de la production de semences de *Stylosanthes*

Résumé

Cet article présente les aspects pratiques de la production de semences sur la base de travaux effectués au Department of Primary Industries à Queensland (Australie) et au CIPEA. Les thèmes abordés vont de la multiplication au champ à la conservation en passant par le nettoyage et le contrôle de la qualité des semences.

Introduction

Pasture seed production of *Stylosanthes* species is a complex activity which requires knowledge of the plant morphology, the physiological mechanisms by which flowering is controlled and the way in which these factors interact with one another and with the environment to produce a seed crop. It is important both to know how they differ and to be aware of commonly recurring characteristics so that when a new situation arises the appropriate management strategy can be selected. This paper has been designed to be used in conjunction with the ILCA Herbage Seed Unit fact sheets (Annex).

Plant characteristics

The type of plant growth habit will result in a limited or continuous flowering period. Most determinate species produce only one seed crop a year. Indeterminates have a greater capacity to produce multiple crops annually. *Stylosanthes* species are determinate in growth and their seed production can be well managed in a known environment (Audru, 1971). The plant habit will also affect the production strategy, establishment, weed control, crop management and the harvesting technique.

The reproductive physiology of a pasture species is of fundamental importance to seed production. It affects the choice of locality and the management and harvesting of the crop. Two mechanisms usually control flowering in tropical pasture legumes. One is the short-day (SD) photoperiodic response. The other is stimulation of reproduction by stress.

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A short-day plant tends to flower at the same time each year during shortening days, and to cease flowering at some time during lengthening days. There is normally a sharp transition from totally vegetative to mainly reproductive development helping to promote heavy and well-synchronised flowering. Stylos tend to flower in short or shortening days though there may be variation within species (Trongkongsin and Humphreys, 1987). Cook stylo under rigid photoperiodic control is entirely dependent on environmental changes to help it seed. If a species has a short-day response, new cultivars of the same species will probably also flower in short days, even if they flower at slightly different times. Photoperiodic or stress responses can be influenced by interactions with temperature. Juvenile stages, when the plant is too small or young to respond to or receive stimuli, are often unresponsive.

Table 1. *Flowering mechanism of some* Stylosanthes *species.*

Species	Photoperiodic response	Stress control
S. guianensis var *guianensis*	Most SD	Some LD
S. guianensis var *intermedia*	LD	–
S. hamata cv Verano	Weak SD	–
S. scabra	Variable SD	Inferred

SD = Short day; LD = Long day.

Source: J. H. Hopkinson, Department of Primary Industries, Walkamin, Queensland, Australia (personal communication).

Establishment of seed crops

Choice of locality

The correct choice of locality for seed production is very important. More failures are caused by poor choice of site than any other factor. Experience has shown that for any cultivar, successful seed production on a long-term basis is possible only within a narrow climatic range.

Climate has a major effect on yield and, unlike nutrient and moisture supply, may only be marginally modified by the grower. The ideal climate is one which has suitable radiation, temperature and rainfall for the vegetative growth of the crop, favourable photoperiods and temperature for floral induction and stable dry, relatively still weather during the maturation stage (Hopkinson and Reid, 1979).

Seed production is best where the average annual rainfall is within the range 800–1000 mm per growing season. Common stylos can yield well in wetter conditions in spite of disease and harvest problems. Reliable, well-defined wet and dry seasons are needed. A wet season of about four months duration is suitable for most stylos. Irrigation is useful, especially to emulate drought stress. A reliable dry season improves reproductive vigour, reduces lodging, makes harvesting easy and minimises seed losses due to diseases and rain-induced shattering. Strong seasonal winds may cause loss of mature seed from the parts.

Provided mineral nutrient deficiencies are recognised and corrected, common and shrubby stylos may be grown on a wide range of well-drained soils for seed production. Sandy top soils are preferred for persistence of Verano and fine stem stylo. Poor drainage, however, delays flowering, reduces flowering vigour, and delays machine-harvesting of crops. Cracking soils should be avoided if seed is to be swept up off the ground.

Choice of site and grower

The first requirement is for a suitable area of 'clean' soil, free from seed of old 'cultivars' and weeds. Farm equipment such as tractors and ploughs, and a capacity for mechanical or manual harvesting, drying, cleaning and storing seed are needed. Storage facilities must be sufficient to hold the volume of seed during drying and threshing as well as in bags. The 'grower' must have technical competence, integrity, be reliable, and possess a general ability and temperament to handle the detail required to produce seed not forage. Specialist or opportunist production systems can be used. The former requires considerable attention to detail but the latter can be adopted where the stylo is used as a pioneer crop (Agishi, 1986).

Seed crop establishment

The first requirements for a healthy, productive seed crop are good ground preparation, adequate mineral nutrients, early attention to weeds, pests and diseases and suitable growing conditions after planting. Early wet season is the common planting time. Unless early rain is reliable, mid- to late-season sowings are safer. A clean, well-prepared seedbed is necessary; stylo seed crops are established directly from scarified seed, with inoculation of an appropriate *Rhizobium* strain. Forty per cent hardseed is considered a useful precaution against irregular rains, although seeds are normally retailed with a 10% hardseededness.

Row planting at a shallow depth is advisable and rolling after planting is useful. Row planting allows inter-row cultivation and other weed-control measures as necessary. Sowing rates of 4 kg per hectare are common, although Townsville and Verano stylo may require a higher sowing rate of up to 40 kg/ha (Shelton and Humphreys, 1971). A phosphate application of 100 to 400 kg per hectare may be used as a precaution initially and then every other year to correct deficiencies, if suspected (Shelton and Humphreys, 1971; Rai and Kanodia, 1980).

Seed crop management

The aim of stylo management is to obtain a closed vegetative canopy which smothers weeds and provides a structure on which the seed crop will be built. Weed control during this stage is very important (Kachelriess et al, 1992). Fortunately stylos are tolerant to a wide band of herbicides (Table 2). When a vegetative cover has been achieved, a short-day legume is easy to manage. To ensure the greatest density of inflorescences, cutting or grazing for synchronisation is useful but is only possible with common stylo. Excessive growth as in *S. guianensis* cultivars can be a hindrance at harvest, causing flower heads to appear at different heights and the tangling of stems in mechanised harvest operations. Defoliation must be done, but early enough to ensure canopy recovery before or at flower initiation. The effects of defoliation on seed production of *S. hamata* cv Verano were studied by Wilaipon et al (1979).

Anthracnose (*Colletotrichum gloeosporioides*) is the most prevalent disease of stylo. It requires the selection of suitable sites (often of less than 1000 mm annual rainfall), tactical treatment with the fungicide benomyl, or production of a stylo variety with reasonable field tolerance, such as cv Seca.

The useful life of commercial seed crops varies from three to four years. Townsville and Verano stylo behave as annuals. The others are perennials and require renovation according to the degree of weediness, especially in shrubby species. Common stylo is vulnerable to fire and excessive grazing or low cutting. In all cultivars the population densities may become too high and require thinning.

Table 2. Stylosanthes *tolerance of herbicides.*

	Herbicide and method of application								
Species	Acifluorfen	Benfluralin	Bentazone	Dinosed	Fluazifopbuty	Sethoxydim	Trifiuralin	2,4-D	2,4-D,B
S. guianensis	VT3	T5	VT6	VT4	MS1.5	–	T2	T1	T
S. guianensis	MS6	–	–	–	–	–	–	–	MS2
var *intermedia*	–	–	VT6	–	TO5–2	T1	–	VT2	VT4,8
S. hamata	S3	T5	VT3,T6	VT4	MS1.5	MS2–4, R	T2	T1–2	T
S. scabra	S3	T5	T3-6	VT4	T1.5	–	T2	T1–2	T

Recommended rate litre/ha indicated by figures, otherwise normal recommendations apply 400 g/l or g/kg.

VT = Very tolerant; T = Tolerant; MS = Moderately susceptible; S = Susceptible.

Source: D. Hawton, Queensland Department of Primary Industries (QDPI), Australia (pers. comm.).

Harvesting the crop

Optimum harvest time

The selection of a suitable harvest time for seed crops is often difficult because of the uneven ripening. It is best to judge when the greatest quantity of viable seed can be harvested by observing the proportions of shattered, mature and immature seeds throughout the ripening phase. If hand-harvesting is to be used, this should begin as soon as the earliest seed ripen. It is necessary to remind seed producers to become familiar with the procedures for monitoring seed-crop development and productivity. It is important to relate flowering to ripening and eventual harvesting. Progressive counts need to be taken of the numbers of flowers, green and ripe pods. In *Stylosanthes* species distinctions between the stage of development of inflorescences are difficult and only total counts of inflorescences can be done without great difficulty. Supplementary information as to the stages of development can be determined by dissection under low magnification (Loch et al, 1976), which will also help provide information on the extent of any failure to set seed. Subsampling of field quadrats (0.4–0.5 m) is required to reduce the work load of sampling caused by the large numbers of growing points, inflorescences, flowers and pods. After cutting a quadrat, ripe fallen seed can be swept up using a pan and stiff brush and subsequently cleaned. Tagging floral development and sequential harvesting experiments may help build up experience on how to determine harvest ripeness. Thereafter, close and regular observation of the ripening crop, to look for colour changes as well as ease of shedding and seed removal helps complete the assessment as to optimum harvest time.

Harvest method

The method used to harvest stylo depends on the nature and size of the crop, availability of labour and machinery, the quantity and purity of seed required, the weather and many other factors.

Hand-harvesting is used where purity and maximum recovery are critical, or when labour is inexpensive. Seeds are shaken or knocked into bags or the whole crop is cut and rolled, threshed and the fallen seed swept, together with soil particles, for sieving and drying. Direct combining is possible in common and shrubby stylos, since little seed falls to the ground, but machines of 200 bhp are required to handle the vegetative mass. Suction harvesters were previously popular but are now rapidly falling out of favour, primarily due to the cost of maintenance caused by excessive wear and tear from the abrasive nature of the soils.

Post-harvest processing

Seed drying

Freshly harvested seeds of stylos may be quite moist and must be dried to 8–12% moisture content before storage. However, the seeds must not be dried too quickly or at excessive temperatures. Indirect sun drying on tarpaulins, canvas or hessian racks, concrete or wooden floors, or the bare ground is preferable to direct exposure. It is important that the ambient air and seed temperature does not exceed 35°C. Currently, oven drying is the only reliable technique for estimating moisture content, but as a guide the following table of percentages of ambient relative humidity and seed moisture content can be used. Figures were obtained using a hair hygrometer in a sealed, transparent bucket of seed (Table 3).

