TOWARDS PRODUCTION TECHNOLOGIES FOR MAIZE AND COWPEA IN SEMI-ARID WEST AND CENTRAL AFRICA

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Preface

West and Central Africa has been experiencing decreasing per capita food production since the 1970's. The drought incidence of the early 1970's and its multifarious effects on crop production, coupled with an ever-increasing rate of human population, have accentuated the problem of food crisis in the semi-arid zones of the sub-region. SAFGRAD, the Semi-Arid Food Grain Research and Development Project, was created in 1977 in response to this unfortunate trend.

Now, in its second phase, the SAFGRAD Project aims at reinforcing research and development efforts of the NARS on the major staple food crops in the sub-region (sorghum, millet, maize and cowpea) through networking among the national program scientists, with backstopping from the relevant international centers for agricultural research (IITA and ICRISAT).

Two years after their establishment, the Maize and Cowpea Networks of SAFGRAD convened a Joint-Workshop at Lome, Togo (March 20-24, 1989) to review progress made in generating technologies to resolve the constraints to maize and cowpea production in the sub-region. Eighty-four scientists and agricultural administrators from national and international research institutions participated. In addition to appraising efforts in collaborative research, the scientists presented scientific communications on their research and development activities. This volume includes the edited versions of papers presented at the Workshop. The papers for both crops were in the areas of breeding, agronomy, plant protection and utilization.

Workshops and workshop proceedings provide an important forum for interaction and an outlet for publication and dissemination of research findings. It is hoped that this effort will further encourage NARS scientists to greater performance.

We wish to express our thanks to the workshop participants and to the Government and people of Togo, especially the Director of the Department of Agricultural Research and his staff, for their contribution to the success of the Workshop. We acknowledge the financial support of the United States Agency for International Development (USAID) and the logistic support of the OAU/STRC-SAFGRAD Coordination Office, Ouagadougou, Burkina Faso.

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Joseph M. Fajemisin and
Nyanguila Muleba

PART I

OPENING ADDRESSES

1. Overview of SAFGRAD Activities

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His Excellency, the Minister of Rural Development of the Government of the Republic of Togo; the Deputy Director General, International Cooperation Programme, IITA, Ibadan (Nigeria); the Director of Agricultural Research Togo ; maize and cowpea researchers; distinguished guests; ladies and gentlemen.

On behalf of both the Executive Secretary of OAU/STRC and the International Coordinator of SAFGRAD, I welcome all of you to this scientific workshop.

When SAFGRAD was conceptualized almost a decade ago, it was envisaged that its major thrust in research and coordination efforts would be to enhance increased production and productivity of maize, cowpea, sorghum, and millet in the semi-arid regions of Africa. As you know, the stagnation of food production has been the core agricultural crisis in sub-Saharan Africa during the last two decades. Food self-sufficiency and security have not been attained in many African countries, principally because of biotic, environmental, and socio-economic constraints.

The consequence of the repeated drought in the 1970's and the 1980's have continued to destabilize African economic development, in general, and agricultural development, in particular. The major factors that contributed to the decline of the resource base for productive agriculture include population growth outpacing the rate of increase in food production, environmental degradation aggravated by poor land use, and governmental policies that relegate agricultural development to the background.

The 1985 OAU meeting of Heads of States and Governments recognized the relatively low allocation of resources to the agricultural sector by African governments. Thus, although about 75 per cent of the working force in most African countries are employed in agriculture, only 5 to 10 percent of respective budgets is allocated to this sector. To rectify this anomaly, the Heads of States pledged to increase public expenditures on agriculture to between 20 to 25 percent by 1989. The apparent economic difficulties encountered during this decade in most countries of Africa have, however, impaired attainment of the target in many countries.

The Lagos Plan of Action stipulates regional economic groupings as the best approach to promote agricultural and industrial production, as well as agricultural research, throughout the continent. As an OAU-affiliated agency, SAFGRAD was conceptualized almost a decade ago to facilitate the developement, promotion, and adoption of suitable food grain production technologies in semi-arid Africa.

The SAFGRAD progamme was designed to effectively mobilize and coordinate available regional resources, including those of the International Agricultural Research Centers (IARCs) and the National Agricultural Research Systems (NARS), to provide the knowledge base for achieving significant advances in food grain production.

The estimated population of SAFGRAD mandated area is about 250 million, about 80% of whom are small farmers who produce most of the region´s staple food supplies. Maize and cowpea are important staple crops of the region. According to FAO statistics, the area cultivated to maize has increased substantially during the last decade, due to the use of elite varieties and hybrids. The production of cowpea has also increased, particularly in Nigeria and Niger.

During its first phase, SAFGRAD succeeded in developing early maturing, high yielding, pest and disease resistant varieties of maize, cowpea and sorghum some of which have been accepted and adopted by NARS. One of the lessons learned from SAFGRAD Phase I has been that the support of agricultural research and development in member countries largely depends on the capabilities of individual NARS.

Since 1986, SAFGRAD activities have focussed on the strengthening of collaborative research networks. A conference of the Directors of Agricultural Research took place in February 1987 to institutionalize SAFGRAD collaborative research networks and their management entities. The research directors reoriented the activities of the SAFGRAD project to emphasize collaborative networks involving the following partners: NARS, IARCs and OAU/STRC. At the above meeting, the NARS Directors specified the objectives of networks and the roles of the Oversight Committee. The major objective of collaborative research networks is to mobilize available resources, such as those of the International Agricultural Research Centers (IARCs) and regional programmes, to minimize duplication of research efforts and to reorient research towards the needs of the farmer.

Based on the guidelines of NARS Directors, the Steering Committees for respective networks were elected. Already, the Steering Committees of maize and cowpea networks have achieved the following.

a. Inventoried biotic, environmental, and socio-economic constraints that limit the production of maize and cowpea.

b. Identified research priorities and developed network programme to alleviate contraints.

c. Monitored the implementation of network plans and reviewed research results.

d. Assessed the strengths, weaknesses, and research gaps among participating NARS.

What has been the accomplishments of the maize and cowpea collaborative research networks? This topic would be discussed in greater details during the next four days of this workshop. Some of the highlights of the accomplishments of these two networks are:

a) More than at any other time, NARS scientists, administrators of regional programmes, and IARCs have collaborated in the improvement and production of maize and cowpea. Lead centre and technology adapting NARS are playing key roles in the generation and adoption of technology to alleviate major regional constraints to maize and cowpea production.

b) There is considerable flow of relevant elite germplasm (through regional trials) and related technologies among NARS and between NARS and IARCs. NARS scientists are in better position to verify these technologies in their respective environmental and socio-economic conditions.

c) NARS, IARCs and regional programmes, like SAFGRAD, are better aware of the type of research programme that could promote the production of food grains in the region.

d) In collaboration with national research programmes, the networks have continued to develop a number of varieties of maize and cowpea of different maturity groups for Sahel, Sudan and northern Guinea savannas.

e) NARS research programs were assisted by field visits, appraisal of research programs, provision of research materials, funds, training and seminars. By being assigned research responsibilities (based on availability of qualified research staff, and optimum environmental conditions to screen varieties or elite germplasm for resistance to specific biotic and abiotic stresses) lead NARS have taken research leadership and are being developed as future satellite "Centers for research excellence".

The renewed interest in networking by member countries of SAFGRAD is advised by the desire to break down linguistic and political barriers and to judiciously pool their human, and financial resources to solve common problems of agricultural production and productivity. Furthermore, SAFGRAD's emphasis is to encourage leading African scientists to provide leadership and to conduct research in their areas of competence. The approach provides easy access to technical information. The network strategy takes into account the differences in the levels of research strengths among national research programmes. In addition, a definite effort is made to improve weaker national programmes.

The objective of Maize and Cowpea Joint Workshop is to strengthen cooperative research among NARS scientists working in different disciplines in the improvement of these two crops, thereby ensuring the flow of useful technical information among participating NARS. The agenda of the workshop shows that various aspects of maize and cowpea improvement and production would be discussed. However, collaborative networks only compliment NARS efforts and should not be regarded as substitutes for NARS. Indeed, national research capability is the backbone of agricultural development of respective countries. The present achievements of networks could be impeded if strong donor support to NARS is not forthcoming, or if it is not matched by firm financial commitment by member countries. SAFGRAD is in the process of developing medium and long-term plans designed to shift network leadership and management to NARS.

In strengthening regional research cooperation, the duplication of efforts could be a setback. In this regard, the Council of NARS Directors in its February 1989 Conference examined in detail the whole question of harmonization of the two maize networks in West and Central Africa and reaffirmed its earlier decision of February 1987 that harmonization is necessary for optimal utilization of funds for maize improvement in the sub-region. The Council noted attempts made since 1987 in several meetings between SAFGRAD, CORAF, and IITA to effect this harmonization. The matter is high in the agenda of a CORAF meeting scheduled for March 21-24, 1989 in Dakar (Senegal), and the Council has mandated the International Coordinator of SAFGRAD and the Director of Research of Cameroon (who also happens to be the CORAF Maize Network Coordinator) to attend the meeting and to use their good offices to ensure that the main outstanding issues are resolved.

Before I conclude, I would like to take this opportunity to thank all partners involved in the implementation of the research programmes of respective networks. The lead NARS, for example, should be encouraged and congratulated for taking their responsibilities to the networks very seriously. The technology adapting NARS keen interest and active participation have been inspiring. On behalf of OAU/STRC, I would like to express genuine appreciation and congratulations to the energetic and dedicated Network Coordinators and the respective steering committees. We are grateful to IITA for its continued support of various aspects of network development.

OAU/STRC-SAFGRAD would also like to express its sincere gratitude to its donors, particularly USAID, which supports the four commodity collaborative research networks of SAFGRAD. Finally, on behalf of all participants and OAU/STRC, I would like to express our sincere thanks to the Government and people of Togo for warm hospitality and for enabling us to hold this Joint Maize and Cowpea Scientific Workshop in Lome, Togo.

2. Cowpea Improvement Programme of International Institute of Tropical Agriculture (IITA)

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In the essential plan for the improvement of cowpeas, IITA will continue to focus on the importance of pest and disease resistance, but there will be a change from the past policy of breeding varieties for only grain production as sole crops, using insecticides to control insect pests. Although this strategy has been sucessful, and will continue at a reduced scale, it is dependent on the availability and the price of insecticides and sprayers, despite the fact that most of African cowpea production is, and will continue to be, grown by resource-poor, small holders as intercrops in cereal-based mixtures. In addition, breeding objectives need to take into account the production of haulms, which are a principal source of animal feed in most of the cowpea growing regions of West Africa. Thus, the major thrust of future research will be to breed varieties that are well-adapted to the cereal-based farming systems of the African savannas and that meet the dual needs for grain and fodder.

Major Components of IITA's Future Cowpea Improvement Programme

In the medium term, the following three areas will be given special attention.

Cowpea breeding and improvement

The main breeding objectives of the essential plan will be :
(i) the development of cowpea varieties that are morphologically and physiologically adapted to interplanting with cereals in a range of environments with varying lengths of growing seasons ; (ii) the incorporation of multiple resistance to insect pests and diseases into adapted varieties ; and (iii) the improvement of drought tolerance in cowpea varieties, especially those intended for the millet-based farming systems of semi-arid zone. The scientists who will execute this programme will be located in Kano, northern Nigeria and at the ICRISAT Sahelian Center, Niamey, Niger.

Cowpea germplasm enhancement

The main limitation to cowpea grain production in Africa is the damage caused by post-flowering insect pests. The following three components comprise IITA's essential plan to incorporate host-plant resistance into cowpea varieties.

a) Refinement of existing screening methods, and the development of new ones, to identify better sources of insect pest resistance. This will require that significant resources be allocated to research on the biology and the rearing of the pests.

b) Extensive collection of new germplasm, especially of wild relatives of cowpea in Africa, and the intensive evaluation of both existing and new collections, and of breeding materials.

c) Research in IITA's Biotechnology Unit, and contract basic research for the study of pest biology, wide crosses, resistance mechanisms, and innovative screening methods.

Essential work will also continue at IITA to improve the level of resistance to the cowpea storage weevil, Callosobruchus maculatus; the higher resistance will subsequently be incorporated into all of IITA's elite breeding lines.

The above pre-breeding research will be done at the Ibadan headquarters by one breeder and an entomologist working together with scientists in the Biotechnology Unit, and in collaboration with scientists at advanced laboratories.

Cowpea genetic resources conservation

IITA has the CGIAR world mandate to collect and preserve the genetic resources of Vigna and, as part of its essential plan, will continue to collect, evaluate and preserve cowpea germplasm, and to make it freely available to scientists world-wide. Over the next five years, priority will be given: (i) to collecting genetic diversity in the wild relatives of cowpeas in Africa, and (ii) to using the latter in breeding for host-plant resistance to post-flowering insect pests.

Projected Impact of IITA's Cowpea Improvement Programme

With the expectation that the objectives outlined above will be achieved, the impact of IITA's Grain Legume Improvement Programme could be summarized as follows :

a) In the medium term, the development of a range of photoperiod-sensitive, indeterminate cowpeas : (i) adapted, through their response to photoperiod, to a range of season lengths ; (ii) possessing the desirable characteristics of traditional varieties grown at present in mixtures with sorghum and pearl millet, and (iii) with multiple resistance to the major pathogens in the West African savanna.

b) In the long-term, sources of resistance to post-flowering insect pests will be identified and incorporated into otherwise superior genotypes for : (i) cereal intercropping, (ii) grain production from sole crops, and (iii) vegetable pod production.

c) In the medium term, improved levels of resistance to the cowpea storage weevil, Callosobruchus maculatus, will be identified and incorporated into elite varieties.

d) In the medium term, a greatly enlarged collection of genetic diversity in the wild relatives of cowpeas would have been collected, preserved, evaluated and documented. IITA will continue to maintain the world collection of cowpea germplasm, and to distribute it freely to cowpea scientists world-wide.

e) IITA will continue to support and strengthen national grain legumes improvement programs in Africa, and will continue to participate in cowpea research networks.

PART II

CROP BREEDING

3. Cowpea Genotypes for Intercropping with Pearl Millet in a Sudano-Sahelian Environment

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ABSTRACT

Cowpea is an important source of grain and fodder in the semi-arid zone of West Africa, a major cowpea producing region in which cowpea is grown in a millet- or sorghum-based mixture. Because of the importance of millet/cowpea intercropping, two experiments were conducted to study the response of contrasting cowpea cultivars intercropped with millet. Tests over three years have shown that yields of intercropped millet and cowpea depend partly on cowpea plant type. Early maturing (60-70 days), erect cowpea cultivars competed less with millet than late maturing cultivars, but produced the lowest grain and fodder yields. In contrast, photoperiod-sensitive, late maturing cultivars were more aggresive and caused the largest reduction in millet yields. These and other results indicate that the most suitable cowpea cultivar for intercropping with pearl millet in a Sahelian environment should be spreading and indeterminate, weakly competitive with millet, early maturing (to escape end-of-season drought), and produce satisfactory grain and fodder yields. Cowpea sole crop yields were positively correlated with those of intercropped cowpea.

Using yield as a selection criterion, 42% of the highest-yielding lines in intercropping would also have been selected on the basis of their yields as sole crops over a 3-year period. It is concluded that selection of cowpea cultivars for intercropping with millet should be based on their performance in the intercrop.

RESUME

Le niébé constitue une source importante de graines et de fourrage dans la zone semi-aride d´Afrique Occidentale, principale région où le niébé se cultive en association soit avec le mil soit avec le sorgho. Compte tenu de l´importance de la culture associée mil/niébé, deux essais ont été conduits afin d´étudier la réponse des différents cultivars de niébé cultivés en association avec le mil. Ces essais ont démontré au bout de trois ans que les rendements de la culture associée mil/niébé dépendent partiellement de l´architecture de la plante du niébé.

Les cultivars de niébé à maturité précoce (60-70 jours) à port érigé, ont été moins compétitifs avec le mil que les cultivars à maturité tardive, mais ont donné les rendements les plus faibles en grains et en fourrage. Par contre, les cultivars à maturité tardive, sensibles au photopériodisme se sont révélés plus compétitifs et causèrent la réduction la plus importante aux rendements du mil. Ces résultats et d´autres indiquent que le cultivar du niébé le plus approprié pour la culture en association avec le mil dans une écologie sahélienne devrait avoir un caractère expansif et indéterminé, être faiblement compétitif avec le mil, à maturité précoce (afin de se trouver à l´abri de la sécheresse de fin d´hivernage) et au rendement satisfaisant en grains et en fourrage. Les rendements de la culture pure du niébé ne présentaient pas de différence avec ceux du niébé cultivé en association.

En utilisant le rendement comme critère de sélection, 42 % des lignées donnant le rendement le plus élevé dans le système de culture associée auraient été également sélectionnées sur la base de leurs rendements en culture pure sur une période de 3 ans. L´on conclue que la sélection des cultivars du niébé pour la culture en association avec le mil devrait se fonder sur leurs performances dans le système de culture associée.

INTRODUCTION

Cowpea is an important food legume in the semi-arid regions of West Africa, a major cowpea producing region. Most of the cowpea is grown at low densities in association with cereals, especially pearl millet and sorghum (Steiner, 1982; Stoop, 1986). Farmers do not normally apply plant protection chemicals, while they apply very little amounts of artificial fertilizer. As a result, cowpea yields are extremely low.

The maturity periods of local varieties, largely photoperiod sensitive, are longer than the average length of the rainy season. Consequently, in years with low rainfall, these varieties produce very little or no grain.

Although there are no rigid intercropping patterns, the most prevalent combination is the millet/cowpea system (Fussell and Serafini, 1985). The two crops are grown under conditions characterized by poor soils, frequent drought, high temperatures, and many insect pests and diseases.

Progress has been made at the International Institute of Tropical Agriculture (IITA) in developing cowpea cultivars which mature in about one half of the time required by the local varieties (Singh and Ntare, 1985). These cultivars, however, were developed in sole crop systems and it has not been established that they perform well in intercropping systems. In addition, experience has shown that few farmers are prepared to change their traditional methods of intercropping cowpea with cereals in order to grow pure crops.

Varietal selection for improved intercrop performance is dependent on the objectives of the farmer. In the Sahelian zone, the objective of the farmer is to get a full yield of millet and a supplementary yield of cowpea grain and fodder.

Studies on the evaluation of crop genotypes for their suitability to intercropping have been reviewed (Smith and Francis, 1986; Galway et al., 1986). They indicate that there is a differential response of genotypes to intercropping systems.

The present study examined the performance of contrasting cowpea cultivars as sole crops and in millet-cowpea intercrops to determine the relationship between their performance in the two systems, in order to select cowpea cultivars suitable for intercropping with millet.

MATERIALS AND METHODS

Two trials were conducted in three years (1984-1986) at the ICRISAT Sahelian Center (ISC), 40 km south of Niamey, the Republic of Niger. This station (13°14′N latitude, 2°18′E longitude, and 240 m elevation) is in the Sahel bioclimatic zone, an extensive semi-arid belt immediately south of the Sahara desert. The 1984 cropping season was the driest on record; the total rainfall was 56% below the average. The sandy, reddish coloured soils are strongly acidic and are low in native fertility and organic matter.