Table 3. Stylosanthes *seed moisture equilibrium with content and ambient relative humidity.*

Relative humidity (%)	50	60	70	80
Stylo seed moisture content (%)	8.0	10.0	12.0	14.0

Seed cleaning

The aim of seed cleaning is to remove all contaminating matter. It is always easier to remove inert material than weed seed therefore seed cleaning should begin in the growing crop by careful weed control. It is important to avoid even the slightest contamination by weed species, as the weed may become a perpetual contaminant of new pasture.

Stylo seeds occur in various forms, hooked (Verano) and unhooked (shrubby stylo) and within a hull (common stylo). The seeds should be cleaned according to morphology.

Air-screen cleaners are widely used, relying on wind and moving screens to separate material of different size and density. Sieves can vary from 1.5–10.00 round holes and 0.3–5.5 slots. Gravity tables also exploit density differences and are useful for separating different grades of seed that are already clean. Length separators (indent cylinders) are used to separate seed of different length. Scarification is required to reduce hardseededness (Table 4). It is possible to make home-made farm cleaners (most of which are simple screen/air machines) and use hammer mills as scarifiers; they are cheap and may be useful where capital is short.

Table 4. *Current recommendations for reducing levels of hardseedednesss in* Stylosanthes *seeds.*

Species	Treatment methods	Treatment preferred
Stylosanthes guianensis var *intermedia* (fine-stem stylo)	Hot water at 80°C for 6–8 min	Heated cylinder (120°C for 15 min
Stylosanthes scabra (shrubby stylo)	Clover polisher (< 50% dehulling) Hot water at 80°C for 5 min[1]	Hammermill (50% dehulling)
Stylosanthes hamata (Caribbean stylo)	Hot water at 80°C for 6–8 min Clover polisher (partial dehulling)[3]	Heated cylinder (150°C for 15–25 sec)[2]

1. Do not exceed 5 minutes as some seed death has been recorded after longer periods of treatment.
2. Optimum times and temperatures may vary depending on specific construction of the heated cylinder.
3. Further validating work required.

Cleaned seed yields are very variable due to the different seed production management practices. Yields range from 200 to 800 kg/ha with a potential (standing and fallen seed) of up to 1800 kg per hectare.

Seed storage

Stylo seeds have ‘hard’ or impermeable coats and can survive longer than grasses, which have a higher equilibrium with surrounding atmospheric conditions determined by temperature and relative humidity. Seeds stored under cool dry conditions maintain seed viability for longer periods. Storage hygiene to control insects, moulds and rodents must be exercised and the premises designed and built of materials to help maintain cool dry conditions. Seed quality should be continuously monitored from season to season.

Seed packaging

To prevent moisture absorption, polyvinyl chloride (PVC) of 480 micron thickness or 180 micron high density polythene is often used to line jute and paper bags. The outer packaging material is then printed with relevant information and may in addition be labelled with information on seed quality. The seed itself may be coated (pelleted) with inert material which incorporates micronutrients, various “fungicides or insecticides”, growth promoters and rhizobia to facilitate flowability and establishment of the crop.

Seed testing

The accuracy and usefulness of any test depends on how representative the subsample is of the whole. The moisture content of stored seed can be difficult to measure accurately. More details on equilibrium moisture contents have been indicated under section seed drying.

Pure seed is used for germination or viability tests. Separating non-seed material from stylo seed is easy, although they often have high weed seed counts. Immature seeds can also be easily separated. Germination tests are needed and can be conducted with a minimum of equipment. Seed trade standards appear to be 40% germination and 96.5% purity with 10% hardseededness for common stylo seed.

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Annex

Checklist for seed production fact sheet

A.	Species:	Include Latin (botanical) and common names
	Cultivar(s):	Restrict to those with comparable seed production characteristics
B.	Origin:	Ecological and geographical (accession passport data), any pre-release breeding programmes.
C.	Adaptation:	Rainfall (include drought-tolerance) Temperature (include cold/frost/heat tolerance) Soil (include texture/pH/fertility preferences, salinity/ toxicity/waterlogging/flooding tolerances)
		Shade
		Fire
		Defoliation (include location of plant crown)
		Rhizobium (legumes)
		Seeding ability (shy or free-seeding)
D.	Morphology:	Plant habit (include determinate/indeterminate, herbaceous/woody, prostrate/stoloniferous/twining/ sprawling/shrubby/erect, annual/biennial/perennial) Inflorescence/flower (structure)
E.	Flowering behaviour:	Controls (day-length, stress, temperature) Seasonality (approximate dates of flowering)
		Developmental phases (approximate time in weeks to floral initiation, first flowering, harvest maturity)
		Diurnal flowering (daily flowering time)
F.	Reproduction:	Sexual (self-pollinating or out-crossing, include isolation requirements)
		Asexual (seeding by apomixis, vegetative by cuttings/splits)
G.	Site selection	
H.	Production strategy:	Sward (pure/mixed)
		Trellis (legumes)
		Crop rotation/renovation (include annual/perennial basis) Farming system (opportunist/specialist, combine with hay etc)
I.	Establishment:	Timing (if special requirements) Seeding rate (include kg/ha and quality)
		Seed scarification/treatment (include scarification method and procedure, pelleting)
		Seed inoculation (legumes)
		Seedbed (include rolling)
		Sowing depth (note exceptions to surface sowing)

		Planting pattern (broadcast/row width/grid pattern)
		Fertiliser (quantity and type, application method)
J.	Weed control:	Establishment (also for annual or occasional renovation, include pre-emergence and post-emergence control)
		Established crop (post-emergence)
K.	Crop management:	Defoliation (grazing/cutting, height, time)
M.	Harvesting – Manual:	Technique and details (e.g. sickle and stook, sickle and sweat, shake, sweep, trellis for legumes, hand-plucking)
		– Mechanised: Equipment
		Adjustments
		Special techniques (wind-rowing, rethreshing etc)
N.	Drying:	Natural
		Artificial
O.	Seed characteristics:	Shape and dimensions
		Appendages (awns, hairs, sterile florets/spikelets)
		Seed volume (weight per litre)
		1000-seed weight (in grams)
		Dormancy/hard-seededness (include degree and duration)
P.	Conditioning:	Air/screen (size and shape of screen apertures)
		Indent cylinders (pocket size)
Q.	Expected yields:	Cleaned seed yields (kg/ha per crop, number of crops per year)
		Seedheads/m^2 and other components at maturity (include fertiliser history with kg N/ha per crop for grasses)
R.	Seed testing procedures:	Purity (include pure seed definition, hand or blower method)
		Germination (include pretreatment, temperature regime, light, alternatives, first and final counts)
		Tetrazolium (details of conditioning, cutting, staining, evaluation)
S.	Benchmark quality standards:	Purity
		Germination
		Pure live seed (PLS)

Section 7

The impact of *Stylosanthes*

An assessment of farmers' adoption rate and potential impacts of stylo-based feed production systems

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Abstract

In this paper the fodder bank concept and the procedures of establishment, fencing and management are briefly described. The adoption rates by farmers and agropastoralists are discussed, highlighting the importance of credit, which has been part of the extension package. Other factors influencing this rate include problems with land ownership, finding labour for establishment and the high failure rate especially in the drier areas of Nigeria.

With the continuing devaluation of the Nigerian currency, establishment costs have escalated. As credit levels did not keep pace with this upward trend, adoption rates slowed down. Increasing credit, better training of extension staff in package delivery and propagating the fodder-bank message more effectively through the media may reverse this trend. Placing stronger emphasis on the impact on both livestock and crops will strengthen the message as it appeals to both small farmers and agropastoralists.

Between 1987 and 1991, a total of 637 fodder banks were established under "farmer-managed" supervised loans of the World Bank Second Livestock Development Project. Adoption rates were high amongst pastoralists having title to land or those already settled inside grazing reserves.

With the downward trend in the Nigerian economy, farmers prefer to put their available land to profitable crop production rather than tie it down to pastures. However, the impact of fodder banks has been felt through improved animal growth rates, increased milk production and calf survival in herds with access to fodder banks as compared to those without.

This paper assesses the future development of fodder banks across Nigeria on the basis of interest and resources available to the pastoralists in view of the demand for land and scarce feeds for the national herd.

Evaluation du rythme d'adoption et de l'impact potentiel des systèmes de production d'aliments du bétail à base de *Stylosanthes*

Résumé

Cet article expose brièvement le concept et les techniques d'installation, de clôture et de gestion des banques fourragères. Le rythme d'adoption de cette innovation par les paysans et les agropasteurs est examiné et l'accent mis sur l'importance du crédit, lequel fait partie intégrante de l'ensemble des mesures vulgarisées. L'adoption dépend d'un certain nombre d'autres paramètres, y compris les problèmes liés au mode de propriété de la terre, les pénuries de main-d'oeuvre et le taux élevé d'échecs, notamment dans les régions les plus sèches du Nigéria.

Avec la dévaluation continue de la monnaie nigériane, le coût d'installation des banques fourragères n'a cessé d'augmenter. Et, étant donné que le montant des crédits n'a pas suivi le mouvement, le rythme d'adoption s'est ralenti. L'augmentation des crédits, une meilleure formation des agents de vulgarisation et une technique plus élaborée de diffusion du message à travers les médias pourraient permettre de renverser cette tendance. En mettant davantage l'accent sur l'impact de cette innovation sur la production animale et végétale, on rendrait le message plus attrayant dans la mesure où il séduirait à la fois les petits paysans et les agropasteurs. Un total de 637 banques fourragères ont été installées entre 1987 et 1991 grâce à des crédits gérés sous supervision par les paysans et consentis dans le cadre du Deuxième Projet de développement de l'élevage financé par la Banque mondiale. Le taux d'adoption était élevé parmi les éleveurs possédant des titres de propriété ou installés sur des aires de pâturages protégés.

Avec la récession économique au Nigéria, les paysans préfèrent consacrer leurs terres à des cultures — plus rentables — plutôt que de les immobiliser avec des pâturages. Cependant, les conséquences des banques fourragères étaient évidentes, notamment à travers une croissance plus rapide des animaux, l'augmentation de la production laitière et la baisse de la mortalité des veaux.