Trial 1

Six cowpea cultivars (two erect, extra-early, 55-60 days; two spreading, early maturing, 70-75 days; and two prostrate, medium maturing, 80-90 days) were intercropped with one millet cultivar, CIVT. The spacing of millet was 1 x 1 m while cowpea was sown between millet rows. The erect and spreading cowpea cultivars were sown at densities of 5 and 3 plants/m², respectively. Sole crop millet was an additional treatment. Treatments were arranged in four randomized blocks with six replications.

Trial 2

In 1984, 300 cowpea cultivars were grouped into 15 different trials, each consisting of 20 entries. These trials were based on plant type, seed colour, and maturity period. They were evaluated as monocrops, as well as in mixtures with one millet cultivar, as in trial 1. Sole crop cowpea plots consisted of three, 4-m rows, 1 m apart, the intra-row spacing being 30 cm. Intercropped cowpea consisted of a single 4-m row alternating with one row of millet.

Millet and cowpea were spaced 1x1m and 1mx30cm, respectively. Cowpea was sown on the same day as the millet in six trials; in the remaining nine trials, it was sown 13 days after millet. Sole and intercrop plots were in adjacent blocks. Four randomized complete blocks were used in each case. Millet was thinned to three plants/hill, while cowpea was thinned to two plants per hill. Two insecticide applications were used to control cowpea insect pests.

From the 1984 trials, 75 cultivars, including local controls, were selected for the 1985 and 1986 trials. In both years, the 75 cultivars were evaluated in mixture with a standard millet cultivar, CIVT. The trial consisted of two blocks, one for sole crop cowpea and the other for cowpea/millet mixture. The cowpea lines were randomized in two replicates in each block. Both crops were sown on the same day in each of the 2 years. Cowpea was sown at 75 cm and 1.5 m within and between rows, respectively, in both cropping systems.

All trials received a basal application of 18 kg P_2O_5/ha, in addition to 45 kg N/ha as urea banded to the millet in two doses, 23 and 45 days after sowing.

Analyses of variance were performed for data from trial of each year. Simple correlation coefficients between means of cultivars in the sole crop and in the intercrop were calculated.

RESULTS

Trial 1

The yields of cowpea and pear millet in 1984-1986 are presented in Table 1. In 1984, both crops were seriously affected by severe drought. Millet grain yields were severely reduced by intercropping and no cowpea fodder was obtained because of premature leaf senescence due to water stress.

In 1985 and 1986, the rainfall distributions were favourable and the crops did not suffer from moisture stress. Early maturing cultivars produced the lowest grain and fodder yields and were apparently less competitive with the millet than late maturing cultivars. Suvita-2 and 58-57 were the highest yielders in both 1985 and 1986 and appeared to be tolerant of intercropping. Spreading, medium maturing cultivars significantly reduced millet grain yields in 1985, but not in 1986.

Table 1. Effect of cowpea plant type on yield (t/ha) of cowpea and millet when intercropped at ICRISAT Sahelian Centre, Niamey in the rainy seasons of 1984-1986[1].

Plant type[2]	Yields in: 1984		1985			1986		
	Cowpea grain	Pearl millet	Cowpea grain	Cowpea fodder	Pearl millet	Cowpea grain	Cowpea hay	Pearl millet
IT82E-60 (EE)	0.16	0.23	0.10	0.32	2.04	0.09	0.11	1.30
IT82D716 (EE)	0.32	0.19	0.12	0.40	2.17	0.10	0.18	1.14
TVx 3236 (E)	0.18	0.27	0.40	0.13	1.79	0.20	0.23	1.10
SUVITA-2 (E)	-	-	0.62	1.34	1.55	0.43	0.50	1.13
TN88-63 (M)	0.15	0.28	0.42	1.06	1.60	0.16	0.46	1.23
58-57 (M)	-	-	0.60	1.30	1.56	0.38	0.77	1.17
Sole millet	0.67	0.67	-	-	2.24	-	-	1.30
SE	+0.30	+0.07	+0.08	+0.08	+0.12	+0.06	+0.06	+0.21

[1] Amount of rainfall received from planting to harvest in 1984, 1985 and 1986 = 186, 430 and 447 mm, respectively.

[2] EE = extra-early erect (60-65 days); E = early spreading (70 days); M = medium maturity (80 days).

Trial 2

In 1984 yields were drastically reduced by drought which occurred in August and September. Nonetheless, an attempt was made to relate intercrop and sole crop yields but the correlation coefficients (0.16-0.33) were not significant. Pooled over trials, a significant (P=0.01) positive correlation was obtained but the coefficient (0.45) was too low to permit prediction of the best cowpea cultivars for intercropping on the basis of their sole crop yields.

In both 1985 and 1986, the effects of cropping system and cultivar on grain yields were significant but the effect of cultivar x cropping system interaction was not significant. Intercropping significantly reduced cowpea yields, although the degree of reduction varied among genotypes (Table 2). The extent of millet yield reduction tended to be related to cowpea plant type. Thus, early maturing, erect cowpea cultivars had the least adverse effect on millet yield, while late maturing, prostrate genotypes exerted the greatest yield-reducing effect in millet. Cowpea sole crop yields were significantly (P=0.01) correlated with those of intercropped cowpea (r values for 1985 and 1986 being 0.75 and 0.91, respectively).

Table 2. Effect of cowpea plant type on performance of cowpea and millet when intercropped at Niamey (Niger) in 1985 and 1986 rainy seasons.

Plant type	No. of cultivars	% Yield reduction[1]		
		Cowpea grain	Cowpea fodder	Millet grain
Early-maturing, determinate-erect	15	44	41	26
Early-maturing, determinate-semi-erect	36	33	33	37
Medium-maturing, indeterminate & spreading	17	30	38	44
Late-maturing, indeterminate & spreading	7	26	22	52

[1] % yield reduction (significant, P = 0.05) in relation to sole crop yields averaged over 1985 and 1986 cropping seasons.

Using grain yield as a selection criterion, 29-80% of the top 20% of the cultivars had similar ranks in both cropping systems. Based on the combined results of the three years, with 20% selection, 42% of the highest-yielding lines in the intercrop would have been selected on the basis of their sole crop yields.

DISCUSSION

Results from these experiments have shown that yields of both cowpea and millet in an intercropping system are dependent in part on the plant type of cowpea. Early maturing (60-70 days) cultivars were intolerant of competition with millet but had little effect on millet yields. On the other hand, late maturing, photoperiod-sensitive types were more aggressive and caused the largest reduction in millet yields.

In the Sudano-Sahelian zone, the objective of farmers is to get a full yield of the cereal and satisfactory yields of cowpea grain and fodder. The local varieties (largely photoperiod-sensitive) have maturity periods that are longer than the rainy season; in years of erratic rainfall, these varieties produce very little grain. To grow two crops in mixture in an environment with short rainy season requires two compatible, drought resistant genotypes.

The results of the present study indicate that a suitable cowpea for intercropping with pearl millet will be a compromise between grain and fodder types. Such a cultivar should ideally not compete with millet, and should be early maturing (to escape end-of-season drought) and possess the ability to produce both grain and fodder. This type of cultivar has the potential of improving the productivity of the cowpea/millet cropping system without radically changing the traditional farmer´s system.

Regressing yields of cowpea cultivars intercropped with millet on cowpea sole crop yields showed that the performance of cultivars in intercropping was, to some extent, a reflection of their performance in sole crop. Sole crop yields accounted for 56 and 84% of the variation in yield of intercropped cowpea in 1985 and 1986, respectively. This suggests that there is scope for using the performance of cowpea cultivars and progenies in sole crops to select for their performance in intercrop systems. Indeed, using grain yield of sole crop cowpea as a selection criterion to identify high-yielding cultivars revealed that 42% of the highest yielding lines in the intercrop system would have been selected in both years. This suggests that selection of cowpea cultivars for inter-cropping should be based on their intercrop performance.

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4. Genotype x Environment Interactions in Maize and Their Implications in Breeding for Stable and High Yields in Ghana

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ABSTRACT

Yield data from six locations in two years were used to examine genotype x environment interactions and their implications regarding the breeding and testing of improved maize varieties in Ghana. Analyses of variance showed that yields of maize varieties were significantly different from each other and that variety x year as well as variety x location interactions were significant. However, the year x location x variety interaction was not significant.

Stability analyses revealed that five varieties (Dobidi, La Posta CRI, Okomasa, EV 8329 SR BC_3, and EV 8328 SR BC_3) with regression coefficients of approximately 1.0 produced above average grain yields across locations, indicating that they have good general adaptability. Ferke(1) 7828 had a regression coefficient of just over 1.0 and produced below average grain yield, suggesting its sensitivity to some of the environmental conditions in the test sites. Across LSR-W81 had a regression coefficient substantially below 1.0 but it produced above-average grain yield, indicating that it may be considered as an ideal variety. The local variety, with a regression coefficient of 0.684, produced below average grain yield, indicating that it combines above average stability with adaptability to low-yielding environments.

RESUME

Les données de rendement recueillies en deux ans et provenant de six localités ont été utilisées pour étudier les interactions génotype x écologie et leurs implications en ce qui concerne la sélection et l´expérimentation des variétés améliorées de maïs au Ghana. Les analyses de la variance ont révélé que les rendements des variétés de maïs étaient nettement différents les uns des autres et que les interactions variété x année de même que les interactions variété x localité étaient importantes. Toutefois, l´interaction année x localité x variété n´était pas considérable.

Des analyses d´aptitude à la stabilité ont révélé que cinq variétés (Dobidi, La Posta CRI, Okomasa, EV 8329 SR BC3 et EV 8328-SR BC3) ayant des coéfficients régressifs d´environ 1,0 ont donné des rendements en grains au-dessus de la moyenne à travers les localités ; ce qui indique qu´elles ont une bonne adaptabilité générale. Ferke (1) 7828 donnait un coéfficient régressif légèrement au-dessus de 1,0 et un rendement en grains au-dessous de la moyenne ; ce qui montre sa sensibilité à certaines des conditions écologiques au niveau des sites d´essai. Across LSR-W 81 avait un coéfficient régressif nettement en-dessous de 1,0 mais elle donnait un rendement en grain au-dessus de la moyenne, indiquant qu´elle peut être envisagée comme variété idéale. La variété locale dont le coéfficient de régression était de 0,684, donnait un rendement en grains en-dessous de la moyenne, montrant qu´elle allie l´aptitude à la stabilité au-dessus de la moyenne à l´adaptabilité aux écologies à faible rendement.

INTRODUCTION

Genotype x environment interactions are present when the relative rankings of two or more genotypes differ in different environments. The interactions create problems in demonstrating significant superiority of any variety in yield tests. It is, therefore, generally agreed, among plant breeders, that interactions between genotypes and environments are important considerations in breeding and testing of improved varieties. Attempts are frequently made to estimate the magnitude of variances attributable to interactions and to utilize such estimates to develop more precise methods of selection.

Information relating to the genotype x environment interactions in maize in Ghana is limited. Akposoe (1978), in a four-year study of some aspects of maize improvement in Ghana, showed significant year x location and year x variety interactions. However, there was no significant location x variety, or location x variety x year interaction. The study was conducted at only three locations in Ghana.

The purpose of the present study was to examine genotype x environment interactions and their implications with respect to development of maize varieties for the different ecological zones of Ghana (namely, forest, forest-transitional, and savanna).

MATERIALS AND METHODS

The analyses were based on the data from full-season (120 days to maturity) variety trials conducted in 1984 and 1985 at six locations (Kwadaso, Ejura, Pokuase, Kpeve, Damongo, and Nyankpala) representative of the three ecological zones of Ghana. A randomized complete block design, with four replications within each year and location, was used. Each plot consisted of four, 5-m rows with an inter-row spacing of 80 cm but data were collected on the two central rows. A number of plant characters were recorded but only grain yield is reported in this study. Combined analyses of variance were done in which genotypes, locations, years and their interactions were partitioned separately. Genotypes, years and locations were regarded as random effects and expected mean squares and tests of significance were performed following the method developed by Snedecor (1962). Variance components were estimated by equating the mean squares of their expectations and solving for the components.

For each variety, a linear regression of individual grain yield on the mean grain yield of all varieties for each site in each year was computed (Yates and Cochcran, 1938; Finlay and Wilkinson, 1963; Eberhart and Russel, 1966). The variety mean yields over all locations were also computed.

RESULTS AND DISCUSSION

The analysis of variance for yield of the eight maize varieties at the six locations revealed significant differences (P = 0.01) among varieties as well as significant (P = 0.05) variety x year and variety x location interactions. However, the year x location x variety interaction was not significant. The significant variety variance component indicated that the varieties differed in their genetic potential for yield. The significant variety x location interaction implied that certain varieties tended to rank consistently differently in the two years of testing at individual locations. The lack of significant location x year x variety interaction implied that in any particular year, individual locations did not exert a major influence on the relative performance of varieties.

The variance component analysis revealed that the influence of years on the relative response of varieties was of the same magnitude as that of locations. Since variety x year and variety x location interactions were significant, variety recommendations should be based on multilocational testing over years.

The presence of significant location x genotype interaction suggests three different approaches for the maize breeding program in Ghana. The first approach is to develop specific varieties for each of the special environments, i.e. varieties adapted to specific conditions of temperature, rainfall, soil fertility, etc. This is because it is much easier to alter the crop genotype than the environments. The genotypes may be altered during the developmental stages of the breeding program when the breeder attempts to select superior genotypes from a genotypically variable population, by testing the progenies in various environments. Based on the progeny yield tests, the top 10% performers across each ecological zone could be recombined to form a variety specifically adapted to each zone (i.e. environment). In order to make optimum use of resources, the generation of families for progeny yield tests, as well as the recombination of superior families, could be done in one environment prior to multi-locational tests conducted throughout the country.

The second approach to solving the problem posed by the significant location x variety interaction would be to further divide each ecological zone into more testing sites. This would increase the chances of identifying genotypes adapted to several environments. However, for logistic reasons, this approach is not considered feasible.

The third and, probably, the feasible approach for overcoming the problems associated with the high variety x location interaction would be to develop cultivars widely adapted to all maize-growing environments in Ghana. This would involve the use of a selection strategy to identify maize cultivars with high grain yields and wide adaptation in these environments. One strategy is to use regression techniques to characterize the responses of genotypes in varying environmental conditions. Thus, to determine the most high yielding and stable varieties for production throughout the country, the degree to which the varieties used in variety trials responded to changes in environment was measured by regression of individual variety grain yield upon the mean yield of all varieties in a single environment.

The variety mean yields and the regression coefficients are presented in Table 1. Variety mean yield varied from 2.2 to 5.0 tons/ha for the local and Dobidi varieties, respectively. Varieties characterized by regression coefficients approximating 1.0 are considered to have an average stability across environments. Five varieties (Dobidi, La Posta CRI, Okomasa, EV 8329 SR BC_3 and EV 8328 SR BC_3) had regression coefficients of the order of 1.0 and produced above average yields across locations, suggesting that they have good general adaptability. On the other hand, Ferke(1) 7928, with a regression coeficient of just over 1.0, produced below average grain yield. This was probably due to the fact that Ferke (1) 7928 was too sensitive to some of the environmental conditions in the test sites. Although Across LSR-W81 had a regression coefficient substantially below 1.0, it produced above-average grain yield. This suggests that Across LSR-W81 is very stable and capable of exploiting high yielding environments. It may be considered the ideal variety.

Table 1. Performance of eight full-season maize varieties at six locations in 1984 and 1985.

Variety	Grain yield (tons/ha)	Regression coefficient
La Posta CRI	4.85	1.161
Dobidi	5.00	1.019
Across LSR-W81	4.42	0.696
Okomasa	4.70	0.887
Ferke (1) 7928	3.81	1.154
EV 8329 SR BC_3	4.64	0.878
EV 8328 SR BC_3	4.69	0.864
Local	2.22	0.684
Mean	4.29	

The local variety had a regression coefficient of 0.684 but it produced below average grain yield. This is characteristic of varieties with greater resistance to environmental change (above average stability) and adaptability to low-yielding environments. This is not surprising since the local variety has been observed to respond poorly to high management practices, such as nitrogen fertilization and other improved agronomic practices.

The mean grain yields for each of the six location in 1984 and 1985 are presented in Table 2. The highest and lowest site means were obtained at Nyankpala in 1984 and 1985, respectively. Similarly, while the location mean was lowest at Pokuase in 1984, the location mean at Pokuase was one of the highest in 1985. These results illustrate the importance of variation in climatic factors (such as rainfall) as a major factor of the environment in the test sites. Differences in edaphic factors (such as temperature and fertility status) at the test sites, appeared to be of relatively little importance compared to fluctuations in climatic factors.

Table 2. Site means (tons/ha) of eight full-season maize varieties in 1984 and 1985.

Location	Year	
	1984	1985
Pokuase	2.79	4.80
Kpeve	4.60	6.48
Damongo	3.45	3.46
Nyankpala	5.64	2.64
Kwadaso	3.01	5.17
Ejura	3.49	4.04

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5. The Contribution of Introduced Maize Varieties to the Improvement of Cameroon Local Maize Accessions

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ABSTRACT

The combining ability and the heterotic effect of five Cameroon indigenous maize varieties testcrossed to three improved introduced maize varieties were evaluated at two locations in 1987.

Average heterotic effects were highly significant and seemed to be correlated with differences in maturity cycle of the parents. Crosses involving CMS 8503 (EV 8449 SR) as one of the parents gave 72% more grain yields than their respective local parents; also CMS 8503 showed high parent heterosis of about 20%. However, the lower yielding and early maturing tester, Pool 16 SR, exhibited the highest significant variations in testcrosses. The line x tester analysis revealed predominance of non-additive gene effect for all measured traits.

RESUME

L´aptitude à la combinaison et l´effet hétérotique de cinq variétés indigènes de maïs du Cameroun testcroisées à trois variétés améliorées de maïs introduites ont été évaluées dans deux localités en 1987.

Les effets hétérotiques moyens se sont révélés très importants et semblaient montrer des différences au niveau du cycle de maturité des parents. Des croisements comprenant CMS 8503 (EV 8449 SR) comme l´un des parents ont donné des rendements en grains de 72 % de plus que leurs parents locaux respectifs ; de même CMS 8503 a révélé un hétérosis parental élevé d´environ 20 %. Toutefois, le testeur à rendement plus faible et à maturité précoce, Pool 16 SR, a montré les variations les plus élevées au niveau des croisements tests. L´analyse de la lignée x testeur a révélé une prédominance de l´effet non additif du gène pour tous les caractères étudiés.

INTRODUCTION

Except for the savanna zone, research achievement in the lowlands of Cameroon has not resulted in significant yield increase at the small farmer level. This is partly attributed to reluctance of the farmer to grow improved varieties. These varieties, mainly introductions from International Research Centres, do not always meet the needs of the small farmer. The local maize preferred by the farmer has a soft and thin pericarp, floury endosperm, and is apparently better adapted to low input agriculture. The maize variety BSR 81 (Bertoua streak resistant 81), developed from a cross between TZSR-W-1 and a local maize accession from Bertoua, is more easily accepted in the eastern part of Cameroon than the high yielding, introduced TZSR-W-1. This study was initiated to measure the combining ability and the heterotic effect of five Cameroon indigenous maize varieties testcrossed to three improved, introduced maize varieties.

MATERIALS AND METHODS

The local accessions used in this study were named after their sites of collection. They were Bafia, Bougzoudou, Yaounde, Mfoumou and Asip. In the first season of 1987, these varieties were crossed to each of the following three introduced maize varieties used as testers: Pool 16-SR, CMS 8503 (EV 8449 SR) and Ndock 8701. During the second growing season of 1987 and the first growing season of 1988, 15 F1s, along with the eight parents, were evaluated at Nkolbisson. The design was RCBD with three replications (2-row plot, 5 m long). Spacing between rows was 75 cm. Three seeds were planted per hill, while seedlings were later thinned to two plants to give a final stand of 53,333 plants per hectare. Measurements were taken from each plot for DTS (days to 50% silking), plant height (cm), and grain yield at 15.5% moisture content. In addition, rust ratings, on scale of 1 to 5 (1 - resistant, 5 = very susceptible) were taken 3 weeks after flowering.

Initial statistical analyses for genotypic differences were done across the two environments for all measured traits; the linear model used was:

$$Yijm = U + Ii + LRij + LGim + Mijm$$

where : Yijm = the performance of the m genotype at the ith location in the jth replication, U = overall mean, Li = the random effect of the ith location (i = 1,2), Rj = the random effect of the jth replication (j = 1-3), LRij = the random effect associated with the ith location and the jth replication, Gm = the random effect of the mth genotype (m = 1...22), and Mijm = error.

The orthogonal partition of the sum of squares for genotypes was performed to provide estimates of the variation among testcrosses, parents and average heterosis. In addition, the testcrosses sum of squares were partitioned to determine the relative contribution of each tester. Finally, the line x tester analysis as outlined by Kempthorne (1957) was used to determine the breeding value of each of the parents.

RESULTS AND DISCUSSION

The combined analysis of variance over the two environments (Table 1) revealed no significant genotype x environment interaction for all traits measured. However, highly significant variations were detected among the tested genotypes for all measured traits. These differences were partly attributed to the inherent differences among the parents. In addition, highly significant differences were observed among the testcrosses. Average heterosis effects, measured by comparing the parents to the F1s, were highly significant.

Table 1. Pertinent mean squares from analysis of variance for all measured traits of maize parents and test crosses over two locations.

Source of variation	D.F+	Yield (t/ha)	DTS+	Plant height	Rust score
Genotypes	22	4.27**	98.36**	4733**	6.40**
Parents	7	5.35**	128.80**	6914**	14.02**
Testcrosses	14	2.79**	52.37**	2806**	3.77**
Parents vs. testcrosses	1	14.54**	461.00**	12597**	0.33NS
Genotype x environment	22	0.21	3.13	205	0.42
Error	88	1.02	2.85	711	3.21

+D.F. = degree of freedom ; DTS = days to 50% silking.

Among the parents, Ndock 8701 had the highest resistance to rust and the highest grain yield (6.07 t/ha) while Bafia, the local early maturing accession, was the most susceptible to rust and the lowest yielder (Table 2). Pool 16 SR, the earliest maturing entry, yielded as much as all local late maturing accessions, except Mfoumou; this was partly due to its greater resistance to rust.

Table 2. Performance of maize parents for all measured traits.

Variety	Yield (t/ha)	DTS^{+}	Plant height	Rust score
Ndock	6.07	61.0	212	1.7
CMS 8503	4.47	57.0	175	1.3
Nfoumou	4.10	67.3	283	4.0
Yaounde	3.40	65.3	258	3.7
Pool 16 SR	3.13	49.7	158	2.0
Bougzoudou	3.07	66.3	278	4.0
Asip	2.53	61.7	263	4.0
Bafia	1.67	52.3	207	5.0
L.S.D. (0.05)	0.66	2.9	24	1.1

$^{+}$DTS = days to 50% silking.

Among the F1s, four crosses having CMS 8503 (EV. 8449 SR) as one of the parents ranked among the five highest yielders (Table 3); each of the four was a cross between an intermediate maturing variety and a local, late maturing maize accession. By contrast, the cross between two early maturing varieties (Pool 16 SR and Bafia) yielded the least. This suggested that heterosis and/or performance appeared to be correlated with the maturity periods of the parents.

Table 3. Performance of maize testcross progenies for all measured traits.

Testcross		Grain yield (t/ha)	DTS^{+}	PHT^{+}	Rust score
CMS 8503	x Asip	5.50	57.3	197	2.0
	x Bougzoudou	5.20	55.7	233	3.3
	x Yaounde	5.67	57.3	220	3.3
	x Mfoumou	5.43	58.3	233	3.3
	x Bafia	4.50	46.3	190	3.7
Pool 16 SR	x Asip	3.70	53.0	167	2.3
	x Yaounde	4.20	53.7	178	4.0
	x Bafia	2.40	45.3	135	3.7
	x Bougzoudou	4.70	54.0	237	4.0
	x Mfoumou	4.70	54.3	212	3.7
Ndock 8701	x Asip	4.30	55.7	202	2.7
	x Bougzoudou	4.30	58.3	22	3.0
	x Yaounde	5.50	58.3	214	3.3
	x Bafia	3.30	47.3	165	4.3
	x Mfoumou	4.85	58.3	221	3.3
L.S.D. (0.05)		0.66	2.9	24	1.1

$^{+}$DTS = days to 50% silking ; PHT = plant height.

Testcrosses involving CMS 8503 as one of the parents produced, on the average, 72% higher grain yield than their local parents (Table 4). Similarly, tescrosses involving Ndock 8701 and Pool 16 SR yielded, respectively, 58 and 36% more grains than their local parents. By contrast, testcrosses involving Pool 16 SR and CMS 8503 were 20 and 28% shorter than their local parents, respectively. Similarly, rust ratings of testcrosses involving Ndock 8701 and CMS 8503 were lower than those of their lcoal parents. In addition testcrossees involving Ndock 8701 had no yield advantage over Ndock 8701. However, testcrossees yielded 22% and 25% higher than their improved tester parents in crosses involving CMS 8503 and Pool 16 SR, respectively. Also, CMS 8503, as one of the parents, exhibited positive high parent heterosis; this suggests that CMS 8503 and all local accessions used in this study belong to different heterotic patterns and thus could be used in a reciprocal selection programme.

Table 4. Performances of maize testcross as percentages of those of local parents.

Testcross		Yield(%)	DTS+	PHT+	Rust score
CMS 8503	x Asip	117	-7	-25	-50
	x Bougzoudou	70	-16	-16	-18
	x Yaounde	68	-12	-14	-11
	x Mfoumou	32	-13	-18	-19
	Average	72	-12	-19	-25
Pool 16 SR	x Asip	46	-14	-36	-43
	x Yaounde	53	-18	-15	-
	x Bafia	24	-13	-13	-
	x Bougzoudou	15	-19	-25	-8
	x Mfoumou	41	-19	-34	-20
	Average	36	-16	-28	-14
Ndock 8701	x Asip	70	-9	-23	-33
	x Bougzoudou	40	-12	-20	-25
	x Yaounde	62	-11	-17	-11
	x Bafia	98	-9	-20	-14
	x Mfoumou	18	-13	-2	-18
	Average	58	-11	-20	-20

+DTS = days to 50% silking ; PHT = plant height.

The partitioning of the testcross sums of squares to determine the relative contribution of each of the three testers (Table 5) revealed that the highly significant variations, observed for testcrosses for all traits, were mainly attributable to the significant variation among testcrosses with Pool 16 SR as one of the parents. These variations were also the highest among the three testers; this suggests that Pool 16 SR would be the best tester for evaluating the combining ability of the lcoal maize accessions. Thus, the higher yields of the testcross progenies of CMS 8503 or Ndock 8701 were largely due to higher relative contributions by these two testers. Lonquist and Lindsey (1970) postulated that the tester parent contributed one half of the genetic constitution of the testcross combinations. Thus, the better the tester, the better the topcross progenies. Therefore, it would be of little value to use Pool 16 SR in an effort to improve local maize accessions because of the low performance of their F1s.

Table 5. Pertinent mean squares from the partitioning of maize testcross sums of squares for all traits.

Source of variation	D.F.+	Yield	DTS+	PHT+	Rust score
Testcrosses	14	2.74**	50.37**	2806**	3.77**
Testcrosses with CMS 8503	4	0.12	3.67	722**	3.0**
Testcrosses with Pool 16 SR	4	2.75**	43.23**	469**	1.43*
Testcrosses with Ndock 8701	4	2.11	81.42**	1874**	1.55

+D.F. = degrees of freedom; DTS = days to 50% silking; PHT = plant height.

The maize line x tester analysis of variance (Table 6) revealed highly significant line x tester interaction, suggesting the prodominance of only non-additive gene effect for all measured traits.

Table 6. Maize line x tester analysis of variance.

Source of variation	D.F.+	Yield	DTS+	PHT+	Rust score
Testcrosses	14	2.7**	50.37**	2806**	3.77**
Local varieties	4	0.86	39.78	1403	0.73
Testers	2	0.35	2.95	183	0.04
Local x testers	8	4.48**	76.72**	4468**	6.40**
Error	20	0.21	3.13	206	0.42

+: for explanation, see table 5.

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6. Réponse de Trois Cultivars de *Vigna unguiculata* (L.) Walp. à deux Régimes Contrastés d´Humidité du Sol.

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RESUME

Trois cultivars de *Vigna unguiculata* KN-1, SUVITA-2 et TN88-63 ont été cultivés en serre dans des pots contenant un mélange de terre de granulation précise (2 à 5 mm), dont la capacité au champ a été déterminée. Dix jours après le semis, chaque pot a été démarié à deux plants et chaque cultivar a été alimenté en eau suivant deux régimes: Régime 1 : 80% de la capacité au champ du mélange de terre et régime 2 : 40% de cette même capacité au champ. Différents caractères de croissance végétative, de production et la transpiration ont été étudiés.

Les plantes alimentées avec 80% de la capacité au champ ont montré qu´il existe une variation variétale pour tous les caractères étudiés. Les plantes alimentées avec 40% de la capacité au champ montrent qu´à l´exception de la longueur moyenne des gousses, le poids moyen de 100 graines chez TN88-63 et la date de floraison chez SUVITA-2, tous les autres caractères sont significativement réduits par l´alimentation insuffisante en eau. En outre, au niveau de la transpiration, on observe un avancement de l´heure de la transpiration maximale dans la journée, et un déplacement de la température optimale de la transpiration vers les températives les moins chaudes. SUVITA-2 supporte mieux les températures élevées que KN-1 et TN88-63.

ABSTRACT

Three cultivars of cowpea (KN-1, SUVITA-2 and TN88-63) were grown in pot culture in the greenhouse. Ten days after sowing, plants were thinned to two plants per pot. Pots were watered to effect two soil moisture regimes, namely 80% or 40% of field capacity. Different vegetative and reproductive traits, as well as transpiration, were recorded.

The results showed that at 40% field capacity all traits (except average pod length and 100-seed weight for TN88-63 and flowering date for SUVITA-2) were significantly decreased by insufficient water supply. For instance, maximum transpiration rate was attained earlier and there was a decrease in maximum transpirtation temperature. SUVITA-2 tolerated high temperatures better than KN-1 or TN88-63.

INTRODUCTION

Dans la zone intertropicale d´Afrique, la sécheresse comprise comme une période de temps suffisamment longue ne comportant pas de jours pluvieux ayant un impact sur la croissance de la plante (MULEBA, 1988) est pratiquement un phénomène.

Certains auteurs pensent que pour l´agriculture dans ce milieu, ce sont essentiellement les précipitations aléatoires du début de la saison des pluies qui affectent surtout les jeunes plantes et le raccourcissement de cette saison qui peut toucher les derniers stades de la maturation des grains chez les céréales (LOUGUET, 1985).

Mais pour d´autres, même avec une pluviométrie globale apparemment suffisante pour les besoins des plantes, des périodes de sécheresse de sévérité variable se manifestent chaque année en période de végétation provoquant des baisses de rendements parfois très graves (GAUTEAU, 1985).

De ce fait, l´un des problèmes majeurs que doit résoudre la recherche agronomique dans ces zones pour plus contribuer au développement de l´agriculture est celui de la sécheresse. Aussi, beaucoup de recherches ont été entreprises pour trouver des variétés résistantes à la sécheresse. Les premières tentatives d´amélioration de la résistance ont surtout porté sur la sélection de cultivars à cycle de développement raccourci permettant de ne pas subir les aléas du début et de la fin de la saison des pluies en évitant ainsi la sécheresse (Drought avoidance), (LOUGUET, 1985). Très vite, on s´est rendu compte que la précocité affecte négativement le rendement potentiel, et que la sélection pour la précocité à la floraison réduit moins le potentiel de rendement que la sélection pour la maturité (HALL et PATEL, 1985 cités par KONDA, 1987).

En outre, la sélection pour la précocité n´est pas satisfaisante en cas de sécheresse en période de végétation (GAUTREAU, 1985). Les conditions climatiques de la savane Sahélienne imposent l´utilisation de variétés non photosensibiles et tolérances à la sécheresse à tous les stades de développement (MULEBA, 1988).

Il est donc nécessaire que des variétés tolérantes à la sécheresse soient sélectionnées. Cette forme de sélection doit avoir pour base la connaissance des critères physiologiques de résistance à la sécheresse. Pour DA SILVA (1985), le physiologiste est d´une utilité certaine, et doit obtenir sa motivation à partir des problèmes soulevés au niveau du système agricole et fournir des informations à l´améliorateur pour ce qui est des bases physiologiques de la résistance et de la productivité.

Ainsi, beaucoup de travaux à caractère physiologique ont été entrepris sur le niébé (MULEBA, 1985, 1988 ; WOSTEN, 1981). La plupart de ces travaux ont consisté à étudier la réaction des plantes de niébé soumises à la suppression de l'alimentation en eau pendant une période plus ou moins longue. Cette sécheresse est parfois combinée à une variation de la température.

A notre connaissance, aucune étude n'a été entreprise sur le comportement du niébé dans une situation d'alimentation régulière mais insuffisante en eau durant le cycle de développement. C'est l'objet du présent travail.

MATERIEL ET METHODES

Matériel

Le matériel végétal utilisé est constitué par trois cultivars de Vigna unguiculata (L.) Walp. Il s'agit de :

- KN-1
- SUVITA-2
- TN88-63

Ces trois cultivars ont été choisis de manière à nous permettre de bien appréhender notre thème.

KN-1 s'oppose à TN88-63 et SUVITA-2 ; il est associé aux sites les plus humides à pluviométrie supérieure à 600 mm. Il ne s'exprime bien que dans les zones à pluviométrie élevée et s'adapte mal aux zones sèches (Institut du Sahel, 1984). TN88-63 et SUVITA-2 trouvent une correspondance plus marquée avec les sites à pluviométrie inférieure à 600 mm. Dans ce dernier groupe, SUVITA-2 est sans doute le mieux adapté aux conditions dévavorables mais présente une moins bonne adaptation aux conditions humides. TN88-63 s'accommode mieux aux écologies les plus variées.

Méthodes

Tous les essais sont menés en serre. Les essais sont réalisés dans des pots contenant un mélange de terre constitué par deux types de sol : limon argileux, brunâtre contenant beaucoup de matière organique dans les proportions 2/1. Ces sols sont tamisés de manière à obtenir des particules avec un diamètre compris entre 2 et 5 mm.

On détermine la capacité au champ du mélange en utilisant un tuyau PVC de 6 cm de diamètre et 20 cm de haut. Une extrémité du tuyau est fermée avec une grille moustiquaire en fer ou en nylon ayant des mailles inférieures à 2 mm ; on le remplit du mélange de sols jusqu'à 2 cm du bord. Le poids sec de la terre est déterminé (X). Puis on le sature d'eau. On ferme l'autre extrémité du tuyau pour éviter l'évaporation et on laisse la terre égouter pendant 24 heures. On pèse alors la terre mouillée (Y). La capacité au champ (CAC) est déterminée par la formule suivante :

$$C.A.C. = \frac{Y - X}{X} = \text{gr H20/gr de terre sèche}$$

On met alors dans chaque pot une quantité d'eau égale à 80% de la capacité au champ.

<u>Ensemencement</u>. dans chaque pot, on sème 10 graines de niébé à la profondeur d'un cm. 10 jours après le semis, on démarie à deux plantules saines et vigoureuses, puis l'on recouvre la surface avec une feuille de papier aluminium afin de limiter l'évaporation.

L'essai comporte 30 pots par cultivar. Chaque cultivar est semé dans 26 pots et les 4 sans plantes serviront de témoins. Les pots témoins permettent de déterminer l'évaporation. Si le pot rempli du mélange de terre et arrosé avec 80% de la capacité au champ pèse 5 kg, chaque jour ou tous les 2 jours, selon la vitesse de l'évapotranspiration, on ramène le pot au poids initial soit 5 kg, par un rajout d'eau. Mais au fur et à mesure que les plantes grandissent, on corrige en ajoutant le poids de la plante.

A partir du démariage, la moitié des pots de chaque cultivar ne sont plus arrosés qu'à 40% de la capacité au champ. Chaque semaine, on récolte 4 pots par cultivar : 2 pots avec 80% de la capacité au champ et 2 autres avec 40%. Pendant la récolte, les mensurations suivantes sont effectuées :

- Hauteur de la plante
- Nombre de feuilles
- Poids de la matière fraîche de la partie aérienne et des racines.
- Nombre de nodosités.

La transpiration est mesurée également par semaine. Dans ce cas, on mesure toutes les heures (de 7 heures à 18 heures) les paramètres suivants :

- L'évaporation
- L'évapotranspiration
- La température de l'air
- L'humidité relative de l'air
- Eventuellement la température du sol.

On obtient la transpiration par la différence entre l'évapotranspiration et l'évaporation.

Tous les résultats présentés sont la moyenne d'au moins quatre mesures, même si les écarts-types n'apparaissent pas sur les courbes.

RESULTATS

Les caractères de croissance végétative (Tableau 1)

La hauteur des plantes. En comparant la hauteur des 3 cultivars, il apparaît qu'à la quatrième semaine après le semis, KN-1 présente des plantes plus grandes que les 2 autres. Les plantes alimentées avec 40% de la capacité au champ sont significativement plus courtes que celles qui sont alimentées avec 80% de la capacité au champ (Tableau 1). KN-1 est plus sensible à l'effet de l'alimentation insuffisance en eau que les deux autres cultivars qui ont un comportement similaire.

Le nombre de feuilles. L'évolution du nombre de feuilles donne les indications suivantes à quatre semaines après le semis : TN88-63 présente un nombre de feuilles significativement supérieur aux autres cultivars (Tableau 1); SUVITA-2 a le moins de feuilles. KN-1 présente le nombre de feuilles le moins sensible à l'effet de l'alimentation insuffisante en eau ; TN88-63 et SUVITA-2 ont une réaction similaire et sont plus sensibles.