Enfin, cet article examine les perspectives d'avenir des banques fourragères dans l'ensemble du Nigéria et ce, en tenant compte de l'intérêt suscité par cette innovation, des ressources dont disposent les agropasteurs, du problème de la rareté de la terre et des pénuries d'aliments du bétail.

Introduction

Nigeria is a country with immense agricultural potential as it extends from the Atlantic coast to the fringes of the desert. In most of its territory crops and livestock can be grown successfully; the livestock sector includes cattle, sheep and goats and is important for the supply of meat, milk, hides and skins and secondary products such as manure and traction.

Over the years, inadequate nutrition has been identified as the major constraint to livestock production (Mohamed-Saleem, 1986) which becomes more serious as the dry season progresses. Pastoralists who still own about 75% of the national herd, go through this difficult period by supplementing their animals with agricultural by-products which are becoming scarcer and therefore more expensive. The natural grazing lands provide poor-quality feed which at the beginning of the dry season contains about 3% crude protein and is therefore inadequate for animal maintenance, let alone production.

Many years of on-station research by ILCA in the subhumid zone of Nigeria led to a stylo-based feed production system called the fodder bank which provides concentrated legume feed to be preserved for dry-season grazing. Over a decade ago this package was passed on to National Livestock Projects Division (NLPD) for extension and transfer to the livestock owners. A critical evaluation of this extension programme is necessary for the assessment of the adoption rate and impact on the livestock production systems of the country.

Fodder-bank establishment and management

The fodder-bank concept

The fodder-bank concept resulted from demands for better livestock production systems in the subhumid zone of Nigeria. Even though livestock owned by pastoralists move from pasture to pasture they lose weight during the dry season because they do not receive the right amount of nutrients, in particular crude protein. Therefore, fodder production by intensive cultivation of forage legumes was seen as a solution.

The establishment and management of fodder banks requires the following activities:

- fencing a block of about four hectares
- preparing a proper seed bed
- broadcasting stylo seeds that are scarified or soaked in hot water
- applying phosphorus fertilisers
- grazing before and after sowing to reduce grass competition
- deferring stylo grazing until full establishment is accomplished
- grazing during the dry season while protecting the bank against fire
- allowing sufficient seed reserves to build up for regeneration in subsequent years.

Fencing fodder banks

A good site should be selected, i.e. stony or waterlogged areas should be avoided. The size of fodder bank would depend on the number of animals in the herd. Under the supervised credit scheme for pastoralists, NLPD designed different types and appropriate sizes of fodder banks, ranging from one hectare for small-scale farmers to 4 ha for agropastoralists.

It is necessary to fence fodder banks to prevent trespassing and uncontrolled grazing. Materials available for fencing include wooden posts and barbed wire while some farmers experimented with metal or live posts. Fire breaks are essential to prevent accidental fires which are a common risk during the dry season. Most fencing materials are expensive and constitute a major cost component of fodder-bank establishment.

Seed bed preparation

A successful fodder bank starts with thorough seed-bed preparation. Whilst tractors for ploughing and harrowing are ideal, most farmers cannot afford this investment or lack the cash to hire equipment. Therefore other methods of seed-bed preparation have been devised such as kraaling of animals on planned sites and burning before sowing (Mohamed-Saleem, 1986). Undersowing legumes in crops at appropriate times during the last growing season in the cropping cycle is an alternative method of establishment. All these methods have their advantages and disadvantages; for instance, some pastoralists complained of worm infestations of animals kraaled for several days, animal dung was lost to the detriment of crops and instead created serious weed infestation in what was hitherto considered communal land. Therefore, except for its high cost, preparation of clean seed-beds with tractors was the most desirable option.

Seed sowing

Sowing rates of stylo depend on seed quality (purity and germination rate). Since hand-harvested seeds are usually of low quality, a seeding rate of 15–20 kg/ha is recommended for adequate establishment. Sowing should be done when the rains have properly stabilised, because seed-harvesting ants are most active when there are dry spells following sowing. However, a mixture of wood ash and stylo seed sown as a slurry prevented theft by harvester ants (Ajileye, unpublished data).

Stylo seeds possess a high degree of hard-seededness which can be reduced by hot-water treatment. For optimal results only half of the seed should be scarified, because most treated seed germinates immediately after the first post-sowing rain falls while unscarified seed remains dormant until more favourable conditions prevail later.

Application of fertilisers

For good establishment, stylo-based fodder banks should be fertilised with sulphur and phosphorus which are often deficient in tropical soils. Single superphate fertilisers contain these elements and using 150 kg/ha at establishment is recommended.

Reduction of grass competition

Fast-growing grasses compete with stylo seedlings during establishment. Grazing and fertiliser application enables the stylo seedlings to get established and bulk-up rapidly. Since grasses are more palatable than stylos at this stage, they are selectively grazed thus reducing competition. Animals should be withdrawn as soon as the stylo starts flowering to allow high seed production to occur.

Management of established stylo fodder bank

Average pastoralist herds consist of about 50 head of cattle of which 15 to 20 are cows (Mohamed-Saleem and Suleiman, 1986). These cows could be adequately supplemented by a four-hectare fodder bank for a six-month dry season given a potential dry-matter yield of four to five tonnes per hectare with a crude-protein content of stylo of about 12%. The selected animals should graze the bank only for 2.5 hours per day either in the early morning or after returning from savannah grazing in the evening. With a stocking rate of upto five animals per hectare over six months many banks have been sustained for several years. However, many pastoralists are reluctant to restrict the use of fodder banks to pregnant and lactating cows alone because they believe that all their cattle are important and should benefit equally.

Adoption rates of fodder banks

Since the fodder-bank programme was initiated in the early 1980s, by 1986 about 25 banks were established before the credit package was introduced by NLPD (Figure 1). The second Livestock Development Project of NLPD started in 1987 with a World Bank loan. Several livestock development models were considered including providing credit for the establishment of fodder banks. This credit scheme increased the rate of adoption so that by 1990 over 400 fodder banks had been established (Figure 2). However, in 1991, this rate dropped due to the following reasons:

Land tenure

This is one of the most important constraints as traditional pastoralists rarely own land nor have fully recognised usufructuary rights. It is therefore difficult to recruit pastoralists for this programme since they face a myriad of problems in securing land from the local crop farmers, the traditional owners of land. Therefore the government has tried to create grazing reserves and allocate them to pastoralists; as a result some fodder banks were established there. However, few grazing reserves have been gazetted and allocated to pastoralists; thus land availability for fodder-bank development will remain a major constraint especially now that marginal land is being competed for by other sectors of the economy.

Lack of labour

Finding labour to start and maintain fodder banks is another problem. Since early in the rainy season much labour is required for crop production, hired labour is scarce. Thus, demand for hired labour is very high and pastoralists have to pay dearly to attract workers.

Ecological problems

Fodder banks were designed for and tested in the subhumid zone and proved quite successful. Attempts to introduce the package into the semi-arid zone met with less success due to the lower rainfall and shorter growing season, thus creating a less favourable environment for the legume of choice — Verano stylo. The few farmers who adopted the package in Bauchi, Katsina, Sokoto and Borno states gave up a few years later. They failed to see the merits of the package “since the stylo was not there when they needed it”. This failure discouraged other farmers in the semi-arid zone to enlist in the programme.

Figure 1. *The number of fodder banks established in Nigeria from 1981 to 1986.*

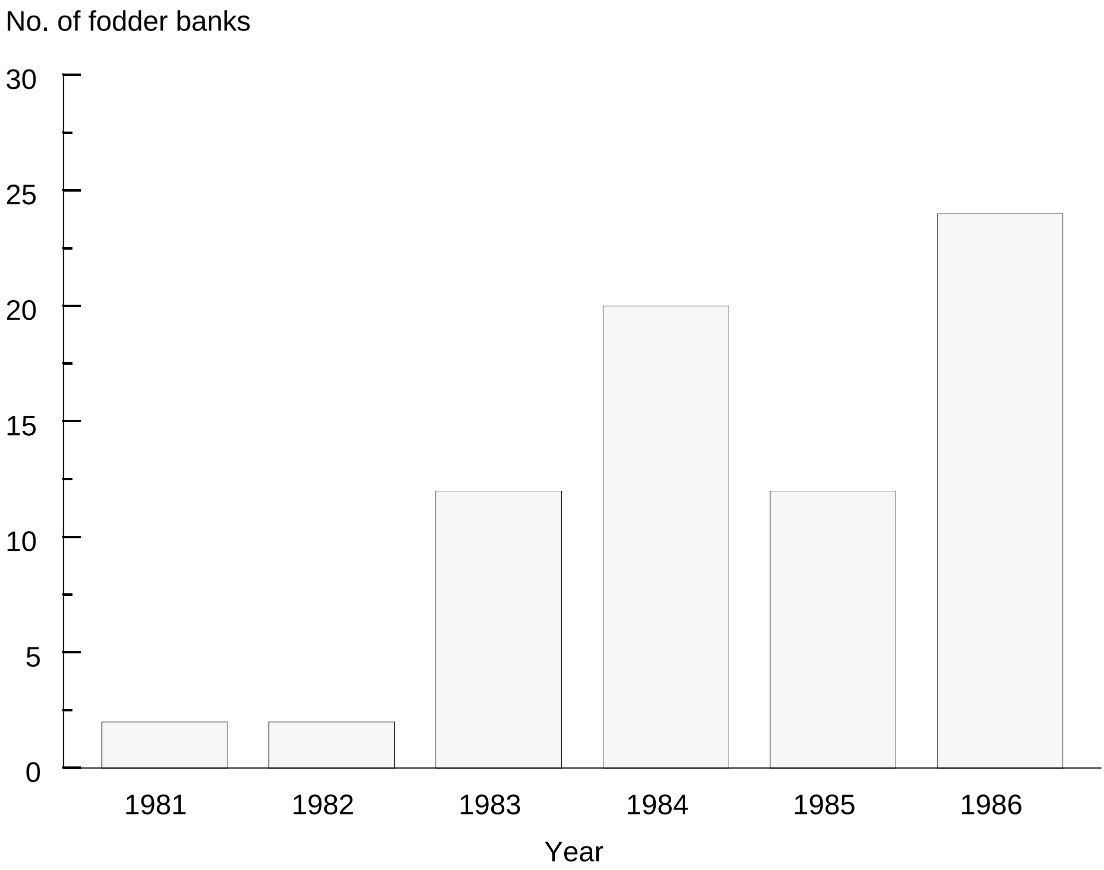
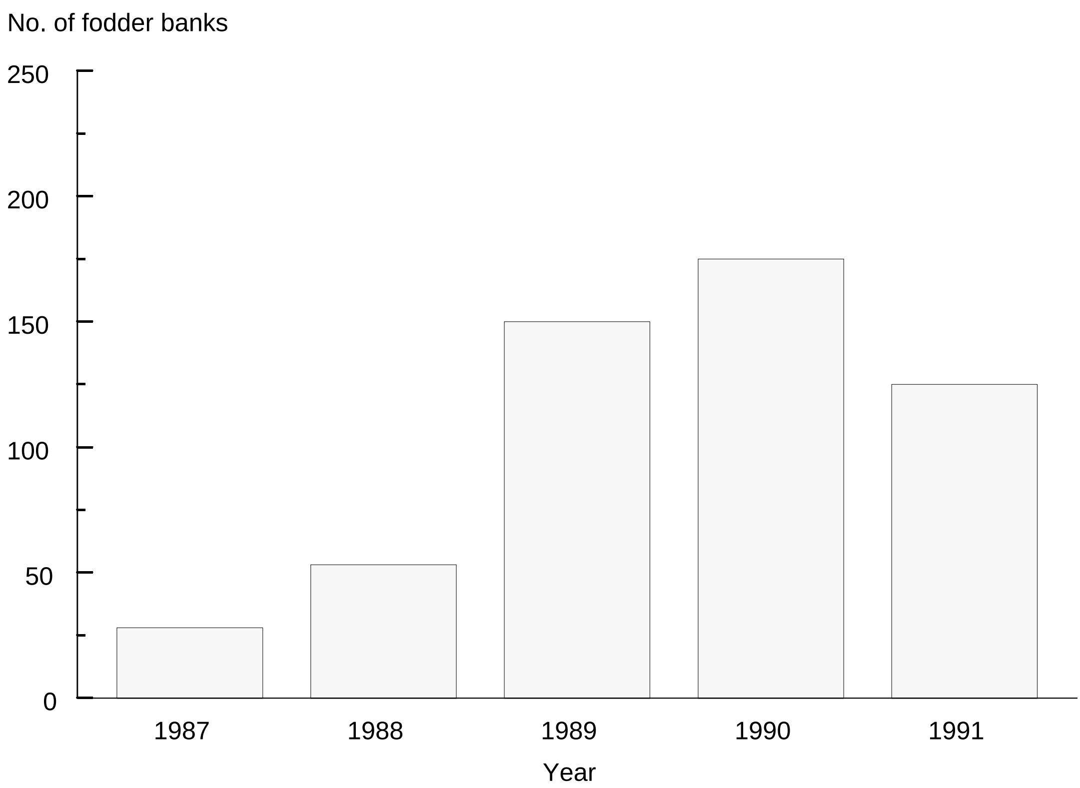