Le poids de matière sèche des trois cultivars. En comparant le poids de matière sèche (somme de poids sec A + poids sec S) des trois cultivars (Tableau 1) quatre semaines après le semis, on constate que TN88-63 produit la matière sèche la plus faible. La jeune plante de SUVITA-2 produit plus de matière sèche que les deux autres.

L'effet de l'alimentation insuffisante en eau des plantes sur le poids de la matière sèche des trois cultivars est très net aux stades de quatre semaines après le semis. Au niveau de la partie aérienne, l'effet est moins sensible chez TN88-63, plus sensible chez SUVITA-2 et KN-1 ayant une position intermédiaire. En revanche, au niveau des racines, cet effet est moins sensible chez SUVITA-2; KN-1 étant toujours le plus sensible. D'une façon générale, il y a une amélioration du rapport (poids sec A : poids sec S) chez les plantes de SUVITA-2. Il est faible chez les plantes de KN-1; le cultivar TN88-63 occupe une position intermédiaire.

Le nombre de nodosité. Quatre semaines après le semis, il n'y a pas de différence significative entre les trois cultivars quant au nombre de nodosités.

L'effet d'une alimentation insuffisante en eau entraîne une réduction importante du nombre de nodosités chez SUVITA-2 et TN88-63. KN-1 semble être le cultivar dont le nombre moyen de nodosités est plus sensible.

Tableau 1. Effet de l'alimentation normale (80% CAC) et insuffisante (40% CAC) en eau sur quelques caractères végétatifs de trois cultivars de niébé, quatre semaines après le semis.

	KN-1			SUVITA-2			TN88-63		
	80%	40%	S	80%	40%	S	80%	40%	S
Hauteur tige (cm)	44,5±1,41A	26,37±1,62B	40,7	37,36±2,76A	22,93±1,95B	38.6	36,63A	22,5B	38.6
Nombre de feuilles	9±0,86B	6±0,33	33.3	9±2,55B	5±0,43D	44.4	14±12A	8±,71C	42.9
Poids sec A	6,01±0,29	2,34±0,25	61.1	8,68±1,84A	2,53±0,21C	70.8	4,7±0,11AB	1,98±0,17C	57.9
Poids sec S	1,24±0,14A	0,33±0,03B	73.4	0.88±0,33A	0,46±0,04B	47.7	0,95±0,04B	0,29±0,06	69.5
Nombre de nodosités	97±42,21A	36±17,07B	62.9	83±38,80A	21±3,08B	74.7	105±52,64A	29±7,18B	72.4

Poids sec A = Poids de matière sèche de la partie aérienne.

Poids sec S = Poids de matière sèche des racines

$$S = \frac{\text{Paramètres mesurés sous 80\% CAS-paramètres mesurés sous 40\% CAC}}{\text{paramètres mesurés sous 80\% CAC}} \times 100$$

S = Indice de sensibilité (ROBELIN, 1985).

Les moyennes suivies de la même lettre pour un paramètre donné ne sont pas significativement différentes au seuil de 0,05 test de Newmann-Keuls.

Les caractères de production (Tableau 2)

La date de floraison. Le Tableau 2 montre qu'il n'y a pas de différence entre la date de floraison des différents cultivars en condition d'alimentation normale en eau.

Face à une alimentation insuffisante en eau, la date de floraison n'est pas affectée significativement chez KN-1 et SUVITA-2. En revanche, elle est retardée chez TN88-63.

Le nombre de gousses par plante. TN88-63 produit le plus grand nombre de gousses par plante ; KN-1 forme moins de gousses par plante que SUVITA-2 mais la différence n'est pas significative.

Sous une alimentation insuffisante en eau. KN-1 ne produit presque pas de gousses ; tandis que TN88-63 et SUVITA-2 ne se différencient pas et sont sensibles que KN-1.

Le poids d'une gousse. En condition normale, les gousses de SUVITA-2 pèsent plus que celles de KN-1 et TN88-63, cette dernière ayant le poids le plus faible.

L'alimentation insuffisante en eau diminue sensiblement le poids des gousses chez SUVITA-2 et TN88-63.

La longueur d'une gousse. Parmi les trois cultivars, la gousse de KN-1 est la plus longue ; SUVITA-2 a les gousses les plus courtes et TN88-63 se situe entre les deux.

L'alimentation insuffisante en eau n'a pas d'effet sur la longueur des gousses.

Le poids de 100 graines. SUVITA-2 a le poids de 100 graines le plus élevé, tandis que TN88-63 présente le poids le plus bas. KN-1 occupe une position intermédiaire.

Une alimentation insuffisante en eau réduit significativement le poids de 100 graines chez SUVITA-2. Elle n'a pas d'effet significatif sur TN88-63.

Le nombre de graines par gousse. Les trois cultivars ne présentent pas de différences en ce qui concerne le nombre de graines par gousse. Les plantes de SUVITA-2 et TN88-63 soumises à 40% de la capacité au champ ont des gousses qui contiennent significativement moins de graines qu'en alimentation normale en eau. Le nombre de graines par gousse est moins sensible à l'effet d'une alimentation insuffisante en eau chez TN88-63 que chez SUVITA-2.

Tableau 2. Effet de l'alimentation normale (80% CAC) et insuffisante (40% CAC) en eau sur quelques caractères de production chez trois cultivars de niébé, quatre semaines après le semis.

	KN-1			SUVITA-2			TN88-63		
	80%	40%	S	80%	40%	S	80%	40%	S
Date de floraison	47	48	0	48	49	0	43	52	0
Nombre de gousses/plt	7±2,86	1	-	8±1,92A	5±1,12B	37.5	12±3,94A	5±3,20B	58.3
Poids moyen/ gousse (cm)	1,70±0,27	-	--	1,98±0,23A	0,90±0,48C	54.5	1,07±0,18B	0,68±0,40B	36.4
Longueur moyenne/ gousse (cm)	12,25±0,95	-	-	8,91±0,90	8,21±0,98	7.86	9,17±0,37	9,17±4,42	0
Poids moyen 100 graines (gr)	13,96±2,33	-	-	20,07±70A	15,004±4,74B	25.2	10,87±0,37C	10,52±4,57C	3,22
Nombre moyen	8±1,09	-	-	8±1,48A	5±2,17B	37.5	8±1,22A	6±2,46B	25,0

La transpiration à 29 jours après semis.

On observe une augmentation régulière de la transpiration chez les plantes des trois cultivars alimentés normalement de 7 h à 13 h pour SUVITA-2 et 14 h pour KN-1 et TN88-63. Puis elle baisse progressivement (Figures 1, 2).

Le cultivar KN-1 présente la transpiration journalière le plus élevée ; cependant, la matinée, TN88-63 transpire plus que KN-1 ; SUVITA-2 présente la transpiration journalière la plus faible.

L'effet de l'alimentation insuffisante en eau se traduit chez les trois cultivars par une réduction très importante de la transpiration journalière ; l'heure de la transpiration maximale de la journée se déplace de 14 h à 12 h. L'amplitude de la transpiration est ici très faible. SUVITA-2 demeure toujours le cultivar qui a la transpiration journalière la plus faible. On ne note pas de différence entre les deux autres cultivars (Figure 2).

Chez les plantes alimentées normalement, la transpiration augmente avec la température à partir de 28°C jusqu'à 34°C pui décroit à partir de 34°C ; la température optimale de transpiration se situe à 34°C pour les trois cultivars (Figure 3).

Les plantes qui ont été soumises à une alimentation insuffisante en eau transpirent très faiblement par rapport à celles alimentées normalement. La température optimale de la transpiration se situe à 33°C au lieu de 34°C. l'amplitude entre la température optimale et la température où la transpiration est la plus faible est insignifiante. L'alimentation en eau constitue ici le facteur limitant (Figure 3).

Il y a une diminution de la transpiration au fur et à mesure que l'humidité relative augmente (Figure 4). Cependant, l'abaissement brutal de la transpiration observé à 42% est indépendant de l'humidité relative, car bien que la transpiration soit liée négativement à l'humidité relative, elle n'en est pas le facteur déterminant. Tout comme pour la température on voit que TN88-63 transpire plus que KN-1 aux humidités relatives plus élevées. Les observations faites sur les comportements des plantes soumisees à une alimentation insuffisante en eau concernant la température sont valables également pour l'humidité relative. On note surtout une amplitude de la transpiration presque nulle pour SUVITA-2.

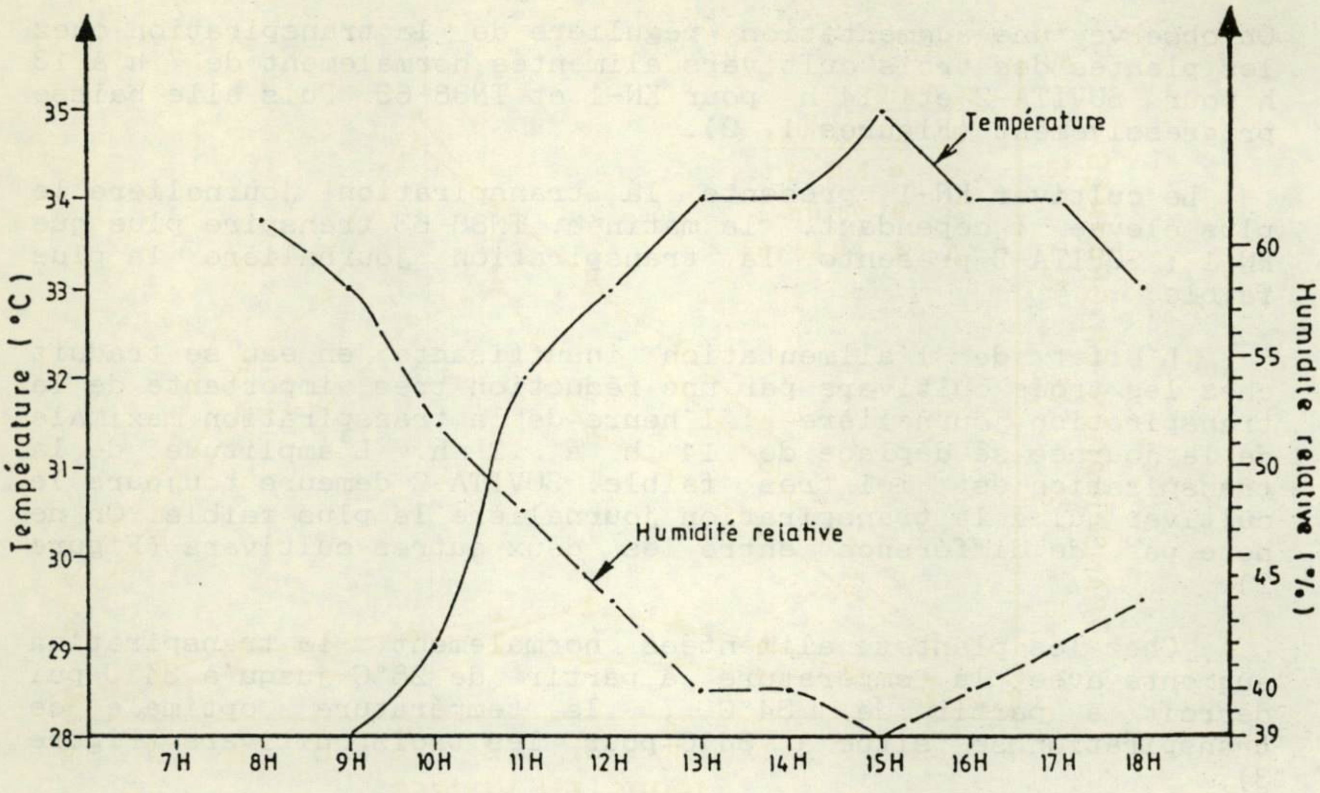

Figure 1 : Variation de la température et de l'humidité de l'air en fonction de l'heure de la journée (29$^{\text{ème}}$ jour après les semis).

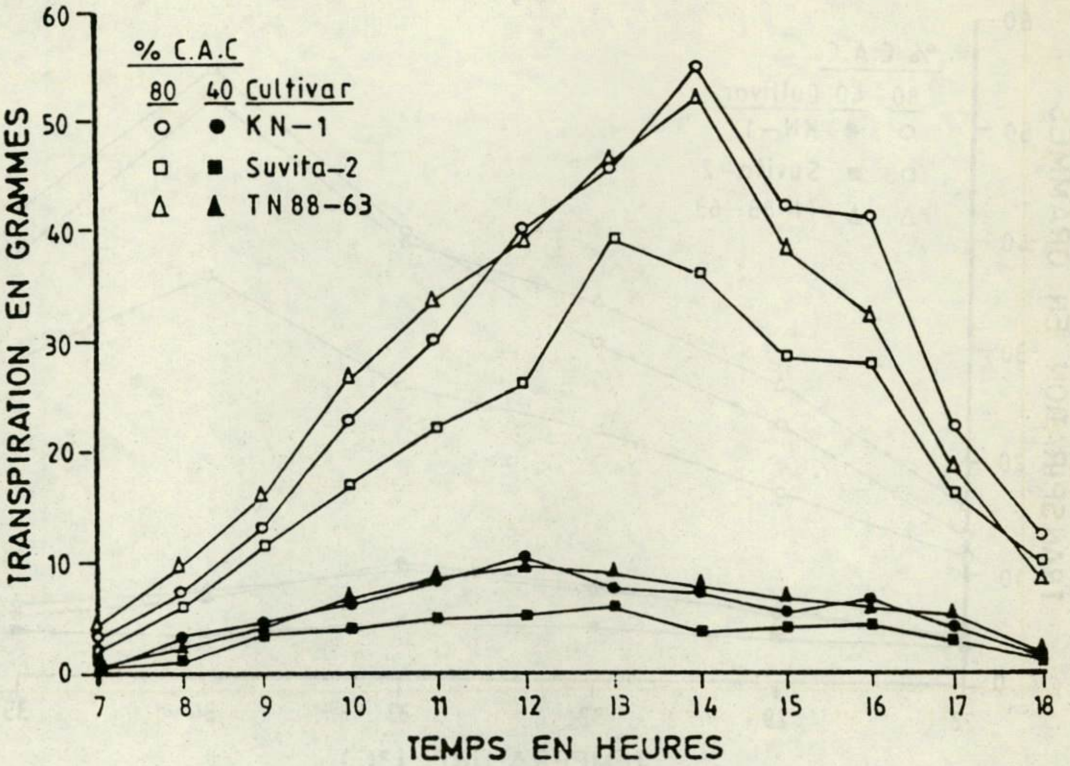

Figure 2 : Transpiration des plantes agées de 29 jours sous deux régimes hydriques : 80 % et 40 % de capacité au champ, en fonction du temps ; culture en pot, Ouagadougou.

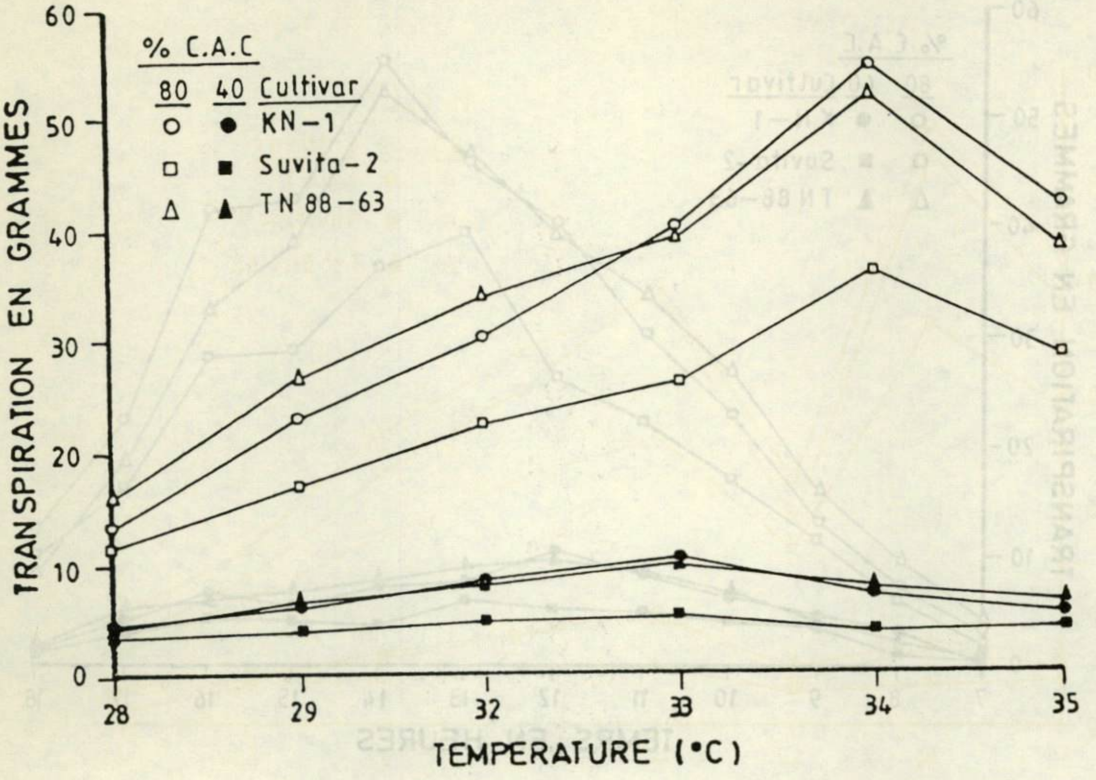

Figure 3: Transpiration des plantes agées de 29 jours, sous deux régimes hydriques : 80 %. et 40 %. de capacité au champ, en fonction de la température ; culture en pot, Ouagadougou.

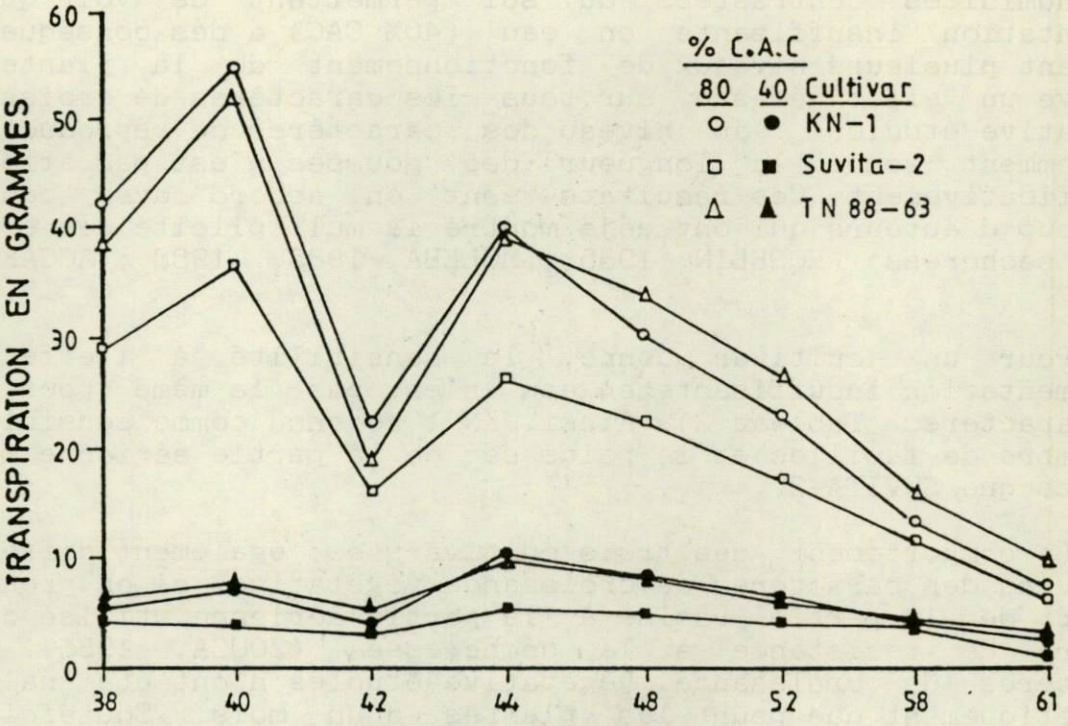

Figure 4 : Tranpiration des plantes agées de 29 jours, sous deux régimes hydriques : 80 % et 40 % de capacité au champ, en fonction de l'humidité relative; culture en pot, Ouagadougou.

DISCUSSION

L´étude de certains caractères de croissance végétative et de production, de la transpiration de trois cultivars de niébé connus pour leur sensibilité différente au stress hydrique, sous deux humidités contrastées du sol permettent de voir qu´une alimentation insuffisante en eau (40% CAC) a des conséquences touchant plusieurs niveaux de fonctionnement de la plante. On observe un effet néfaste sur tous les caractères de croissance végétative étudiés : au niveau des caractères de reproduction, apparemment seule la longueur des gousses n´est pas affectée significativement. Ces résultats sont en accord avec ceux de beaucoup d´auteurs qui ont déjà montré la multiplicité des effets de la sécheresse (ROBELIN, 1985 ; MULEBA, 1985, 1988 ; AGGARWAL, 1985).

Pour un cultivar donné, la sensibilité à l´effet de l´alimentation insuffisante en eau n´est pas la même pour tous les caractères (Tableau 2). Ainsi, KN-1 reconnu comme sensible, a le nombre de feuilles et le poids sec de la partie aérienne moins réduits que SUVITA-2.

Le comportement des trois cultivars est également différent au niveau des caractères de croissance végétative, si on prend le rapport de la partie racine à la partie aérienne utilisé comme critère de résistance à la sécheresse (ZOUZA, 1985). Les caractères de croissance végétative étudiés n´ont été analysés statistiquement que pour les plantes d´un mois. Toutefois, à l´âge d´un mois, cette sensibilité n´est peut-être pas la plus caractéristique. La sensibilité de la jeune plante rendrait plus compte des difficultés d´établissement en début de saison, et sa sensibilité pendant la phase de reproduction serait directement liée à sa phase très critique du rendement (LOUGUET, 1985). Cette observation d´autant plus pertinente que WOSTEN, 1981 confirmé par MULEBA, 1988 a montré qu´une sécheresse pendant la phase végétative a peu d´effet sur le rendement ; la sécheresse appliquée pendant la phase reproductive, surtout pendant la floraison a des effets très critiques sur le rendement.

Les effets de l´alimentation insuffisante en eau sur les caractères de reproduction retenus montrent que KN-1 est très sensible, la production de fleurs étant très limitée. Ainsi, son effet sur les autres caractères de reproduction retenus n´a pu être étudié chez KN-1.

SUVITA-2 et TN88-63 sont plus tolérants à une alimentation en eau insuffisante. Mais leur sensibilité est très variable selon le caractère choisi. Par exemple, l´alimentation insuffisante en eau influence peu la date de floraison de SUVITA-2. En revanche, elle retarde celle de TN88-63. A l´inverse, elle influence peu le poids de 100 graines chez TN88-63 alors qu´elle le réduit significativement chez SUVITA-2. Le nombre moyen de gousses par plante est moins sensible chez SUVITA-2 que chez TN88-63. Ce dernier caractère a une bonne corrélation avec le rendement (AGGARWAL, 1985). Mais TN88-63 est moins sensible que SUVITA-2 pour le poids moyen d´une gousse, le poids de 100 graines et le nombre moyen de graines par gousse.

L'étude de la transpiration montre que SUVITA-2 transpire moins que KN-1 et que TN88-63 occupe une position intermédiaire. KONDA (1987) avait déjà montré que SUVITA-2 été caractérisé par sa transpiration journalière faible. L'heure de la journée où la plante transpire le plus se situe vers le début de l'après-midi pour les plantes âgées d'un mois. La température optimale de transpiration est variable. Il apparait aussi que la température n'est pas le facteur déterminant de la transpiration. On observe les mêmes caractères au niveau de l'humidité relative. Les plantes qui ont été alimentées avec 40% CAC ont énormément réduit leur transpiration journalière.

De cette étude, il apparaît que : TN88-63 et KN-1 ont un comportement presque similaire, surtout lorsqu'il s'agit de la transpiration. Les deux cultivars se distinguent nettement de SUVITA-2. Ces résultats bien que portant sur des caractères différents sont en accord avec ceux de MULEBA, 1988 qui montrent que SUVITA-2 et TN88-63 malgré leur commune origine sahélienne ont un comportement contrasté face aux températures élevées du sol. L'approfondissement de l'étude en incluant le comportement stomatique, le potentiel hydrique et la turgescence relative permettra peut-être une meilleure compréhension de la résistance à la sécheresse chez le niébé.

CONCLUSION

L'étude des effets de l'alimentation normale en eau (80% de la capacité au champ) et de l'alimentation insuffisante (40% de la capacité au champ) sur trois cultivars de niébé (SUVITA-2, TN88-63 et KN-1) permettent de tirer les conclusions suivantes :

L'alimentation insuffisante en eau entraîne une réduction significative des caractères de la croissance végétative et de production. Cette réduction est variable selon le cultivar. Elle est sans effet sur la date de floraison de SUVITA-2 et KN-1 et retarde la date de floraison de TN88-63. Elle est sans effet sur la longueur des gousses des 3 cultivars et sur le poids de 100 graines chez TN88-63. Elle réduit le potentiel de tous les autres caractères étudiés chez les trois cultivars.

Les plantes alimentées normalement ont une transpiration variable selon le cultivar. KN-1 a une transpiration journalière plus élevée que SUVITA-2. TN88-63 occupe une position intermédiaire.

L'heure de la journée, où on observe une transpiration maximale des plantes varie. Elle se situe à 13 heures et 14 heures pour des plantes de 29 jours, respectivement pour SUVITA-2 d'une part, et KN-1 et TN88-63 d'autre part.

La température de l'air, la température du sol et l'humidité relative de l'air ont des effets caractéristiques sur la transpiration, l'alimentation en eau étant le facteur déterminant.

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7. Recent Progress on Breeding for Striga Resistant Maize at IITA

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ABSTRACT

Striga hermonthica is regarded as a major biotic constraint to maize production in savanna belt of West and Central Africa. At IITA, breeding for resistance/tolerance has been the major thrust to combat the parasite since 1982 ; soucres of tolerance have been identified. In 1988, a technique for artificial infestation of the soil was developed for pot culture conditions in the screenhouse. Sources for tolerance have been confirmed in inbreds, hybrids, and open-pollinated varieties, with most of the tolerance sources originating from the U.S. Corn Belt. Most open-pollinated varieties and all Tuxpeno groups (Pop. 21, 43, 44, 49, TZPB) are highly susceptible. Among the IITA-developed hybrids, 8322-13, 8425-8 and their related inbreds appear to possess some level of resistance.

RESUME

Striga hermonthica est considéré comme la principale contrainte biotique à la production du maïs dans l écologie de savane de l´Afrique Centrale et Occidentale. A l´IITA, la sélection pour la résistance/tolérance a été la principale initiative pour combattre le parasite depuis 1982 ; des sources de tolérance ont été identifiées. En 1988, une technique d´infestation artificielle du sol a été mise au point pour la culture en pot en serre. Des sources pour la tolérance ont été confirmées au niveau des inbreds, des hybrides, et des variétés à pollinisation libre ; la plupart de ces sources de tolérance provenaient de Corn Belt, des Etats Unis. Un plus grand nombre de variétés à pollinisation libre et tous les groupes Tuxpeno (Pop 21, 43, 44, 49, TZPB) se sont révélés très sensibles. Parmi les hybrides mis au point par IITA, 8322-13, 8425-8 et leurs inbreds assimilés semblaient avoir quelque degré de résistance.

INTRODUCTION

Striga, a parasitic weed, is one of the most important constraints to increased maize production in sub-Saharan Africa. In 1983, IITA maize scientists identified sources of tolerance among IITA inbreds and hybrids (IITA, 1984).

A survey conducted in 1984 showed that, among five species of Striga that attack maize in West and Central Africa, S. hermontica and S. aspera caused important crop losses in maize and other cereals, such as sorghum, millet, and rice (IITA, 1985). However, the progress in breeding for Striga resistance in maize has been slow due to lack of uniformly infested fields in which screening for resistance can be done.

In 1988, two international workshops on Striga were held in Africa. The first one on "Combating Striga in Africa: Opportunities for Research Collaboration" was held at IITA, Ibadan (Nigeria) from 22-24 August ; it was financially sponsored by IDRC, Canada and organized jointly by IITA and ICRISAT. The second workshop, held in Banjul, Gambia (5-6, December), was organized by FAO and OAU; its theme was Striga control. The Ibadan workshop identified priority areas for Striga research at all levels (from basic to adaptive research) for the various crop-based systems of West and Central Africa. The objectives of this paper are to:

(i) provide available information about yield losses caused by Striga in both tolerant and susceptible maize hybrids, and

(ii) present results of preliminary screening of open-pollinated maize varieties and U.S. Corn-Belt maize inbred resistant (MIR) lines for resistance to Striga in the screenhouse.

METHODOLOGY AND RESULTS

Yield loss assessment

Information about maize yield losses caused by Striga is very limited. Studies conducted by IITA scientists with 100 maize hybrids grown in soil artificially infested with S. hermontica showed a negative correlation (r = -0.35) between grain yield and Striga damage and positive correlations between Striga damage and the number of emerged Striga plants (r = 0.46), on one hand, and between Striga damage and stalk lodging (r = 0.44) on the other.

Two experiments were carried out to further study the effect of infection by Striga on yield and agronomic traits of maize. Two hybrids, one tolerant (8322-13) and the other susceptible (8338-1), were used in the first experiment conducted at Mokwa, Nigeria, in 1985, using five levels of soil Striga infestation (namely, 1 = zero, 2 = 20, 3 = 40, 4 = 60 and 5 = over 80% infestation). The two hybrids were planted side by side in 200-m rows replicated four times. Grain yield and yield components at each infestation level were recorded (Table 1). Both hybrids yielded almost equally (7.6 and 7.5 t/ha) at the zero infestation level. However, they differed greatly in their response to Striga infection. For example, at intermediate soil infestation level (level 3), the yield loss of the susceptible hybrid was 54% while that of the tolerant hybrid was only 19%; at this level of Striga attack, the yield of affected and unaffected tolerant hybrids were not significantly different from each other. Other yield components affected by Striga included plant height, number of ears harvested, stalk lodging, ear length, ear diameter, and 100-kernel weight.

Table 1. Grain yield (t/ha) and agronomic traits of two maize hybrids grown in soil with five different levels of Striga infestation at Mokwa (Nigeria) in 1985.

Maize hybrid	Striga infestation level in soil⁺	Grain yield (t/ha)*	Yield index (%)	No. of ears/ plant
8322-13 (tolerant)	1	7.6a	100	1.2
	2	7.5a	99	1.5
	3	6.2a	81	1.1
	4	4.6b	60	1.1
	5	2.7c	36	0.7
8338-1 (susceptible)	1	7.7a	100	0.9
	2	5.5b	71	0.9
	3	3.5c	46	0.8
	4	1.9d	25	0.7
	5	0.0e	9	0.3

⁺Striga infestation level: 1 = zero infestation, 5 = 80 percent infestation.

*Yields followed by different letters are significantly different (P = 0.05).

In the second experiment conducted in a screenhouse between February and May, 1988, two susceptible (8338-1 and 8321-21) and two tolerant (8322-13 and 8425-8) hybrids were used ; they were known to have similar yield potentials under *Striga*-free conditions. A *Striga* seed-sieved sand mixture (0.06 g *Striga* seed: 90 g sieved sand) was used to inoculate 2.5 m row plot at a depth of 5 cm before maize was sown directly above the *Striga* seeds. Data were collected from 10 plants for each of the five replications. The average grain yields of the two tolerant hybrids were considerably much higher than those of the susceptible hybrids (Table 2).

Table 2. Grain yield (g/plant) and agronomic traits of four maize hybrids grown in soil artificially infested with *Striga hermonthica* in the screenhouse in 1988.

Maize hybrids	Grain yield (g/ plants)*	Ear length (cm)*	Ear diameter (cm)*	Maize stover (g/ plants)*	No. of *Striga*/ plot*	*Striga* damage rating*	Stalk lodging (1-9)+*
Tolerant							
8322-13	99.7a	11.6a	4.6a	123.8a	20.6	2.9a	1.2a
8425-8	79.5a	12.6a	3.6a	60.6a	22.6	2.6a	3.8a
Susceptible							
8338-1	40.4b	6.2b	3.0b	40.8c	76.6	7.1b	7.0b
8321-21	31.5b	8.2b	2.7b	46.0bc	27.0	7.7b	8.2b

*Values followed by different letters are significantly different (P = 0.05) from each other.

+Rating based on scale of 1-9 in which 1 = highly resistant and 9 = highly susceptible.

Screening open-pollinated and synthetic maize varieties for resistance to *Striga*

Twelve open-pollinated and six synthetic maize varieties were screened for *Striga* resistance in the screenhouse at IITA between November, 1988 and February, 1989. The checks comprised two susceptible hybrids (8321-21 and 8338-1), two tolerant hybrids and two tolerant inbreds.

Each entry was planted in two row plots, each row being 1.25 x 0.75 m. A mixture of 0.035 g of *Striga* seed and 45 g of sieved sand was used to infest each row at a depth of 5 cm before maize seeds were planted as described above.

Cumulative *Striga* counts per m^2 were recorded from a month after planting until harvest. *Striga* damage rating (on a scale of 1-9) was made about 76 days after planting ; at that time symptoms of *Striga* infection had become very distinct.

The results are presented in Table 3. Hybrids and inbreds with *Striga* damage rating of between 2.3 and 3.6 were considered to be tolerant to *Striga*. Moderately tolerant varieties comprised those with *Striga* damage rating of between 4.1 and 5.7. Other varieties with higher scores were regarded as being susceptible to *Striga*. However, emerged *Striga* counts for these three categories varied greatly among the cultivars and did not follow a specific pattern.

Screening of MIR (maize inbred resistant) lines for Striga resistance in artificiallly infested soil

Seventy maize inbred resistant (MIR) lines collected from U.S. Corn Belt were screened for resistance to *Striga* attack in articially infested soil at IITA in the screenhouse between October, 1988 and January, 1989. Plot size and soil infestation with *Striga* seeds were as described above. *Striga* damage rating, with which grain yield was more negatively correlated than *Striga* count, was used for selection, scoring being done about 70 days after planting.

Inbreds with average *Striga* damage ratings of at least 4.0 were rejected. Out of the 70 MIR lines tested, only 22 had average *Striga* damage ratings of less that 4.0 (Table 4); the most tolerant lines were Hi28, Hi4263, and Hi98. It is interesting to note that MIR lines, B73 and N28, from which 9450 and 9030 (male parents of two tolerant hybrids, 8425-8 and 8322-13, respectively), were developed were among the lines rated as tolerant. It is likely that more *Striga* resistant hybrids will be developed after further screening of MIR lines.

Table 3. Striga damage rating (1-9) in, and number of emerged Striga from, 26 maize varieties under screenhouse conditions at IITA, Ibadan in 1989.

Maize entry[b]	Striga damage rating*	Number of emerged Striga plants/m2
9030(o)	2.3	0
8322-13(+)	2.8	1.5
9006(o)	2.8	0
B73 x B84	3.3	1.0
Mo17 x MBS(+)	3.6	1.5
TZUT-W(+)	4.1	4.0
8425-8(+)	4.8	11.0
Synthetic-2	5.3	7.3
Drought Synthetic	5.3	5.8
TZESR-W	5.5	5.5
Synthetic-1	5.7	15.8
Synthetic-5	5.7	4.0
TZESR-Y	5.7	2.0
Western Yellow	6.1	6.5
MK TZSR-Y	6.2	21.8
MK TZSR-W	6.5	24.3
Suwan-1-SR	6.5	2.5
TZB-SR	6.6	14.0
Synthetic-6	6.6	4.3
EV8443-SR	7.0	21.0
8321-21(s)	7.0	14.0
Synthetic-3	7.1	37.3
TZPB-SR	7.2	9.0
Synthetic-4	7.2	15.8
Tuxpeno drought	7.4	23.8
8338-1(s)	7.8	17.0

* Rating based on a scale in which 1 = highly resistant ; 9 = highly susceptible.

[b]: (o) = resistant inbreds ; (+) = tolerant hybrids ; (s) = susceptible hybrids.

Table 4. **Striga** damage rating of tolerant MIR (maize inbred resistant) lines grown in artificially infested soil at IITA in 1989.

Maize line	Striga damage rating	Origin of maize line	Parentage
Hi28	2.4	Hawaii	CM105 (India) Peru 330≠≠ ≠≠
Hi4263	2.4	Hawaii	(Hi34 x Hi25) (Ky226) BC2
H98	2.4	Indiana	HY x Oh45
B37 (Hi)	2.5	Iowa	Iowa Stiff Stalk Syn.
Hi4269	2.5	Hawaii	(Hi34 x Hi25) (Ga209) BC2
FLAT2AT106	2.5	Florida	Fla. Pop2. BT
B77 (Hi)	2.6	Iowa	Iowa Stiff Stalk Syn. 11
FLA.2BT 73	2.8	Florida	Flat/Pop.2BT
ARGF872	2.9	Argentina	Argentine
Hi27	2.9	Hawaii	CM104 (India)
Hi x 4267	3.0	Hawaii	(Hi34 x Hi25) (Ky226) BC2
H60	3.0	Indiana	(Mo21A x CI14) (Oh28xOh51A)
N28Hi	3.0	Nebraska	Iowa Stiff Stalk Syn.
HI39	3.2	Hawaii	AntiguaGrp.2 x Hi25
FLA2AT116	3.3	Florida	Fla. Pop2. AT
N139	3.4	Nebraska	Nebr.B. Syn.B 111
Oh43Hi	3.4	Ohio	Oh40B x W8
FLAT.2BT 54	3.4	Florida	Fla. Pop.2BT
HI33	3.4	Hawaii	Mo17(=187-2 x C103)
Hi40	3.5	Hawaii	Antigua Grp.2 x Hi25
INV302	3.8	Texas	Maices Trop. sel. Batan x Phil. DMR.
ICA L224	3.8	Colombia	Br2

SUMMARY

Hybrids 8322-13 and 8425-8 were found to be tolerant to Striga attack while hybrids 8338-1 and 8321-21 were susceptible. Average breeding values for tolerant varieties may be about 2.5 times higher than those of susceptible varieties. Some open pollinated and synthetic maize varieties, as well as some MIR lines, were found to be tolerant to Striga in artificially infested soil in the screenhouse. Further experiments are in progress to confirm these results.