Figure 2. *The number of fodder banks established in Nigeria from 1987 to 1991.*



Economic problems

At present, the costs of fodder-bank inputs are higher than the loans provided by the project. For example, the cost of 1 m of barbed wire in 1984 was ₦ 0.35 as compared to ₦ 2.00 in 1992. Fencing costs represent about 80% of the total inputs, while prices of stylo seed and fertilisers have also risen. Thus, pastoralists have to find other sources of cash to complement the available credit. The present inflation rates have also increased the value of the land. Thus, farmers prefer producing cash crops (like cotton, maize, wheat, rice etc) rather than tie land down to fodder banks for several years.

Extension contact

Through a rapid appraisal including several states in the northern parts of the country, it was found that few farmers were aware of the fodder-bank programme. To remedy this, NLPD sponsored many radio programmes to propagate the concept. Also, contacts with current adopters need to be improved while extension staff require adequate training in order to transmit the correct messages to farmers. Frequent visits and supervision are important to sustain the Project.

Benefits of fodder banks

Most pastoralists who have invested in fodder banks agree that they are useful as supplementary feed during the dry season and that animals grazing fodder banks perform better than those without such access. During the dry season pastoralists make less "forced sales" of underfed stock and say that cows grazing fodder banks have higher conception rates and milk production, and that more calves survive. There is also increased security of tenure of fodder-bank land because the fencing component ensures official recognition of ownership and prevents trespassing. Many farmers save the cost of hiring labour for herding by confining their animals inside fenced fodder banks. Crop farmers are taking advantage of the nitrogen build-up in fodder-banks through rotational cropping. They have been convinced by results from experiments which indicated considerable benefits to crops grown on previous fodder-bank sites (Mohammed-Saleem, 1986; Tarawali, 1991). The extension package now recommends rotational cropping emphasising the beneficial interactions between both crop production and fodder banks.

Conclusion

The fodder-bank package has been effective as a simple way of providing supplementary feed to livestock during the dry season while the rate of adoption has increased by providing credit as part of the package. However, since the devaluation of the Naira in 1985, the costs of establishment coupled with other technical problems has slowed down adoption. Although costs are high, some farmers still believe that the benefits are greater than the costs, which they say are equal to the price of two bulls which many pastoralists can readily afford. Therefore, extension efforts should be intensified while at the same time adapting the package to the current economic situation in the country by increasing the rate of credit.

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Stylo-based feed production research: The implications for future development

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Abstract

In most African countries there has been a strong desire to devote resources to pasture development, but it is often not clearly understood how these pastures can be integrated into the overall land development. Legume forages can improve livestock nutrition and restore degraded soil, both aspects being important to farming systems in sub-Saharan Africa. The type of legume, where to grow it, the amount of land to use and the impact from the regional to the village level is difficult to project from the results obtained in a few widely dispersed experimental sites. Land suitability assessments are required to determine the maximum benefits that can be derived from different land-use types and crop mixtures.

The FAO agro-ecological zones (AEZ) methodology provides a simple tool for land suitability assessment that has been successfully adapted to assess land suitabilities for Verano stylo in 10 West African countries. To formulate growth rules for Verano stylo some assumptions were made through expert consultations where actual experimental data were unavailable. The AEZ methodology is time- and scale-neutral and assessment can be refined whenever more hard data become available. This does not, however, reduce the value of land assessment for planning purposes. The application to Verano stylo reported here prompted suitability assessment for other land-use types involving different forages and residues from food crops. The necessary data bases and the required computing capacity may not yet be readily available to national researchers; this identifies an area for collaboration with international agricultural institutions. It is hoped that land suitability assessments will eventually pave the way for the much needed sustainable land-use systems for countries in sub-Saharan Africa.

Recherche sur les systèmes de production d'aliments du bétail à base de *Stylosanthes:* conséquences pour les perspectives de développement

Résumé

Bien que la plupart des pays africains souhaitent sincèrement promouvoir l'aménagement des parcours, ils ignorent bien souvent comment intégrer ce paramètre dans le processus général de mise en valeur des terres. Les légumineuses fourragères permettent d'améliorer l'alimentation des animaux et de restaurer les terres dégradées, deux facteurs importants pour les systèmes agraires des régions d'Afrique subsaharienne. Il est difficile, à partir des résultats enregistrés sur quelques sites disséminés çà et là, de savoir quel type de légumineuse choisir, où les cultiver, quelles superficies y consacrer et quel impact en attendre

lorsqu'on passe de la région au niveau du village. Seules des études de compatibilité entre les terres et les espèces végétales permettront de déterminer les avantages éventuels des stratégies possibles de mise en valeur de terres et des associations de cultures.

Instrument simple d'évaluation de ce paramètre, la méthode des zones agro-écologiques de la FAO a été utilisée avec succès dans dix pays d'Afrique de l'Ouest pour tester la compatibilité entre certaines terres et Stylosanthes *cv. Verano. En l'absence de données réelles d'expérience, certaines hypothèses retenues après consultation d'experts ont servi à déterminer les règles régissant la croissance du Verano. Etant donné que la méthode des zones agro-écologiques est indépendante du moment et de l'échelle de l'étude, il est possible de réajuster l'évaluation au fur et à mesure que l'on obtient des données plus précises, ce qui n'entame en rien l'utilité de cette évaluation pour les besoins de la planification. Les travaux rapportés ici sur le Verano ont conduit à d'autres études destinées à évaluer le degré de compatibilité entre des terres d'une part et d'autre part certaines autres espèces fourragères ainsi que des résidus de cultures vivrières. Les chercheurs nationaux ne disposent pas toujours des bases de données et du matériel informatique indispensables, un problème qui peut être résolu grâce à la collaboration avec des institutions internationales de recherche agricole. On espère que les études de compatibilité entre les terres et les espèces végétales permettront de mettre au point des systèmes durables d'utilisation des terres dont les pays d'Afrique subsaharienne ont tant besoin.*

Introduction

The potential roles leguminous forages can play in supporting seasonally nutrient-deficient livestock production systems are well known but rarely considered in the agricultural planning strategies of most sub-Saharan African countries. This is because the potential impacts of forage production are not presented in a national and regional perspective; yet the main objective of ongoing research on forage crops is aimed at alleviating the nutritional constraints experienced in many livestock production systems in Africa.

Nutritional deficiencies caused by low herbage quality occur where the growing period is long due to nutrient dilution in high biomass yields. Both quality and quantity are deficient in areas with shorter growing seasons. Diverse agro-ecological and edaphic conditions and farming systems in West African countries demand different forage-based land-use types (LUT).[1] In recent years, the search for technologies to sustain crop yields under low inputs has become a major research challenge. It is within this context that forage legumes have entered the arena of tropical farming systems research as potential alternatives to unmanaged natural pastures and fallows.

Research goals

Forage research for Africa therefore aims at developing forage production techniques that fit into prevailing farming systems without reducing food crop production and that provide protective soil cover, arrest fertility decline and restore degraded land.

Experimentation with forage crops is commonly carried out in small plots and at specific sites. Hence, it is impossible for a single institution or the NARS (national agricultural research system) in one country to generate all the data necessary to identify and evaluate forages for all agro-ecological and edaphic conditions. Likewise, to tailor forage production techniques to the entire spectrum of production systems, is a difficult task. This calls for information-sharing through collaborative efforts which can only be effective if standard research methods are accepted. Inter-NARS information-sharing involves common approaches to analysis, interpretation and manipulation of data to

1. LUT is a land-use type described in terms of its products and management practices.

aggregate, generalise and extrapolate in order to predict the unknown from the known. This process should provide answers to the following questions:

i) Where else — within and outside a particular country — can similar forages be grown, and what production constraints can be envisaged in sites that differ from the experimental ones?

ii) What is the extent of suitable land for a given forage LUT within a given country or region and how much of this land should be devoted to forages to maintain and increase the output of the livestock population?

iii) What will be the effect on the livestock-supporting capacity, in a given country when more land is allocated to forage crops?

Methodology

A major goal of collaborative research is to avoid duplication of effort and repetition of past work. Research sites should therefore carefully selected to cover a broad spectrum of agro-ecological and edaphic conditions. For example, West Africa is subdivided into four major ecological zones — humid, subhumid, semi-arid and arid — within which six major soil groups are the most common, namely Regosols, Arenosols, Cambisols, Luvisols, Acrisols, Nitosols, Ferralsols and Andosols (Table 1). These subdivisions give rise to a matrix of potential research locations. If a few sites can be selected that cover most of the agro-edaphic situations and uniform trials are conducted, the results can be statistically compared. For example, *Stylosanthes hamata* cv Verano was tested in uniform multi-locational trials for a number of years in both Nigeria and Mali (Tarawali et al, pp. 81–95). Thus, from this matrix of yield data, optimal conditions for herbage growth and the penalties for not adequately meeting the stylo growth requirements, were estimated.

Application of geographic information to forage research

For forage research to answer the questions listed above the following tasks have to be undertaken:

- Selection of representative research sites with assessment of production potentials of forages.
- Identification of constraints to obtaining potential yields to determine management options and to formulate growth rules for the major forage species.
- Matching forage requirements to land characteristics and estimating the extent of suitable land for different forage species.
- Aggregation of estimated forage production totals by suitable land classes for each ecological zone and matching these aggregated totals with the requirements of livestock populations found in these spatial units.

To ensure that research sites are representative, data on rainfall, length of growing period (LPG) and soils are necessary. The FAO/UNESCO soil/LPG data base provides geo-referenced information on the major soil types and climates of Africa; local knowledge is required to choose the sites. However, if the results from research sites are aggregated to predict potential yield at the district, country or regional levels, geographic information at higher resolutions will be needed.

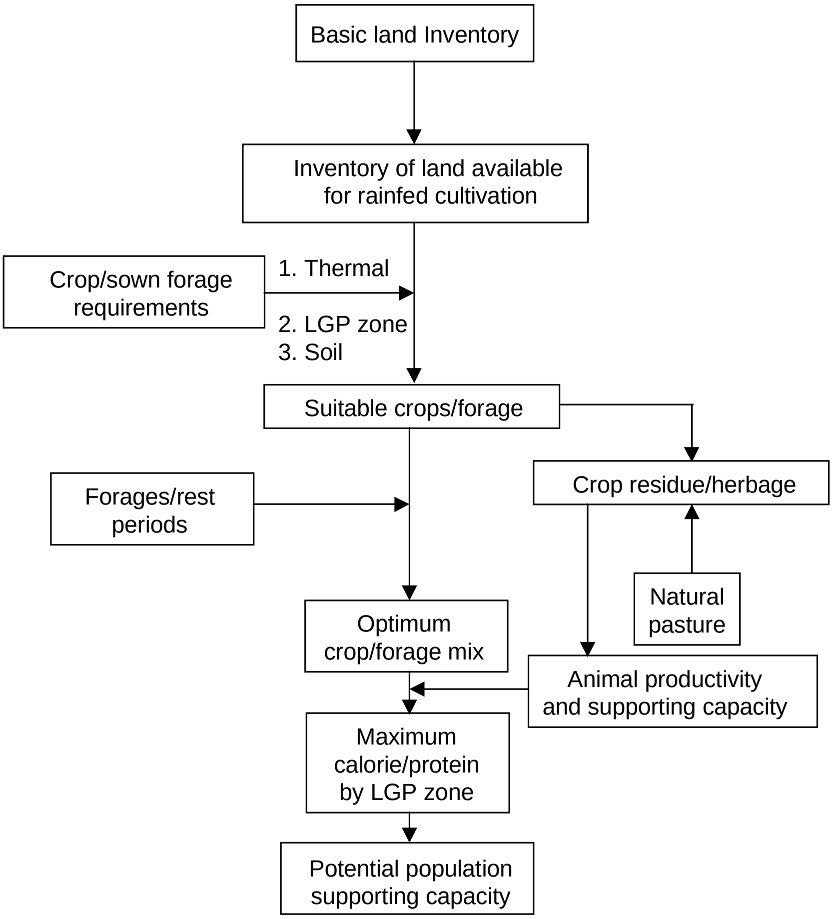
Across Nigeria, *Stylosanthes hamata* cv Verano was established at 20 sites along a north-south transect covering four major ecological zones: semi-arid, subhumid, humid and highlands. Responses of Verano stylo to eco-edaphic conditions were established by inter-site yield comparisons over 3–4 years (Tarawali et al, Table 7, p. 91). For instance, the multi-locational trials provided information on how the cultivar responded to a hard pan within 20 cm of soil profile, to rainfall distribution, levels of fertiliser inputs and grazing

Table 1. *Extent of major soil types in some West African countries.*

	Soils ('000 ha)							
Country	Regosols	Arenosols	Cambisols	Luvisols	Acrisols	Nitosols	Ferralsols	Andosols
Cameroon	1 607	190	274	3 165	2 524	7 354	26 117	374
Burkina Faso	7 478	1 671	1 630	12 681	111	390	–	–
Ghana	59	–	145	11 888	6 024	871	735	–
The Gambia	–	–	–	197	–	327	–	–
Nigeria	4 725	11 510	479	31 524	4 569	13 720	1 074	–
Côte d'Ivoire	3	215	2 700	3 646	22 840	579	1 471	–
Liberia	362	–	168	–	836	10	9 168	–
Mali	13 180	18 278	606	16 368	740	2 001	–	–
Togo	31	–	–	3 390	–	633	–	–
Senegal	2 441	5 964	875	4 165	–	1 395	–	–
Total land	29 886	35 967	6 877	87 024	27 644	27 281	38 565	374

management etc. Data from these trials were used to formulate growth rules. The growth requirements of Verano stylo emerging from these rules were then matched with land qualities using the FAO agro-ecological zonal (AEZ) data base (Figure 1).

Figure 1. *Simplified method for assessing crop–forage productivity and animal/human supporting capacity.*



This data base is geo-referenced in small homogeneous land units or agro-ecological cells; therefore, the agro-climatic and edaphic attributes of any selected area can be matched against the growth requirements of stylo. When climatic and edaphic requirements of Verano stylo are met and there are no further agronomic constraints, the stylo yield attains its maximum or "constraint-free yield" for that area. By applying ratings (based on data from multi-locational trials) to the agro-climatic and soil constraints, land areas can be classified into four suitability classes (vs: very suitable, s: suitable, ms: marginally suitable and unsuitable).

This analysis was done for 10 West African countries namely, Burkina Faso, the Cameroon, Gambia, Ghana, Côte d'Ivoire, Liberia, Mali, Nigeria, Senegal and Togo. The real extent of each suitability class was multiplied by its estimated mean yield of Verano stylo, which through aggregation provided an estimate of the potential forage yield by country. Other aggregation levels, by zone within countries or across zones within the West African region, are possible.

Potential output

ILCA is involved in livestock research in these 10 West African countries either directly or through its networks. This collective research represents all climatic and edaphic variations encountered in West Africa and also represents countries in different stages of agricultural development and levels of resource endowments.

The land areas suitable for Verano stylo in the 10 countries are summarised by suitability class and by ecological zone for low and high input levels. Due to its size Nigeria has potentially the largest area suitable for Verano stylo. Although the land area of Mali is 32 million hectares larger than that of Nigeria, only 6.5 per cent of Mali is suitable for Verano stylo, whereas it can be grown on 35 per cent of the land in Nigeria.

Whereas constraint-free yields are highest in the humid zone, reflecting the longer growing periods, the agronomically attainable yields are much lower as most of the herbage is lost to disease, in particular when LGP exceeds 300 days. In contrast, land areas with an LGP less than 90 days do not support profitable growth of Verano stylo.

Discussion

Land endowed with good rains and soils is suitable for many crops, but the crop combinations that optimise overall output is determined by several factors, such as the present and projected human food and livestock feed demands, peoples' dietary preferences, the supply of inputs and government policies. Countries or regions within countries may meet present demands with low inputs, but may require higher inputs in years to come to meet the future needs arising from increasing populations.

Current land-use systems may produce calories and protein yields below the potential land capability. To maximise land productivity new land-use systems need to evolve. Although to select the best options for land development is a policy issue, it should be based on estimates of land-use potential and the animal and human population supporting capacities. Such assessments would delineate areas where development action is most needed or most rewarding.

Land suitability assessments solely for forages may be irrelevant at the present stage of development of most West African countries. However, land suitability for forages is likely to become a more important component when overall land-use planning is carried out on a longer-term perspective.

Because of the high cultivation intensities in several countries of West Africa, the land is being degraded. To make up for decline in crop yields farmers are encroaching on traditional grazing lands. To reverse this situation several million tonnes of nitrogenous fertiliser will be required in Nigeria alone; like fertilisers, many other inputs will have to be imported.

At the present level of land productivity several West African countries cannot support their national herds at an adequate productivity level. It is in this context that integration of livestock and forages into farming systems has become vital. The role of livestock in cropping systems as a means of providing draft power and manure is well known. But how and where to use compatible forages in rotation or as ley crops with cereal crops which would provide a basis for sustained productivity, is not well explored in Africa. Research results from spot trials are of little value if they are not translated into land-use systems.

Experience has shown that herds significantly increased their productivity when they had access to Verano stylo fodder banks (ILCA, 1986). Verano stylo also raised fertility of the land within a short time. Grain yield of cereal crops grown for two to three years with Verano stylo increased significantly compared with the adjacent land which was continuously cropped or had been under natural fallow (Mohamed-Saleem and Otsyina, 1986; Tarawali et al, 1987). Also, the response of cereal crops to fertilisers was better when applied to fields that had been under a stylo forage compared with those on continuously cropped soil (Tarawali and Mohamed Saleem, pp. 183–192). This supports the view that crop-free rest periods of varying durations depending on the input levels are required for sustaining productivity. Applying mineral fertilisers alone is not enough, and consequently forages like *Stylosanthes* can become very valuable in managing tropical soils besides its potential contribution to the national feed budget. For instance Nigeria has 7.4 million tropical livestock units in the semi-arid zone and has 3.4, 9.7 and 5.4 million ha of land classified as VS, S and MS, respectively, for Verano stylo (Table 2). Assuming that only five per cent of the different land classes are brought under Verano stylo it could potentially yield 4.7 million tonnes of consumable dry matter and 563 000 tonnes of crude protein.