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8. Comparative Study of Three Experimental Designs on Maize Selection Experiments

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ABSTRACT

Three experimental designs, namely randomized complete block design (RCBD), simple lattice, and augmented RCBD (ARCBD) were compared at Ntui and Yaounde (Cameroon) during the second growing season of 1984, to evaluate their efficiency in selection. One hundred maize genotypes from reciprocal 10 x 10 diallel crosses were used as testing materials.

The analysis of variance of data from each of the two sites revealed that only the simple lattice design facilitated genotype differentiation for all measured traits. However, when data were pooled across the two sites, the three designs were equally efficient. Only 47 and 53% of the entries selected with the lattice design were also selected using the ARCBD, at 15 and 30% selection pressures, respectively. However, the ARCBD allowed for 40% savings in labour, land and financial resources, as compared to both the simple lattice design and the RCBD. It was concluded that ARCBD could be a good alternative to use in selection experiments when resources are limited and/or when genotypes to be tested are numerous.

RESUME

Trois dispositifs expérimentaux, notamment le dispositif en bloc complet randomisé (RCBD), en lattice simple, et en ARCBD ont fait l´objet d´étude comparative à Ntui et à Yaoundé (Cameroun) au cours de la seconde campagne agricole de 1984, afin d´évaluer leur efficacité au niveau de la sélection. Cent génotypes de maîs issus des croisements réciproques en diallel 10 x 10 ont été utilisés comme matériels testeurs.

L´analyse de la variance des données prises au niveau de chacun des deux sites a révélé que seul le dispositif en lattice simple a facilité la différenciation du génotype pour tous les caractères mesurés. Toutefois, lorsque les données des deux sites ont été réunies l´on notait que les trois dispositifs avaient une égale efficacité. Seuls 47 et 53 % des entrées sélectionnées à l´appui du dispositif en lattice ont été également sélectionnées en utilisant le système ARCBD, à 15 et 30 % des pressions de sélection, respectivement. Toutefois, le système ARCBD a permis une réduction de la main d'oeuvre, de la surface et des ressources financières de 40 %, par rapport au dispositif en lattice simple et en RCBD. En conséquence ARCBD pourrait être une bonne alternative pour les essais de sélection lorsqu'on a des ressources limitées et/ou lorsque les génotypes à expérimenter sont nombreux.

INTRODUCTION

The establishment of a maize breeding programme in a developing country requires introductions of large numbers of germplasm from international centers, such as CIMMYT, SAFGRAD and IITA as well as introductions from other national programmes. The quantities of seed of such introductions are usually insufficient to permit extensive testing in more than one replication and/or location. In addition, plant breeders from developing countries are faced with increasing reduction in both research funding and testing land. These have forced the breeder to cut down on testing sites and/or testing materials. However, there is the need to study the genotype x environment interaction, before a varietal release recommendation can be made. The use of experimental designs which require less resources, time and labour, while still being relatively efficient, has been proposed.

The first experimental designs considered were the chain block and linked designs proposed by Youden and Connor (1953). Federer (1961) proposed the "augmented design" which was first applied to varietal trials of sugarcane, to compare new seedling varieties with older, well adapted varieties. Brewbaker and Huang (1974) used the augmented randomized block design to detect significant differences among single cross hybrids. Yield trials using designs with unreplicated treatments have been conducted (Cornelius & Byars, 1976 ; Cornelius, 1978). The present study was initiated to compare the efficiency of the augmented randomized completed block design with that of the two most widely used designs (simple lattice and randomised complete block) in maize selection experiments.

MATERIALS AND METHOD

During the second growing season of 1984, two field experiments were conducted to compare two experimental designs: simple lattice and augmented randomized complete block. The entries for both experiments comprised 90 F1s from direct and reciprocal diallel crosses between 10 tropical open pollinated maize varieties and 10 parents. The two experiments were conducted side by side at Ntui and Nkolbisson, Cameroon.

Both experiments consisted of single row, 5-m long plots separated by 75 cm. Spacing between hills on the same row was 50 cm; three seeds were planted per hill but seedlings were later thinned to two per hill. The following were recorded: plant height (PH), kernel row number (KRN), and grain yield.

Experiment I was a 10 x 10 simple lattice with two replications. The analysis of variance (ANOVA) was done according to the procedure described by Cox and Cochran (1957). In addition, the data were analysed as randomized complete block design (RCBD) with two replications.

Experiment II was an augmented randomized complete block design (ARCBD) consisting of a randomized complete block design with four treatments (standard varieties) and five replications; the design was augmented by the addition (in each of the five replications) of 20 unreplicated entries. The unreplicated entries were the same as those in Experiment I. The analysis of variance was conducted on the five replicated standard varieties. When block effect was significant, all the unreplicated entries were adjusted as described by Federer (1951). The error term was used to test both the replicated and the adjusted, unreplicated entries. The efficiencies of the three designs were evaluated by comparing their error mean squares (M.S.) and their coefficients of variation (C.V.). Then the combined analysis of variance were conducted across the two sites for each experiment.

In addition, 15 and 30% selection pressures were applied to the adjusted means of entries from the simple lattice ANOVA. The selected genotypes were compared with those from the RCBD and ARCBD experiments by applying the same selection pressure to the unadjusted means of entries in the RCBD design and the adjusted means of unreplicated entries in the ARCBD ; the percentage of common entries at the same selection pressure was determined. Finally, the relative cost of each experiment was calculated.

RESULTS AND DISCUSSIONS

The pertinent mean squares from the analysis of variance at Nkolbisson and Ntui for the ARCBD and simple lattice for all measured traits are shown in Tables 1 and 2, respectively. At Nkolbisson and Ntui the ARCBD did not allow detection of significant differences among the 100 tested genotypes, for all measured traits. However, the simple lattice and/or RCBD allowed detection of significant differences at both sites for all the measured traits (Tables 3 and 4). Except for kernel row number, the simple lattice design showed significant block effect at both sites, while the ARCBD detected block differences only for grain yield. This suggested the existence of soil heterogeneity at both sites. Although the ARCBD design allowed for data adjustment for block effects, the adjustment was not sufficient to permit discrimination among genotypes. Comparison between the coefficients of variation (CVs) obtained for all designs showed that the CVs for ARCBD were generally higher for grain yield and plant height at both locations.

Table 1. Mean squares from the analysis of variance at Nkolbisson using ARCBD.

Source of variation	D.F.$^{+}$	Yield	KRN^{+}	Plant height
Blocks/Replicates	4	4438199**	1.34	598
Entries	103	1119205	1.36	624
Standards	3	2445535	4.74*	2080*
Unreplicated genotypes	99	108473	1.27	568
Std vs UNR	1	553463	0.01	1869
Error	12	998229	0.85	450
CV (%)		32	7	12

$^{+}$D.F. = degrees of freedom ; KRN = kernel row number.

Table 2. Mean squares from the analysis of variance at Ntui using ARCBD.

Source of variation	D.F.$^{+}$	Yield	KRN^{+}	Plant height
Block/Replicates	4	1963425**	0.24 N.S	1777 N.S
Entries	103	716734**	1.23 N.S	852 N.S
Standards	3	1008150*	3.08**	591 N.S.
Unreplicated genotypes (UNR)	99	636340N.S	0.01 N.S	833 N.S
Std vs UNR	1	7801476*	8.24**	3611 N.S.
Error	12	274821	0.81	1057

*and**: Significant at P = 0.05 and P = 0.01, respectively;
N.S.:Non-significant ; $^{+}$KRN = kernel row number.

Table 3. Mean squares from the analysis of variance at Nkolbisson using simple lattice and/or RCBD

Source of variation	D.F.$^{+}$	Yield	KRN^{+}	Plant heights
Replicates	1	9901	6.55*	2972**
Genotypes	99	1008300**	1.33*	875**
Error interblock	99	87932	0.73	356
Block	18	1755680**	0.68	686*
Error intrablock	81	685199	0.74	282
CV (%)		21	7	8

$^{+}$: see table 1 for explanations.

Table 4. Mean squares from the analysis of variance using the simple lattice and/or RCBD at Ntui.

Source of variation	D.F.$^+$	Yield	KRN$^+$	Plant heights
Replicates	1	36012858**	0.16	612**
Genotypes	99	440493**	1.83**	433**
Error interblock	99	307922	1.065	179
Block	18	1942893**	1.061	396**
Error intrablock	81	189039	1.066	131
CV (%)		16	17	5

*;**: Significant at 0.05 and 0.01 probability levels.

$^+$: see table 1 for explanations.

The error terms obtained for each of the three designs are presented in Tables 5 and 6 while their relative efficiencies are given in Tables 7 and 8. Generally, error values for ARCBD were higher than those for the two other designs except for the RCBD at Ntui. The simple lattice was 46 and 45% more efficient in estimating grain yield than the ARCBD in Nkolbisson and Ntui, respectively; the corresponding figures for kernel row numbers being 15 and 32%. Similarly, for grain yield estimation, the simple lattice was 28 and 62% more efficient than the RCBD in Nkolbisson and Ntui, respectively. However, the two designs were equally efficient in estimating kernel row number.

Table 5. Summary of error mean squares obtained at Nkolbisson for 3 experimental designs.

Design	Yield	Kernel row number	Plant height
ARCBD	998229	0.85	450
RCBD	879831	0.73	356
Simple lattice	685199	0.74	282

Table 6. Summary of error mean squares obtained at Ntui for 3 experimental designs.

Design	Yield	Kernel row number	Plant height
ARCBD	174821	0.81	1057
RCBD	307922	1.065	179
Simple lattice	189039	1.066	131

Table 7. Relative efficency of 3 experimental designs at Nkolbisson.

Designs being compared	Relative design efficiency for:		
	Yield$^+$	Kernel row number$^+$	Plant height$^+$
ARCBD vs RCBD	113	118	127
ARCBD vs simple lattice	146	115	160
RCBD vs simple lattice	128	103	126

$^+$: For each pair of designs under each trait, the efficiency of second design is expressed as percentage of the first.

Table 8. Relative efficiency of 3 experimental designs at Ntui.

Designs being compared	Relative design efficiency for:		
	Yield$^+$	Kernel row number$^+$	Plant height$^+$
ARCBD vs RCBD	112	131	589
ARCBD vs simple lattice	145	132	805
RCBD vs simple lattice	162	100	137

$^+$: See table 7 for explanation.

The analysis of variance across the two environments for all measured traits is presented in Table 9 for the ARCBD and in Table 10 for the simple lattice and/or RCBD. No significant genotype x environment interaction was detected for grain yield for all the three experimental designs. However, each of the three designs permitted detection of significant differences in grain yields among the 100 tested materials.

Table 9. Mean squares from the analysis of variance across sites for ARCBD.

Source of variation	Degrees of freedom	Yield
Location	1	1762537
Entry	103	13318084**
Standard (Std)	3	218402
Unreplicated (UNR)	99	137622*
Std vs UNR	1	724201
Loc. x Entry	103	831327
Error	12	636877
CV(%)		26

Table 10. Mean squares from the analysis of variance across sites for the simple lattice and/or RCBD.

Source of variation	Degrees of freedom	Yield
Location	1	14218058**
Genotype	99	904099*
Loc x genotype	99	505993
Error inter block	99	693877
Error inter block	81	437117
CV(%)		17

The number and percentage of lines selected on the basis of grain yield using the three designs at 15 and 30% selection intensities are shown in Table 11. This table shows that only 47 and 53% of the entries selected with the simple lattice design were selected using the ARCBD, at 15 and 30% selection pressures, respectively. However, the RCBD allowed selection of 67% of the entries selected with the simple lattice design, at both selection intensities. These findings suggest a more efficient use of the ARCBD at a lower selection intensity. When the same study was applied to plant height and kernel row number, the three designs were equally efficient in selecting the same genotypes. This suggests that the ARCBD would be a good alternative to simple lattice design and/or RCBD, when selecting indirectly for yield, i.e. by the use of yield components.

Table 11. Number and percentage of common lines selected on basis of grain yield using 3 experimental designs at 15 and 30% selection pressures.

	Simple lattice+	RCBD+	ARCBD+
Number of common lines at 15% selection pressure	15 (100)	10 (67)	7 (47)
Number of common lines at 30% selection pressure	30 (100)	20 (67)	16 (53)

+Numbers in parenthesis are percentages.

The land area used and the relative cost of each experiment are presented in Table 12. The ARCBD experiment took about one half of the land area required by each of the two other designs. It was also calculated that the ARCBD permitted 40% savings on labour and financial resources as compared to RCBD and simple lattice design.

Table 12. Land area used and relative cost of each of 3 experimental designs.

Design	Land area (m^2)	Cost (CFA)
ARCBD	518	30979
RCBD	919	57720
Simple lattice	919	57720*

CONCLUSION

The ARCBD was less efficient than both the simple lattice design and the RCBD at a single testing site, but it had a relatively comparable efficiency when data were combined across two sites, suggesting that for single location experiments, more replications, and/or blocks, with reduced size should be used. This is in agreement with findings of Brewbaker (1962). In addition, the ARCBD should be used with lower selection intensity when selecting for grain yield. At higher selection pressures, ARCBD should be used only when selecting indirectly for grain yield, i.e. when selection is on the basis of yield components. Finally, the ARCBD would be a good alternative to the other two designs when resources are limited and when the testing materials do not warrant full replication.

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9. Stability in Yield and Threshing Percentage of Introduced Cowpea Varieties in Ghana

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ABSTRACT

Identification of new varieties through screening of introduced varieties has been a major strategy for varietal development in Ghana. The stabilities of yield and threshing percentage of 9 cowpea varieties introduced from the International Institute of Tropical Agriculture, Ibadan (Nigeria) and tested at different environments, alongside a local check, during 1986 and 1987 were studied. Almost all the introduced varieties were found to be stable in yield. Environmental variation accounted for greater proportion of the total variation in yield and threshing percentage, with the latter being more responsive to environmental changes. A positive correlation was found between mean yield and stability parameter for yield. This association suggests that cowpea varieties with high yield potential may be low in yield stability.

RESUME

L´identification de nouvelles variétés par le système de criblage des variétés introduites a été la principale stratégie pour le développement variétal au Ghana. Les stabilités de rendement et le pourcentage au battage de neuf (9) variétés de niébé introduites par l´Institut International d´Agriculture Tropicale, Ibadan (Nigeria) et testées à travers différentes écologies, à côté d´un témoin local en 1986 et 1987 ont fait l´objet d´une étude. Presque toutes les variétés introduites se sont révélées stables du point de vue rendement. La variation écologique représentait la plus importante proportion de la variation totale au niveau du rendement et du pourcentage au battage, le pourcentage au battage étant la principale cause des changements écologiques. Il existait une similitude nette entre le rendement moyen et le paramètre de stabilité pour le rendement. Cette association indique que les variétés de niébé ayant un potentiel de rendement élevé peuvent avoir une faible stabilité de rendement.

INTRODUCTION

Cowpea is a major, traditional food legume in Ghana. The low average grain yield of 100-200 kg/ha has been attributed partly to farmers´ cultivation of low yielding varieties. To increase production, there is a need to replace these varieties with those that produce high and stable yields. The importance, especially in developing countries, of crop varieties with higher yield stability has already been discussed by Funnah and Mak (1980) and Ntare and Aken 'Ova (1985). One of the widely used method for measuring stability is the regression analysis proposed by Eberhart and Russel (1966).

To meet the immediate needs of farmers for improved varieties, the Ghana Grains Development Project (GGDP), funded by CIDA, at the Crops Research Institute (CRI) in Kumasi has been involved with evaluating introduced cowpea varieties from the International Institute of Tropical Agriculture (IITA), Ibadan (Nigeria) and from elsewhere. An important goal has been identification of varieties that fit well in southern Ghana (between latitudes 4°30´ and 8°30´N) which produces about 40% of the total cowpea crop. Bimodal rainfall regime of the ecology facilitates expanded cowpea cultivation, especially during the shorter rainy season when utilization of farm land, particularly after the harvest of the major season maize, is generally low.

In order to study the general adaptability of nine introduced varieties in this region, a series of yield trials were conducted in 1986 and 1987. This paper reports the stabilities of yield and threshing percentage in the nine cowpea varieties; it also reports the relationship between the two traits.

MATERIALS AND METHODS

The data for 10 cowpea varieties tested in yield trials in southern Ghana at several locations during both major and minor seasons of 1986 and 1987 were analysed in this study. The varieties consisted of nine improved IITA lines and a local check, Amantin.

The varieties were first tested during the major season of 1986 at Kwadaso (forest zone: annual rainfall, about 1550 mm); during the minor season of that year, they were again tested at five locations, namely Kwadaso and Fumesua (forest zone), Ejura and Kpeve (transitional zone: annual rainfall, about 1270 mm) and Pokuase (coastal savanna: annual rainfall, about 625 mm). In 1987, the tests were conducted at Kwadaso, Ejura, Kpeve and Pokuase, in both the major and minor seasons.

Within each environment a randomized complete block design, with four replications, was employed. Plots consisted of four, 4-m rows, with 50 cm between rows. Plants within rows were spaced at 20 cm. Two seeds were sown per hill and thinned to one plant two weeks after sowing. Insect pests were controlled with Cymbush 10 ec (50 g a.i./ha) applied at 30 and 40 days after planting (DAP) and Perfeckthion 20 ec (200 g a.i./ha) applied at 50 DAP. Yield data were collected from the two central rows.

Statistical procedures

Analyses of variances for grain yield and threshing percentage were calculated based on a mixed model; varieties were considered to be fixed while locations constituted random effects.

Stability analysis of grain yield and threshing percentage was performed using the regression method of Eberhart and Russell (1966). For each entry, stability was described by three parameters that are defined with following model : $Y^{i}_{j} = u_{i} + b_{i}I_{j} + d_{ij}$, where: Y_{ij} is the mean yield of the ith entry at the jth environment ($i = 1, 2, 3.....v$; $j = 1,2,3......n$), u_{i} is the mean of the ith variety over all environments, b_{i} is the regression coefficient that measures the response of the ith variety at the jth environment, Ij is the mean of the varieties at the jth environment, and d_{ij} is the deviation from regression of ith variety at the jth environment.

The b-values were tested for differences from unity using t-tests. An approximate F-test proposed by Eberhart and Russell (1966) was employed to determine whether the deviations from regressions were significant, as follows: $F=(\Sigma jdij/n-2)$/pooled error, where the pooled error is estimated from the combined analysis of variance.

By this method, Eberhart and Russell (1966) defined a stable cultivar as one with a regression coefficient (b) = 1.0 and mean square deviation from regression as small as possible (deviation mean square = 0).