As mentioned before, land suitability assessments require a massive amount of data requiring entry, processing, analysis and retrieval, involving substantial computing facilities and exchange of information. This is where international institutions have an advantage and could serve their national research partners with backup. Much effort was put into formulating the growth rules, for Verano stylo and it is hoped that these rules when combined with land suitability assessments, will benefit project planning efforts for sustainable land use in West Africa.

Conclusion

Future demands for substantial increase in food and feed will have to be met from the same land resource base which is already overstretched in many of the West African countries. As land resources and demands are unevenly distributed within and between countries it is necessary to know the physical limits of land in relation to its intended use. It was demonstrated how the FAO AEZ methodology for land evaluation can be adapted to assess land suitability for Verano stylo and assist scientists to assess the potential relevance of their research. If this assessment is extended to all potential land-use types in relation to demand, it will delineate appropriate crop–forage mixtures and/or identify critical areas where land resources are insufficient to meet the targets. Hence it is a powerful tool for land-use planning. Although experimental data may not be readily available to make all the climatic and edaphic inventories, expert knowledge can be substituted for assessment without negative results until more data become available.

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Table 2. *Extent of suitable land area ('000 ha) for Verano stylo in 10 West African countries.*

Country	Humid		Subhumid			Semi-arid		Arid	Total
	S*	MS	VS	S	MS	S	MS	S	
High inputs									
Burkina Faso			1 028	557	286	2 348	1 767		5 986
Cameroon	1 233	898	947	1 818	775	1 474	321	18	7 484
Gambia						434	49		483
Ghana	1 351	1 680	999	1 310	1 384	121	212		7 057
Côte d'Ivoire	1 566	2 488	585	1 057	1 329				7 025
Liberia	53	105							158
Mali			719	627	121	2 156	3 838	570	8 031
Nigeria	2 070	2 700	3 484	9 683	5 398	2 677	5 366	560	31 938
Senegal			168	266	183	1 670	1 984	289	4 560
Togo	422	396	203	583	560	62	32		2 258
Total	6 695	8 267	8 133	15 901	10 036	10 942	13 569	1 437	74 980
Low inputs									
Burkina Faso			330	1 167	1 089	633	2 564		5 783
Cameroon	146	2 091	117	1 266	2 363	453	747	18	7 201
Gambia						224	259		483
Ghana	290	3 018	382	1 130	2 203	10	227		7 260
Côte d'Ivoire	260	4 148	79	1 199	2 310				7 996
Liberia	18	166							184
Mali			57	1 303	903	157	4 402	570	7 392
Nigeria	433	2 794	638	7 297	10 563	1 252	2 889	560	26 426
Senegal			52	270	313	513	1 977	289	3 414
Togo	37	545	41	441	785		29	37	1 915
Total	1 184	12 762	1696	14 067	20 529	3 242	13 094	1 474	68 054

*S = suitable; MS = marginally suitable; VS= very suitable.

Stylo as forage and fallow:
Synthesis and review

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Introduction

The papers presented in this workshop show that research on stylo has been conducted with two major aims in mind. The first objective — as in most research — was to expand the "state-of-the-knowledge" of legume technology by controlled experimentation. Secondly, less-formalised farming-systems research was undertaken to adapt the technology to farmers' needs and capabilities. However, complementarity between on-station and on-farm research was highlighted in many papers, covering four main production systems.

- Agropastoralists in the subhumid zone (SHZ) of Nigeria where stylo-based fodder banks function as a major high-quality feed resource for cattle, their major enterprise and source of income.
- Small-scale farmers in Nigeria, who have developed micro-fodder banks as an alternative to unmanaged natural fallows. Fertility maintenance of cropland is their main purpose, while during the cropping season small ruminants (mainly goats) are tethered on these micro-banks.
- Mixed farmers in the wetter semi-arid zone of Mali and Côte d'Ivoire who rely on animal traction to grow cotton (as a cash crop), sorghum and maize. Dual-purpose stylo-based fallows are actively promoted to maintain soil fertility and supply supplementary feed for work oxen and the herds required to supply replacement traction stock.
- Millet farmers in the semi-arid zone of Niger where stylo intercropping may catch on to improve soil fertility and provide feed for sale or for intensive small ruminant production.

In Nigeria, research focusing initially on agropastoralists, produced the "fodder-bank (FB) concept" together with a set of recommendations for FB establishment, maintenance and use. Once this first phase was completed, focus changed to crop-legume interactions as FB owners became interested in exploiting the build-up of soil fertility for cropping in order to both diversify their enterprises and to better secure their usufructuary rights to the land.

Micro-fodder bank development became a target when smallholder crop farmers, as the traditional communal owners of the land, desired to reclaim some of the land occupied by older fodder banks for cropping. Therefore, primarily on-farm research evolved to adapt the acquired technology of large-scale FBs to the smallholder goals of soil fertility improvement and accommodating goat production.

In francophone West Africa where, over the last three decades, cash-cropping cotton with animal traction has developed at a rapid pace, improving soil fertility and livestock feed production have become major aims. Due to the urgent need to encourage sustainable land use incorporating livestock and cash crops, on-the-shelf legume technology was taken directly to the farmers. As a result of the combined action of the extension services and the national agricultural research systems (NARS), about 2% of the cropland is under cultivated fodder crops amounting to some 20 000 ha (Lhoste, 1990; Hijkoop et al, 1991).

Although the drier margins of the semi-arid zone are considered largely unsuitable for *Stylosanthes, S. hamata* cultivars thrived well on deep sandy soils when rainfall distribution was favourable. While millet intercropping with cowpeas is the norm, diversification into stylo-millet systems seems feasible.

Screening and evaluation

The evaluation process as outlined by Tarawali et al (pp. 81–95) and Hanson and Heering, (pp. 55–61) is based mainly on a single cultivar approach; promising cultivars were tested in separate trials in respect of their responses to rainfall, soils, fertiliser application and competitive ability through weeding experiments.

Emphasis on assessing the competitive ability of stylo cultivars became part of the broadened and longer term evaluation process in multi-locational trials (Tarawali et al, pp. 81–95). Over the four-year testing period, plots were weeded during the initial two-years to ensure proper establishment. Thereafter, weeding was omitted to allow competition with volunteer vegetation. Peters (1992) thoroughly investigated several cultivars over a two-to three-year period with P-application and wet-season cutting (to remove competing weeds) as additional treatments to weeding; the low persistence of Verano stylo and new stylo cultivars was at variance with earlier results but the causes of poor performance were not fully elucidated. Monitoring stylo seedling density and growth together with the canopy cover development of competing plants throughout the growing season would probably have thrown light on the dynamics of plant competition (e.g. de Leeuw et al, pp. 105–111).[1]

Given that — apart from several promising stylo cultivars — the screening of other legume genera (*Centrosema*, *Chamaecrista, Aeschimene*, see Peters, 1992) has widened germplasm choice, evaluation could now be done in mixed stands of several stylo cultivars, possibly combined with other introduced legumes, in intra-legume compatibility studies, and with either planted grasses or natural vegetation. Competitive ability should be tested by varying space through weeding (as a proxy for varying soil moisture and nutrients availability) and manipulating light and shade through defoliation treatments and their timing as done by Peters (1992). Space is likely to be the major factor in the early stages of growth while competition for light would feature in the later stages.

Competitive ability when sown with crops (Tarawali and Mohamed-Saleem, pp. 183–192) and responses to protection against grazing (Diarra et al, pp. 255–260) were tested for several stylo cultivars. However, research should further explore appropriate establishment and management techniques that favour the combined legumes and

1. Recent work by Peters (1992) in Kurmin Biri showed that the competitive ability of Verano stylo was low, despite high carry-over seedstocks producing seedling densities of 240–290/m^2. Legume yield dropped from 2.6 t/ha in the establishment year to 2.1 t and 0.3 t in the second and third year with volunteer vegetation contributing 3.3 and 3.9 t/ha, respectively. When three levels of P fertilisers (0, 27, 54 kg P_2O_5) were compared, the response of Verano stylo was low when unweeded, yielding 0.8, 1.1 and 1.3 t of legumes accompanied by 0.6–0.8 t DM/ha of volunteer weeds. Residual effects on total yield in the second year were large, rising from 3.5 to over 5 t/ha but containing only 0.2–0.3 t of Verano stylo. In the third years Verano virtually disappeared and total yields dropped to about 1.5 t/ha. *S. guianensis* (cvs CT 136 and 181) performed somewhat better. Second-year yields in non-weeded plots reached 1.4 and 0.4 t, but comprised only 35% and 12% of the total yield (Peters, 1992: 59). With three levels of P, first-year responses were large ranging from 0.8 to 4.0 t/ha of stylo in unweeded swards and from 0.6 to 5.2 t when competing herbage was cut back early in the growing season. However, in the second year total yields dropped to 1.5–2.0 t ha with stylo contributing 0.5 t in the control and 0.7–0.9 t/ha where P was applied in the previous year. Unlike in Verano stylo swards, weed competition was low amounting to 0.5–0.7 t/ha (Peters, 1992: 119; Tarawali et al, Table 8, p. 92). The question arises why the competitive ability of both stylo cultivars was low after the first year. No monitoring of growth was carried out during the growing seasons; hence, whether this failure was due to poor germination, or dry spells killing most seedlings has not been ascertained.

disadvantage the non-legume competition. The aim is to exploit compatibility and potential synergism within legume mixtures to counter competition from less desirable herbage.

This screening and evaluation process may require several approaches involving trials focussing on:

- Seed mixtures and rates as done by Onifade et al (pp. 175–180) to investigate their effect on subsequent stylo-grass balance and productivity.
- Factorial combinations of cultivars sown at different seed rates subjected to several levels of weeding and fertiliser application.
- Detailed phenomological studies to track individual cultivar behaviour within multiple-species mixtures to pin down their attributes. This would enable the strengths and weaknesses of each to be harnessed to enhance their combined synergism and determine optimal plant canopy manipulation.
- Cafeteria-style and other short-term grazing trials to investigate livestock preferences and assess the impact of herbivory on intra-legume responses and on the associated volunteer vegetation.

Seed production

Several aspects of seed production were covered; seed yields were highlighted as an important attribute in the initial screening process (Yonkeu et al, pp. 97–102). Seed production as an essential component of legume introduction into West African farming systems was stressed by Kachelriess and Tarawali (pp. 287–297) and Agishi (pp. 275–285), whereas the need to maintain large pools of soil seed stock for sustained productivity was demonstrated by de Leeuw et al (pp. 105–111).

Yonkeu et al (Table 1, p. 99) showed that stylo cultivars ranking highest in respect of herbage yield, were also good seed producers. Adding seed yield to the ranking strengthened the selection process of a large spectrum of cultivars. Kachelriess and Tarawali focused on the effect of the frequency and timing of weeding on seed yield and quality, and the interactions between time and method of harvesting. This research mostly aimed at producing high quality seed and complemented earlier work by Agishi (1986), who outlined optimal management procedures for maximum seed production covering the entire process from establishment, grazing and weeding management, to time and methods of harvesting. When discussing labour requirements, Agishi (pp. 275–285) persuasively demonstrated the strong linkage between labour costs for harvesting and subsequent cleaning procedures.

The relevance of these studies should also be seen with respect to farmers and agropastoralists. The procedures recommended by Kachelriess and Tarawali and Agishi are aimed at the commercial market where seed of high purity and germination capacity are major production goals. However, farmers may pursue high seed outputs to keep the crop-stylo system going and harvest seed as a back-up to supplement on-site soil seed stocks. Low-cost harvesting of uncleaned sweepings with low seed content or reseeding through the manure pathway are major options as suggested by de Leeuw (pp. 325–334). However, since producing high biomass with high stylo content underlies successful seed production, the same strategies (grazing, weeding, fertilisers) recommended by Agishi (pp. 275–285) are equally applicable for producing high legume biomass for animal feed and mulch to boost soil fertility.

Responses to fertilisers

In their review, Tening et al (Figure 1, p. 117) showed the responses to P of cultivars Cook, Schofield and Verano. Optimum yields for cv Cook and cv Schofield were reached at 80 kg of P_2O_5 with first-year yields of 6.5 and 4.5 t DM/ha, respectively. Residual yields in the second year decreased to 2.5 and 1.5 t/ha, respectively, but were still 50% and 65% higher than the controls. Verano stylo responded poorly, yielding 2 t in both years across all P-levels. In later trials at the same site with new *S. guianensis* cultivars, incremental yields from P were similar (e.g. Tarawali et al, Table 8, p. 92; Peters, 1992). However, at another site, Verano stylo showed a response of 1 t (from 4 to 5 t; Tening et al, Figure 3, p. 119), whereas when a balanced nutrient mix was applied, this stylo produced 5 t DM/ha in the first, and 2.4 t in the second year (Tening et al, Figure 5, p. 120). The lower yields in the second year are contrary to general trends: in most trials maximum yields were reached in the second year as reported by Agishi and de Leeuw (1986: 474–476) for stylo and *S. humilis*, by Mohamed-Saleem (1986) for Verano stylo and by Tarawali et al (pp. 81–95) in multi-locational trials for several cultivars.

In the manual on fodder banks, Otsyina et al (1987: 10) recommended that 120–150 kg/ha of single superphosphate (22–27 kg $P_2 0_5$) be applied at planting followed by an annual dressing of 80–100 kg/ha (14–18 kg $P_2 0_5$). These levels were higher than those of Winter et al (1989) who recommended 18 kg at planting and 5 kg/ha $P_2 0_5$ for maintenance to retain Verano stylo dominance; they argued that higher levels would, when combined with the build-up of N in the soil from the stylo, lead to grass dominance in the long-term. Revision of P-fertiliser recommendations may be needed. Perhaps, nutrient management — instead of focusing primarily on fodder banks — should embrace the entire cropping and fallow cycle; this issue is discussed below.

Integration of stylos in rotational crop-fallow systems

Tarawali and Mohamed-Saleem (pp. 183–192) in Nigeria, Diarra et al (pp. 255–260) and Fomba and Bosma, (pp. 261–269) in Mali have indicated that stable rotations with flexible cropping and fallow cycles are possible. The underlying biological basis for stable rotations is to retain a sufficient quantity of stylo seed in the soil and manipulate the carry-over effects of seed stocks between years and between seasons within years. It was shown that once a productive stylo pasture was established, it could subsequently be cropped for one to two years and revert again to a similar stylo pasture without requiring re-seeding, provided grazing management favouring the stylo was applied (Tarawali and Mohamed-Saleem, Tables 2 and 3, p. 189).

To proceed from the cropping to the pasture phase, judicious management of stylo seedlings emerging under a crop canopy in the final year is essential. Otherwise, plant density will be inadequate and growth too slow for plants to reach maturity. The ultimate aim of crop canopy manipulation is to produce sufficient seed for stylo regeneration in the first season of the pasture phase. With sufficient seed stocks in the soil, stylo can be weeded out early in the season while relying on later germination waves to provide new seedlings. Delaying seedling emergence until mid-July or six to eight weeks after the beginning of the rains had no effect on final yield, at least not in stylo-rich stands (de Leeuw et al, pp. 105– 111).

Crop canopy cover can be adapted by mixing early- and late-maturing crops or varieties within crops. Harvesting the early crop and/or a strategic thinning of the remaining crops for livestock feed, opens the canopy in the second half of the growing season.[2] This should be combined with weeding to let stylo grow and set seed. The beneficial effects of canopy management of intercropped maize, millet and pasture grasses on stylo seedling density and yield were reported by Agishi and de Leeuw (1986).

2. In western Kenya hybrid maize is planted very densely and gradually thinned to one plant per stand over a six-week period; later the canopy is further reduced by leaf stripping. These procedures produced 1.5 DM/ha during the cropping season, whereas weeds will add another 0.5 t of dry feed (Semenye and Hutchcroft, 1992); these techniques could also be applied to intercropped stylo.

During the 12 years of research on large-scale fodder banks in the SHZ of Nigeria, emphasis remained on improving livestock output of Fulani agropastoralists with relatively large cattle herds (20–100 head) for whom crop production remains a secondary enterprise. However, over time, small-scale farmers have shown increasing interest in developing short-term micro-fodder banks (0.2–0.5 ha in size) to function as improved fallows to boost subsequent crop yields. Many are also used during the rainy season as holding and grazing areas for goats; the animals are often controlled by tethering (Ikwuegbu et al, pp. 167–174). These small fallows are easier to manage than large pastures and given the high labour/land ratios, may receive more intensive management inputs. Therefore, on-farm testing of adapted practices within a dual context of long-term soil fertility maintenance and goat production should be pursued.

Although manure and fertilisers are mostly put on crops, long-term nutrient management strategies should evolve that take into account the interactive and carry-over effects of multiple nutrient inputs during the entire rotation of cropping and fallow. The expected contribution from legumes, manure and in-organic fertilisers applied during the cropping phases to increased soil organic matter and nitrogen content should be assessed in an integrated and interactive manner.[3]

Grain-forage cropping in the Sahelian zone

The introduction of *Stylosanthes* spp in the dry semi-arid zone with growing periods of < 120 days has generally been unsuccessful. *S. humilis* was sown in natural pastures in Nigeria (de Leeuw, 1974) and in central Mali (rainfall 300–400 mm) without much success (de Vries and Djiteye, 1982: 434; Wilson et al, 1983: 121). Failure was attributed to surface crusts preventing germination, dry spells killing seedlings and severe competition from annual species. However, when conditions were more favourable *S. humilis* flowered and set seed, even when the growing season was < 90 days.

In the analysis to identify areas in West Africa suitable for *S. hamata*, land with < 120 days of growing period was considered unsuitable, except for limited areas in Senegal, Mali and Nigeria totalling about 1.2 million ha (Mohamed-Saleem et al, 1988). These sites are confined to deep sandy soils associated with dunal landforms and classified as Arenosols and Regosols (Mohamed-Saleem and de Leeuw, pp. 317–323). According to ICRISAT (1987: 52) these soils occupy about 20% of the areas with 60–100 days of growing period, covering 35 millon ha.

During 1986–89, several *Stylosanthes* species were evaluated on these deep sandy soils; *S. fructicosa* and three cultivars of *S. hamata* were considered most suitable because of their short growing cycle (Garba and Renard, 1992: 44). Yields for *S. hamata* (CIAT 147) ranged from 2.8 t to 5.3 t DM/ha in first-year crops and from 0.9 to 16.7 t DM in second-year growth regenerating from seed. Stylo yields when intercropped with millet are given by Kouamé et al (pp. 193–201); in the year of sowing, forage yields were low (0.2–0.8 t/ha), but second-year legume yields were impressive. *S. fucticosa* produced 2.0–2.5 t/ha compared with 2.2–4.7 t DM for *S. hamata* (Kouamé et al, Table 3, p. 197). However, due to this vigorous growth, millet grain yields were depressed averaging 300 kg/ha as compared to 700 kg in pure stands.

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3. A promising start of this approach can be found in Tarawali and Mohamed-Saleem (pp. 186–187, Figures 1a and 1b for maize), in which the effects of four different stylo fallows on maize yields are compared with continous cropping and long-term grass fallows together with nine levels of N-fertiliser over a range of 0–200 kg of N/ha. These response curves show that without N-input, yieldsfollowing legume fallows varied from 1.3 to 2.6 t grain/ha as compared to 0.3 t and 1.2 t after continuous cropping (3 years) and long-term fallow respectively; at 50 kg N/ha the range was 2.0–3.8 t and 1.4 and 1.9 t, respectively (Figure 1a). Averaged over all sites, the added effect of legume fallow was 1.0 t of maize at low N-input increasing to 1.2 t at higher levels (Figure 1b).