Another parameter, coefficient of determination (r^2) provided information about the fitness of the regression model.

RESULTS

Combined analyses of variance

The combined analysis of variance of data for grain yields and threshing percentages from all the locations (environments) are shown in Table 1. For both characters, variation among genotypes was low and non-significant when tested by the variety x environment interaction, although it was significant against the pooled error. There were highly significant main effects of environment, accounting for 60 and 77.5% of the overall sums of squares for grain yield and threshing percentage, respectively. Highly significant variety x environment interactions were also observed for the two characters.

Table 1. Combined analyses of variance of yield and threshing percentage of 10 cowpea varieties grown in 14 environments in southern Ghana in 1986-87.

Source of variation		Mean squares	
	df	Grain yield	Threshing %
Environments (E)	13	19396297**	970**
Varieties (V)	9	264793	139
V x E	117	170390**	85**
Replications within E	42	332780**	604
Pooled error	378	97545	48
CV(%)		22.3	9.8

Regression analyses

Mean yields, regression coefficients (with associated standard errors) deviation mean squares, and coefficients of determination are presented in Table 2 for individual varieties. The yields ranged from 1238 kg/ha for IT83S-720-2 to 1454 kg/ha for IT83S-728-13, with an overall mean of 1316 kg/ha. One variety, IT83S-720-2, showed a significant regression coefficient which was less than 1.0, suggesting that it was relatively less responsive to the different environments. None of the deviation mean squares was, however, significant. The values of r^2 varied from 0.85 to 0.99; these indicate that much of the varietal mean yields could be attributed to environmental means.

Table 2. Mean yields, regression coefficients (b) with associated standard errors (SE), deviation mean squares and coefficients of determination (r^2) of 10 cowpea varieties evaluated in 14 environments across southern Ghana in 1986-87.

	Mean yield (kg/ha)	b	SE (b)	Deviation m.s.	r^2
Local Amantin	1288	0.98	0.08	39870	0.92
IT83S-728-13	1454	1.08	0.07	25340	0.95
IT84E-1-108	1239	0.95	0.11	77721	0.85
IT83S-742-1	1283	0.94	0.07	41279	0.92
IT82D-812	1293	1.02	0.12	71106	0.86
IT83S-742-11	1349	1.06	0.08	34792	0.93
IT83S-728-5	1379	1.06	0.05	11382	0.99
IT83S-720-2	1238	0.88**	0.04	14120	0.97
IT83S-742-13	1364	1.10	0.05	12073	0.98
IT83S-742-2	1274	0.95	0.07	32853	0.94

In contrast to the yield data, threshing percentage regression coefficients of five varieties were significant (Table 3). Three of them (IT83S-742-1, IT83S-742-11, and IT83S-728-5), had regression coefficients that were greater than 1.0 while two (Amantin and IT83S-728-13) had regression coefficients smaller than 1.0. The r^2 values ranged from 0.30 to 0.92, with majority of them being less than 0.60. This trend suggests that for most of the genotypes, the relationship between varietal and environmental means for threshing percentage could not be adequately explained by the linear regression model. The standard errors associated with regression coefficients for threshing percentage were generally higher than those for grain yield. Nevertheless the deviation mean squares for both characters were not statistically significant for any variety.

Table 3. Threshing percentage, regression coefficients (b) with associated standard (SE), deviation mean squares and coefficients of determination (r^2) of 10 cowpea varieties grown in 14 environments in southern Ghana during 1986 and 1987.

	Threshing percentage	b	SE (b)	Deviation m.s.	r^2
Local Amantin	73	0.57*	0.17	13.79	0.48
IT83S-728-13	73	0.48*	0.12	11.40	0.57
IT84E-1-108	72	0.74	0.33	18.47	0.30
IT83S-742-1	70	1.40*	0.13	2.47	0.91
IT82D-812	70	1.03	0.14	4.69	0.82
IT83S-728-5	70	1.45*	0.17	3.73	0.86
IT83S-720-2	68	1.07	0.43	17.31	0.34
IT83S-742-13	70	1.02	0.30	13.61	0.48
IT83S-742-2	72	1.01	0.27	12.16	0.54
Mean	70.9				

To establish any relationship between the stabilities of yield and threshing percentage, simple correlation analyses were performed. The results are shown in Table 4. The relationship between mean grain yield and stability parameter for yield appeared linear (r = 0.85, P = 0.01). Mean grain yield and threshing percentage were not significantly correlated. A non-significant negative relation was found between mean threshing percentage and stability parameter for threshing percentage. A similar association was found between mean threshing percentage and stability parameter for yield.

Table 4. Simple correlation coefficients (r) among yield, threshing percentage and regression coefficients for both yield and threshing percentage.

	Regression coefficient for yield	Mean threshing percentage
Mean yield	0.85**	0.08
Mean threshing %	-0.21	-
Regression coefficient for threshing %	0.02	-0.54

DISCUSSION

Although there were highly significant variety x environment interactions for grain yield and threshing percentage, the results indicated that, except for IT83S-720-2, all the varieties tested had good levels of yield stability in this region of Ghana. The almost perfect linear relationship between varietal mean yields and environmental means indicated that a substantial proportion of the observed variety x environment variance for yields could be attributed to linear response to environmental indices. Analyses of the regression coefficients, which indicate the direction of individual varietal responses to varying environmental factors (Funnah and Mak, 1980) demonstrated that most varieties tended to respond positively to improved conditions.

The results clearly showed that environmental variation mostly accounted for the variation in both grain yield and threshing percentage. This agrees with several previous reports on cowpea (Erskine and Khan, 1977; Smithson _et al_., 1980; Summerfield _et al_., 1985). The highly significant effects of environment, as well as variety x environment interactions (in spite of the apparently low genetic variability among varieties), underscores the importance of genotype and environment interactions in the region.

From the correlation analyses, it appears that stability of grain yield and that of threshing percentage were independent of each other. However, grain yields gave better indications of the magnitudes of regression coefficients and might, therefore, be useful for predicting relative stabilities of the genotypes.

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10. Empirical Results from a Study of Maize Yield Potential in the Different Agro-ecologies of Nigeria.

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ABSTRACT

Nigeria is naturally endowed with a wide range of agro-ecological zones in which maize (<u>Zea mays</u> L.) germplasm to be grown in most of the sub-Saharan Africa can be evaluated. Four-year data (1985-1988) from Nationally Coordinated Maize Trials, conducted in several sites within each ecological zone, were studied using uni- and multivariate statistical techniques, including the analysis of variance, as well as correlation, regression, and factor analyses. For the lowland ecologies: (i) yield potential was about 4.0 t/ha for the forest and forest-savanna transition zones, 5.0 t/ha for the southern Guinea and Sudan savanna zones, and 6.0 t/ha for the northern Guinea savanna; (ii) ear number, plant aspect, number of plants at harvest, husk cover, and ear rot were the major yield-limiting traits in all zones; (iii) plants were taller and had lower moisture at harvest in the savanna than in forest zones, suggesting a slower dry-down rate in the forest; and (iv) barrenness was the primary cause of yield differences between forest and savanna ecologies.

For varietal development and testing, there are only four distinct zones in Nigeria, namely (i) forest/transition/southern Guinea savanna, (ii) northern Guinea savanna, (iii) Sudan savanna, and (iv) mid altitude. Analysis of grain-yield data on the basis of this classification eliminated or, at least, considerably reduced genotype x environment interaction and more clearly revealed differences among varieties. Across 83 TZSR-W-1 was identified as a distinct forest variety, whereas GUAY 8449-SR and TZ SYN-1 are more of savanna varieties. TZPB-SR tends to the forest but seems to perform equally well in the savanna. The study failed to identify hybrids that are truly of forest or savanna adaptation.

RESUME

Le Nigeria est naturellement doté d'une gamme variée de zones agro-écologiques dans lesquelles le germplasme du maïs (Zea mays L.) devant être cultivé dans la plupart des pays d'Afrique sub-saharienne peut être évalué. Des données recueillies pendant quatre années (1985-1988) à partir des Essais de Maïs Coordonnés au Plan National à travers plusieurs localités à l'intérieur de chaque zone écologique ont fait l'objet d'une étude en utilisant des techniques de statistiques unies et multivariées, comprenant l'analyse de la variance, ainsi que les caractères de corrélation de régression et l'analyse de facteur. Pour les écologies des bas-fonds : (i) le potentiel de rendement s'élevait à 4,0 t/ha pour la zone de forêt et de transition forêt-savane, à 5,0 t/ha pour les zones de savane sud-Guinéenne et de savane Soudanienne, et à 6,0 t/ha pour la zone de savane nord Guinéenne ; (ii) le nombre d'épis, l'architecture de la plante, le nombre de pieds à la récolte, la couverture de spathe, et le pourrissement de l'épi constituaient les principaux caractères limitant le rendement dans toutes les zones ; (iii) les plantes étaient plus hautes avec une humidité plus faible à la récolte en zone de savane qu'en zone de forêt ; ce qui implique un rythme d'évaporation plus lent ; et (iv) la stérilité était la cause principale des différences de rendement constatées entre les écologies de forêt et de savane.

Pour le développement et l'essai variétal, il y a seulement quatre zones distinctes au Nigéria, notamment les zones (i) de forêt/de transition/de savane sud-Guinéenne, (ii) de savane nord Guinéenne, (iii) de savane Soudanienne, et (iv) d'altitude moyenne. L'analyse des données de rendement en grains basée sur cette classification a éliminé ou, au moins, a considérablement réduit l'interaction génotype x écologie et a révélé plus distinctement les différences entre les variétés. Across 83 TZSR-W-1 a été identifié comme variété propre à la zone de forêt, alors que GUAY 8449-SR et TZ Syn-1 conviennent plus à la zone de savane. TZPB-SR a un penchant pour la zone de forêt mais semble également bien performante en zone de savane. L'étude n'a pas réussi à identifier des hybrides qui s'adaptent vraiment soit à la zone de forêt, soit à la zone de savane.

INTRODUCTION

Maize (Zea mays L.) is one of the most important cereal crops in Africa. Its diverse use as human food, livestock feed, and raw material for industry, along with its enormous genetic diversity, germplasm base, and ease of cultivation (alone or in combination with other crops) give it an advantage over most other food crops of sub-Saharan Africa. In Africa the consumption pattern of maize varies from one country to another, but includes green maize, baby food and breakfast cereal, and different types of preparation for local dishes. "Green maize" (maize harvested and consumed at the milk or early dough stage) is particularly useful during the hunger period, i.e. the period before other crops are harvested. Demand for dry grain is even more challenging, especially in recent years when, apart from its use as human food and livestock feed, maize grain is used in the brewing and soft drink industry, flour mills, pharmaceuticals, etc.

Despite its enormous genetic diversity, its high-yield potential (especially in the savanna and mid-altitude ecologies), and the generally favourable weather factors, maize production falls far short of the demand, although its real potential in Africa is yet to be fully exploited. Full exploitation of maize potential in Africa may be achieved by: (i) increasing the land area under cultivation, (ii) growing improved, disease and pest resistant varieties, and (iii) using hybrid varieties.

Nigeria is endowed with a wide range of agro-ecological zones in which it is possible to evaluate maize germplasm that could be grown in most of sub-Saharan Africa. Also, land area under maize cultivation has been on the increase in Nigeria, especially with the introduction of hybrids some five years ago. There has, however, been much controversy on the profitability of F1 hybrids for the typical Nigerian farmer, especially in the forest and forest-savanna transition zones. Thus the objectives of this study were to :

(i) evaluate the yield potential of maize in the different agro-ecologies of Nigeria;
(ii) determine, for each ecological zone, the yield advantage, if any, of hybrids over open pollinated cultivars (OPs);
(iii) identify traits associated with yield differences between forest and savanna zones;
(iv) classify testing sites into similar groups as determined by grain-yield performance;
(v) investigate the effect of site grouping on G x E interaction; and
(iv) identify varieties that are ecological/zone-specific.

MATERIALS AND METHODS

Four-year data (1985-1988) on grain yield and agronomic traits from Nationally Coordinated Maize Trials were analyzed in this study. Each trial was laid out in a randomized complete-block design with four replications. Each entry was planted to 4-row plots but data were obtained from the two centre rows. The rows were 5 m long, spaced 0.75 m and seeds were sown 0.25 m (single-seed/hill) or 0.50 m (double-seed/hill) apart to give approximately 53,300 plants/ha. Combined across locations within each year, the data were separately analyzed for white hybrids, yellow hybrids, late OPs and early OPs (Table 1). Subsequently, genotypic means were used to obtain correlation and stepwise multiple regression coefficients to determine: (i) the similarity between pairs of locations for grain yield, and (ii) the interrelations among yield and agronomic traits.

Table 1. Testing sites within agro-ecological zones where Nationally Coordinated Trials were conducted during the period, 1985-1988.

		1985					1986					1987				1988			
Zone	Site	W	Y	L	E	I	W	Y	L	E	I	W	Y	L	E	W	Y	L	E
Forest	Ibadan	c	c	c	x	c	c	c	x	x	c	c	c	c	x	c	c	c	c
	Ikenne	c	c	c	c	c	c	c	x	x	x	x	c	x	x	c	x	c	c
	Ife	c	c	c	x	c	c	c	x	x	x	c	x	x	x	c	c	c	c
	Benin	c	x	c	c	-	x	c	x	x	x	c	c	x	x	x	x	x	x
	Akure	x	c	c	x	-						c	c	x	x	x	x	x	x
Forest	Onne	c	c	c	c	-													
	Amakama											c	c	c	x				
	Uyo											c	c	c	x	c	c	c	c
Transition	Ilorin	c	c	c	c	-	c	x	x	x	-								
	Lanlate											c	c	c	x				
	Shaki	c	c	c	c	-													
	Ilora																		
S. Guinea	Mokwa	c	c	c	c	-	c	c	x	x	-	c	c	c	x	c	c	c	c
savanna	Badeggi	c	c	c	c	-	c	x	c	c	-	c	c	c	x	c	x	x	x
N. Guinea	Samaru	c	c	c	c	-	c	c	x	x	-	x	x	x	x	c	c	c	c
savanna	Funtua	c	c	c	c	-	c	c	x	x	-	c	c	c	c	c	c	c	c
Sudan	Bagauda						c	c	x	x	-	c	c	c	x	c	c	c	c
savanna	(Kano)																		
Mid-altitude	Jos											c	c	c	x				

W = White Hybrids; Y Yellow Hybrids; L = Late, OP; E = Early, OP; I = Inbred Lines; c = Trial conducted; x = Trial not conducted.

In the present study, principal component factor analysis with varimax rotation for orthogonality was used for:

(i) similarity grouping of locations within each year for each type of varietal trial, and

(ii) delineating the interdependence structure among agronomic traits, including grain yield. Analysis of variance, combined only for locations loaded on each factor, was subsequently performed to determine the relative importance of the different sources of variation. Varietal means and their ranks across locations, within each factor, were used to identify zone-specific varieties.

RESULTS AND DISCUSSION

The yield potential of the different agro-ecologies in Nigeria, as measured by performance of white hybrids from 1985-1988 (Fig. 1), increased as one moves from the forest to the savanna zones., with the northern Guinea savanna having the highest yield (5.8 t/ha). Yield potentials of the forest and transition zones differed little, being about 4.0 t/ha. Relative to the northern Guinea savanna, there was a somewhat lower yield potential in the southern Guinea savanna and in Sudan savanna (about 5.0 t/ha). The lower yield potential in the Sudan savanna is probably attributable to the fact that late maturing hybrids were grown in this relatively short-season ecology. Genetic materials of intermediate maturity would be more appropriate for this zone. In general, the savanna ecologies had a 1-2 t/ha higher yield potential than the forest and transition zones.

Data presented for mid-altitude (Jos) should be interpreted cautiously because they represented a year´s data from one location ; also the entries in the trial were lowland materials. Our experience is that the mid-altitudes have a high yield potential if the appropriate genotypes are grown.

Yield of the best OP was deducted from that of the best hybrid and the difference was expressed as a percentage of the yield of the OP yield. This was done each year and the mean across years for all locations in an ecological zone are summarized in Fig. 2. Yield advantage of white hybrids ranged from about 1 to 1.7 t/ha, with the highest advantage occurring in the northern Guinea savanna. Expressed on percentage basis, however, the Sudan savanna had the highest advantage of about 44%. Similarly, for yellow hybrids, the northern Guinea savanna had the highest absolute yield advantage (1.6 t/ha). Again, on percentage basis, the differences between zones were not too dramatic. Across the two hybrid types, hybrid advantages were about the same (23-30%) for forest, transition, southern Guinea savanna and northern Guinea savanna zones. However, hybrid advantages in the acid forest and in Sudan savanna zones were slightly higher (about 36%) than in other zones. Thus, hybrids are clearly higher yielding than the best OPs in all ecological zones of Nigeria.