Mixed farmers, who decide to grow both grain and leguminous forage as intercrops, can pursue several scenarios. Being a self-regenerating legume, Verano stylo can be kept within the millet system on a continuing basis. It can be manipulated by the farmer according to priorities through weeding and harvesting during or after the cropping season. The farmer's overall strategy is likely to be governed by the amount of grain in store from previous years, total capital in livestock (cattle, small ruminants) and, perhaps, cash resources. By manipulating the legume crop (regrowing from seed stocks of the previous year), the farmer can opt for combinations of grain and feed output. Predictions of expected grain yields early in the season are feasible, so the grain vs feed strategy can be adapted while the rainy season is progressing. For instance, the fields can be monitored and part of the land dedicated to produce more feed and less grain or the reverse. The main prerequisite for strategy decisions is that the farmer has, in each field, sufficient legume seed stock to carry out these switching tactics. This may mean that a back-up seed supply to replenish areas of low seed content or undersow new millet plots is required. Storage of legume hay or manure with high seed content (from livestock having grazed or consumed hay with high seed content) may provide a supplementary seed source.

Economic considerations may predicate farmers' decisions (Williams et al, 1992). In poor rainfall years, emphasis will be on producing millet grain; prices of grain go up and cash returns from surplus millet are likely to be favourable, while at the same time, livestock prices decrease. Thus the ratio between grain and livestock prices will rise in poor rainfall years. In good rainfall years the reverse is true; millet prices will drop and livestock prices will be high. As farmers feel secure because of grain self-sufficiency, they may sell surplus grain to buy livestock, hence livestock prices remain relatively favourable due to high demand. Therefore, production of stylo as livestock feed would occur in good years, when farmers can afford to grow feed together with grain.

Livestock production and grazing management

Although the major aim of fodder bank establishment was to increase livestock productivity mainly through providing legume herbage to grazing stock in the dry season, few papers covered this topic. Mani et al (pp. 155–165) implemented the recommended use, i.e. heifers grazed FB for four hours daily for 150 days from early January to June.[4] During the first three months they lost weight; about 20 kg per head in 1990 (Mani et al, Table 3, p. 159) and slightly less in subsequent years (Mani et al, Figure 1, p. 160). These weight losses were not related to inadequate Verano stylo available for grazing, as stocking rates were low; these rates decreased from 0.7 TLU/ha per six months in 1988 to 0.1 TLU in 1990 with stylo yields of 1.2, 2.1 and 3.7 t/ha at the start of grazing in January containing 10% crude protein (Mani et al, Tables 1 and 2, p. 158). In all years the disappointing performance on FB indicates that restricted grazing for four hours a day in the latter part of the dry season is suboptimal management.

Inadequate P and Na content of Verano stylo in the second part of the dry season is eloquently demonstrated by Little and Agyemang (pp. 147–153), who reviewed Australian and Nigerian data sources. Peters (1992) showed that in the late dry season, N content averaged 1%, P-concentrations were always below 0.10% and Na below 0.01%. Low quality was compounded by rapid leaf fall. In *S. hamata*, leaf content of total herbage was 40% in the early dry season, 5% in the mid-dry and 2% low at the end of the dry season, while comparable rates for *S. guianensis* were 50%, 25% and 10%, respectively (Table 1). Similar declines of stylo forage from 2.0–2.2% of N in October to 0.9–1.2% in April were reported

4. The recommended stocking during a six-month dry season (December–May) consists of 20 cows grazing a 4-ha fodder bank for 2.5 hours each day (Ajileye et al, pp. 311–316). This grazing pressure is equivalent to an annual rate of 1.3 TLU/ha. Assuming an hourly intake of 1 kg DM/cow, total herbage removal would amount to 9 t of feed or 35–55% of the total standing biomass (4.0 to 6.5 t DM/ha) available early in the dry season.

Table 1. *Plant components (%) and their nutritive value of* S. hamata *cv Verano (S.H.) and* S. guianensis *cv CT184 (S.G.) at the start and end of the dry season.*

		Beginning of dry season				End of dry season			
		S.H.		S.G.		S.H.		S.G.	
Plant composition (%)									
	Leaf	40		50	–	2	–	10	–
	Stem	–	60	–	50	–	40	–	70
	Litter	–	–	–	–	–	58	–	20
Nutritive parameters									
NP%	Leaf	2.6		2.2	–	1.6	40.6	1.6	–
	Stem	1.0		1.0	–	0.8	–	1.0	–
	Litter	–	1.0	–	–	–	–	–	1.0
P%	Leaf	0.13		0.14	–	0.06	–	0.06	–
	Stem	0.13		0.07	–	0.03	–	0.02	–
	Litter	–	–	–	–	–	–	–	0.04
d%	Leaf	62	–	60	–	58	0.05	60	–
	Stem	45	–	37	–	32	–	40	–
	Litter	–	–	–	60	–	50	–	650

Source: Adapted from Peters (1992).

by Mohamed-Saleem (1986: 343). Quality losses are particularly severe early in the dry season when relative humidity drops causing heavy leaf loss in Verano stylo and a fall in N from 2.8% in mid-September to 1.2% in December (Agishi, 1982). This seems to indicate that stylos (in particular *S. hamata*) should not be grazed after December if large weight losses in cattle are to be prevented.

The impact of micro-fodder banks on small ruminant productivity was highlighted in two papers (Ikwuegbu et al, pp. 167–174; Onifade et al, pp. 175–180). In on-station trials, productivity of pastures was determined across a series of wet season stocking rates ranging from 300 to 1200 kg or 12 to 70 head/ha (1.1–2.9 TLU/ha when adjusted to a six-month grazing period of live weight/ha). Gains per hectare were similar, ranging from 100 to 135 kg/ha for rams in the National Animal Production Research Institute (NAPRI) and from 81 to 109 kg for breeding does in Abet.

In Abet, when plots were stocked at 30–40 goats/ha over 3.3 months, total herbage and stylo yields before and after grazing remained constant indicating that herbage removal balanced growth (Ikwuegbu et al, pp. 167–174). At NAPRI, although the small stylo fraction was eaten out in the first year, grass yields (mainly *Chloris gayana*) declined by 35-40%; nonetheless, 5-6 t DM/ha was left at the end of the grazing period (Onifade et al, pp. 175–180).

High productivity of Verano stylo–*Cenchrus ciliaris* pastures in NAPRI when grazed by heifers was reported by Agishi (1982); over a range of 0.5 to 1.5 TLU/ha over a seven-month grazing period (April to October), average liveweight gain per hectare increased from 105 to 293 kg with average daily growth rates of 0.4 kg/day across all rates. During the four-year period, Verano stylo content in the sward increased from 10 to 28% at the lowest rate and from 14 to 60% at the highest rate.

These findings seem to indicate that systems of year-round utilisation of stylo-based pastures and fallows should evolve to fully exploit their potential for livestock production.

Timing of use at the right grazing pressure is crucial and requires an intimate knowledge of the growth dynamics of the plant components in the grazing area, be they stylo, grasses or forbs. Potential scenarios of use should be tested — preferably on-farm — that can match the requirements of the farmers' livestock and the perceived production goals. Thus, potential feed budgets should be designed that take into account all potential feed resources, including fallows, crop residues and the communal grazing lands to which farmers have access. Development of quantity and quality profiles by month would assist in designing optimal feed allocation matching animal requirements by species and age/sex groups within species. Reliance on models seems essential to cover the complexity and multiple choice permutations in crop–livestock systems.

Future research

Investments in fodder banks are high at establishment, whereas maintenance costs during the legume phase included fence repairs, reseeding and fertilisers (Otsyina et al, 1987).[5] To assist the extension of the technology, fairly strict procedures for establishment were laid down (Ajileye et al, pp. 311–316; Tarawali and Mohamed-Saleem, pp. 183–192) recommending seed and superphosphate rates, timing and rate of use by livestock. It may be opportune to re-assess these recommendations in the light of changes in the price structures of commodities (livestock, milk, grain), of feeds (salt licks, high protein cakes) and inputs (seed, fertiliser, fencing posts, barbed wire). Hence, the economic analysis as given in Otsyina et al (1987) should be recalculated not only employing new price ratios but also in the light of the findings contained in these proceedings.

The following issues may need review: the initial method of seed-bed preparation grew out of the need to introduce stylo in savannah land that had never been cultivated. With rotational use of legume pastures in cropping cycles becoming more common, other tillage and seeding techniques may be required. For instance, pocket seeding in open patches in fallows with superficial hoe tillage may be tried.

As soil fertility may be enhanced in previous cropping, P-applications may be reduced or applied later rather than as a mixture with seed at establishment which is likely to favour both legumes and volunteer species (Peters, 1992). Pocket application to promising stylo stands may be worthwhile, preferably combined with spot grazing to weaken the non-legumes. If local seed harvesting can be encouraged, seed may become cheaper, justifying higher rates.

Changes in land tenure towards privatisation may reduce the need for expensive fencing; hence, tethering stock will become more feasible allowing localised selective grazing pressure early rather than late dry-season grazing, as recommended by Mani et al (pp. 155–165) and Peters (1992). This would fully exploit the high feeding values and reduce the risk of fire later in the season.

Some of these new management techniques require further research, although much can be achieved in farmer-managed, simple "observational" trials. Consequently, the task of scientists will consist mostly of providing inputs, advice and encouragement and to collecting relevant data, in particular on the labour inputs required. This is essential since many innovations advanced by research and extension personnel are rejected because farmers have other priorities to optimise their labour (e.g. McIntire et al, 1992; Anderson, 1992).

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5. When the recommendations for fodder banks were first formulated in the early 1980s, single superphosphate could be purchased for ₦ 21/100 kg, comprising only 5% of the established costs. The main investment costs were fencing (₦ 1500) and seed (₦ 480), when the exchange rate was about 1 Naira to US$ 1.

In conclusion, despite the number and variety of papers, several gaps in the "state-of-the-knowledge" were identified justifying further research on the following issues:

- Multi-purpose management of fodder banks and fallows involving the optimisation of grazing over time and in space to enhance the competitive advantage of stylo over volunteer vegetation. This would promote the sustained yield and long-term reproductive performance of stylo.
- Integrated fertility maintenance through long-term research on the synergisms between fertiliser inputs (at the installation and during the cropping phases) and the contributions from stylo to soil organic carbon and nitrogen content to optimise crop and livestock output per hectare.
- Assessment of actual and potential benefits to livestock performance and output in biological and economic terms for each of the four farming systems. This may require a thorough scrutiny of available data combined with various modelling activities including component submodels (grass–legume feed supply, livestock performance from feed etc) and a wholistic mixed farm model that integrates the submodels. Extrapolation from individual farms to larger spatial entities should be attempted to forecast how integrated crop-legume-livestock systems may contribute to increased food production, and enhanced resource management in the West African subcontinent.

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