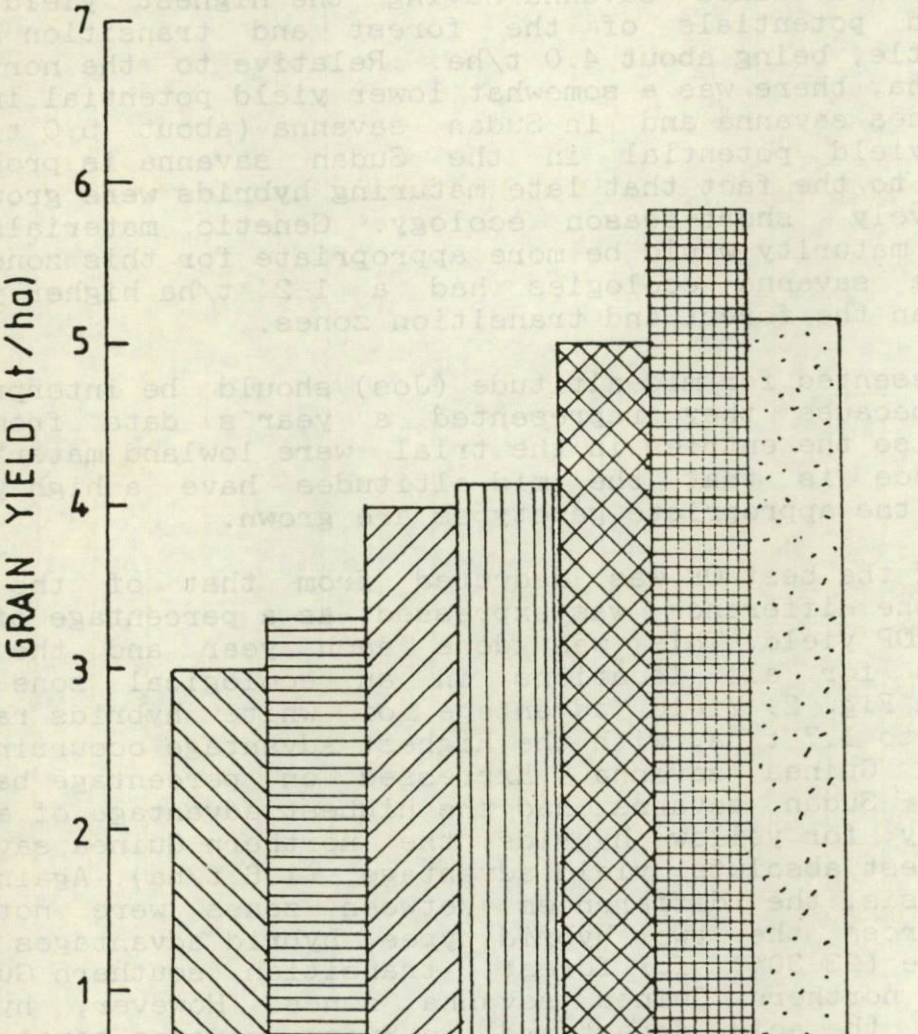

Fig.1 Yield potential of different agro-ecological zones in Nigeria (mean of 1985-88 White Hybrid National trials)

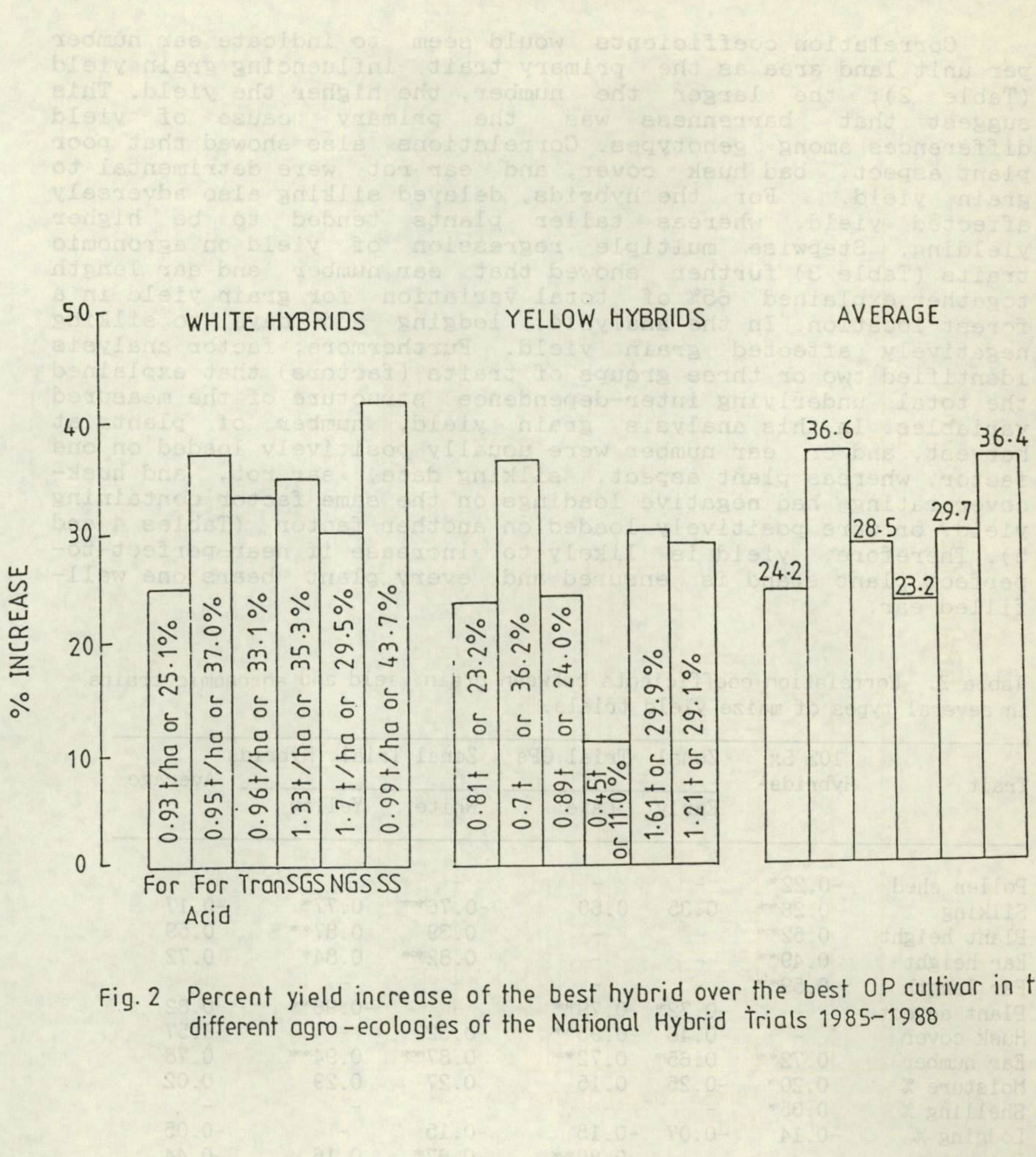

Fig. 2 Percent yield increase of the best hybrid over the best OP cultivar in the different agro-ecologies of the National Hybrid Trials 1985–1988

Correlation coefficients would seem to indicate ear number per unit land area as the primary trait influencing grain yield (Table 2); the larger the number, the higher the yield. This suggest that barrenness was the primary cause of yield differences among genotypes. Correlations also showed that poor plant aspect, bad husk cover, and ear rot were detrimental to grain yield. For the hybrids, delayed silking also adversely affected yield, whereas taller plants tended to be higher yielding. Stepwise multiple regression of yield on agronomic traits (Table 3) further showed that ear number and ear length together explained 65% of total variation for grain yield in a forest location. In the analysis, lodging and days to silking negatively affected grain yield. Furthermore, factor analysis identified two or three groups of traits (factors) that explained the total underlying inter-dependence structure of the measured variables. In this analysis grain yield, number of plants at harvest, and/or ear number were usually positively loaded on one factor, whereas plant aspect, silking date, ear rot, and husk-cover rating had negative loadings on the same factor containing yield, or were positively loaded on another factor (Tables 4 and 5). Therefore, yield is likely to increase if near-perfect-to-perfect plant stand is ensured and every plant bears one well-filled ear.

Table 2. Correlation coefficients between grain yield and agronomic traits in several types of maize yield trials.

Trait	102 Sx Hybrids[1]	Zonal Trial, OPs		Zonal Trial, Hybrids		Average
		Early	Late	White	Yellow	
Pollen shed	-0.22*	-	-	-	-	
Silking	-0.26**	0.35	0.60	-0.76**	0.77*	-0.17
Plant height	0.52**	-	-	0.39	0.87**	0.59
Ear height	0.49**	-	-	0.82**	0.84*	0.72
Ear length	0.59**	-	-	-	-	
Plant aspect	-	-0.72*	-0.79**	-	-0.96**	-0.82
Husk cover	-	-0.46	-0.93**	-0.32	-	-0.57
Ear number	0.72**	0.65*	0.72**	0.87**	0.94**	0.78
Moisture %	0.20*	-0.25	0.15	0.27	0.29	0.02
Shelling %	0.35*	-	-	-	-	-
Lodging %	-0.14	-0.07	-0.15	-0.15	-	-0.05
Ear rot	-	-	-0.80**	-0.67*	0.16	-0.44

(1) Evaluated at Ife in 2 years (1987 and 1988)

*and **: Significant at P = 0.05 and P = 0.01, respectively.

Table 3. Partial regression coefficients and coefficients of determination (R^2) from the stepwise multiple regression analysis of grain yield on several other trials for 102 single-cross hybrids.

No. of traits in model	Intercept	Ear number	Ear length	Ear height	Lodging %	Silking	Shelling %	R^2	DR^2
1	-1.068	0.323						0.515	0.515
2	-5.345	0.264	0.335					0.647	0.132
3	-5.823	0.251	0.262	0.003				0.693	0.046
4	-5.081	0.226	0.193	0.041	-0.021			0.738	0.093
5	3.307	0.190	0.244	0.036	-0.033	-0.125		0.786	0.048
6	2.830	0.175	0.221	0.035	-0.032	-0144	0.031	0.796	0.010

All partial b-values, R^2 and DR^2 are significant at $P = 0.01$.

Table 4. Lodgings on varimax x rotated factors involving yield and agronomic trials in the 1988 Early OP and 1987 Late OP Zonal trials.

Trait	Community	Factor 1	Factor 2	Factor 3
Factor 1		1988 Early OP		
Yield	0.87	0.869	0.053	0.340
Plant stand	0.93	0.940	-0.210	0.038
Plant aspect	0.81	-0.650	0.614	-0.114
Plant harvested	0.87	0.812	-0.447	0.103
Factor 2				
Moisture %	0.80	-0.159	0.821	-0.317
Stalk lodging	0.68	-0.080	0.819	-0.059
Root lodging	0.89	-0.292	0.871	0.216
Factor 3				
Silking date	0.97	0.020	0.177	0.966
Husk cover	0.93	-0.285	0.294	-0.872
Ear number	0.98	0.540	-0.508	0.654
% Total variance		36.87	35.56	27.66
Cumulative		36.78	72.43	100
		1987 Late OP		
Factor 1				
Silking date	0.81	0.898	0.057	
Plant height	0.78	0.878	-0.087	
Ear height	0.80	0.858	-0.256	
% Moisture	0.70	0.830	0.113	
Husk cover	0.52	-0.723	-0.025	
Factor 2				
Yield	0.94	-0.142	0.962	
No. plants harvested	0.77	0.099	0.873	
Ear number	0.79	-0.401	0.791	
Ear rot	0.60	-0.200	-0.745	
% Total variance		55.93	44.07	
Cumulative		55.93	100	

Table 5. Loadings on varimax rotated factors involving yield and agronomic traits in the 1988 White Hybrid and 1987 Yellow Hybrid Coordinated Maize Trials.

Trait	Community	Factor 1	Factor 2	Factor 3
		1988 White Hybrids		
<u>Factor 1</u>				
Yield	0.94	0.864	-0.085	-0.045
Silking date	0.56	-0.721		0.079
Ear height	0.93	0.914	0.261	0.149
No. of plants harvested	0.97	0.983	-0.065	-0.08
Ear number	0.92	0.958	-0.055	-0.043
<u>Factor 2</u>				
Plant height	0.84	0.523	0.713	-0.247
Stalk lodging	0.90	-0.095	0.934	-0.131
Root lodging	0.87	-0.095	0.892	0.256
<u>Factor 3</u>				
Husk cover	0.85	-0.242	0.198	0.868
% Moisture	0.83	0.224	0.482	0.742
% Total variance		53.04	29.41	17.55
Cumulative		53.04	82.45	100
		1987 Yellow hybrids		
<u>Factor 1</u>				
Yield	0.98	0.986	0.073	
Silking date	0.71	-0.707	-0.463	
Plant height	0.94	0.884	0.393	
Ear height	0.86	0.870	0.320	
No. of plants harvested	0.98	0.975	0.186	
Ear number	0.95	0.934	0.275	
Plant aspect	0.09	-0.941	-0.112	
<u>Factor 2</u>				
Ear rot	0.76	0.139	0.863	
% Moisture	0.63	-0.191	-0.767	
% Total variance		74.93	25.07	
Cumulative		74.93	100	

A comparison of forest and savanna locations (Table 6) showed that the yield advantage of the savanna was due primarily to ear number. Whereas number of plants harvested was about the same in the two ecologies, the savanna zone consistently produced more ears per unit land area. Therefore barreness was much more pronounced in forest zone than in savanna ecologies. Maize plants in the savanna were taller with higher ear placement, suggesting greater vigor of growth. Number of days to silking was about the same in the two ecologies, although late OPs and yellow hybrids tended to silk later in the savanna than in the forest zone. However, percentage moisture at harvest was consistently lower at savanna than at forest locations. This implies a shorter grain-filling duration and/or a faster dry down rate in savanna than in forest ecologies. Indeed the "stay-green" character occurs frequently in the forest zone, whereas it is almost non-existent in the savanna zones. For this reason, it is possible to obtain uniform drying in the savanna, thus facilitating mechanical harvesting. Although details of environmental factors causing faster dry-down rate in the savanna are beyond the scope of this paper, and must await further analysis and experimentation, it is probably connected with reduced moisture and increased dryness of the air (low relative humidity) associated with the harmattan in the savannas.

Table 6. Comparison of mean yield and agronomic traits for forest and savanna locations in four types of maize yield trials.

Trait	1988 White Hybrids		1987 Yellow Hybrids		1988 Early OPs		1987 Late OPs	
	Forest	Savanna	Forest	Savanna	Forest	Savanna	Forest	Savanna
Yield (t/ha)	3.7	6.0	3.6	4.4	2.7	5.7	4.5	3.7
Silking date	60	58	57	60	51	50	55	61
Plant height(cm)	175	236	166	197	150	199	195	205
Ear height (cm)	87	126	83	98	71	89	101	106
No. plants harvested	26	32	32	31	39	36	33	31
Ear number	25	34	29	31	29	38	30	25
Plant aspect	2.8	3.2	2.6	2.4	2.5	3.7	-	-
Ear rot[1]	-	-	2.0	1.2	-	-3.3	2.0	1.1
Husk cover[1]	1.8	2.9	-	-	2.4	3.3	2.0	1.9
% Moisture	19	12	22.7	13.2	15.2	12.6	20.0	14.2

[1] Rating on a 1-5 scale: 1 = best, 5 = worst.

Analysis of variance (AOV) for yield showed highly significant location (L), variety (V), and in most cases, L x V interaction mean squares (Table 7). However, the contribution of each source of variation to total sum of squares (Fig. 3) would seem to indicate that the locations and, to a relatively smaller extent, the L x V interaction and error masked the full expression of the yield potential of varieties. It was, therefore, necessary to classify testing sites into more homogeneous groups and run the AOV on group basis.

Table 7. Summary of AOV for grain from the Nationally Coordinated Trials, 1985 to 1988.

Source of variation	White hybrids Df	White hybrids F-test	Yellow hybrid Df	Yellow hybrid F-test
1985				
Location (L)	10	**	9	**
Variety (V)	14	**	11	**
L x V	140	NS	99	**
Error	456	-	330	
1986				
Location (L)	8	**	7	**
Variety (V)	14	**	11	**
L x V	112	**	77	NS
Error	376	-	262	-

*and ** Significant at P = 0.05 and P = 0.01, respectively. NS = not significant.

Source of variation	White hybrids DF	White hybrids F-test	Yellow hybrids Df	Yellow hybrids F-test	Late O.P. Df	Late O.P. F-test	Early O.P. Df	Early O.P. F-test
1987								
Location (L)	10	**	10	**	9	**		
Variety (V)	8	**	6	**	7	**		
L x V	80	**	60	**	63	NS		
Error	262	-	192	-	209	-		
1988								
Location (L)	7	**	6	**	7	**	5	**
Variety (V)	9	**	8	**	8	**	7	**
L x V	63	**	48	NS	56	**	35	*
Error	210	-	164	-	196	-	126	-

*and ** Significant at P = 0.05 and P = 0.01, respectively; NS = not significant.

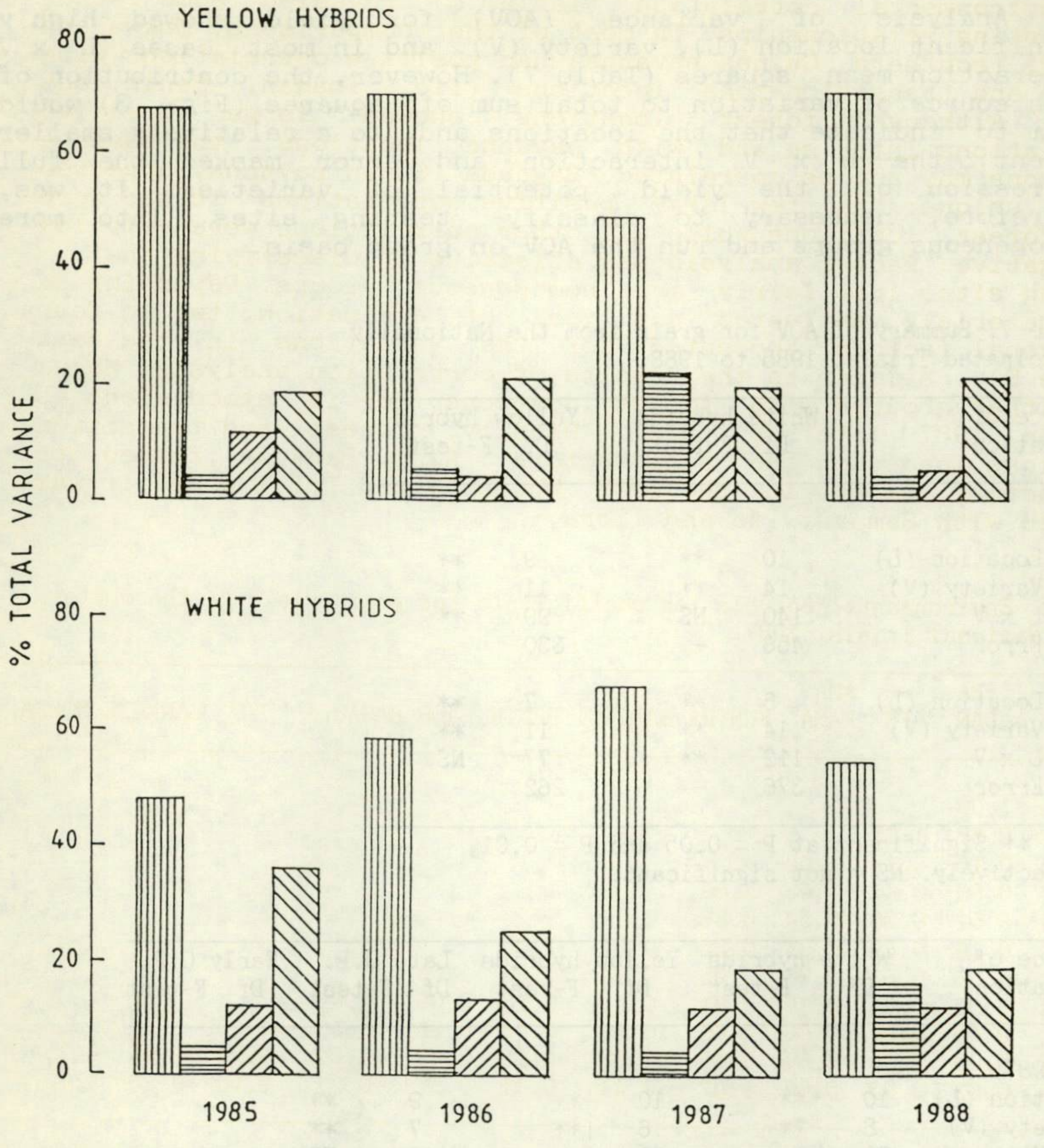

Fig. 3 Percentage of total variance due to the different sources of variation in the National Hybrid Trials, 1985–1988 (▥ = Location, ▤ = Variety, ▨ = L × V, ▧ = Error)

Environmental correlation (Table 8) revealed some rather interesting relationships. In most of the comparisons, Mokwa and Badeggi (southern Guinea savanna) had positive correlations with forest and transition-zone locations (Ife, Ibadan, Benin, and Uyo). Although forest locations showed large positive correlations *inter se* and with savanna locations, the savanna locations may not be correlated. Bagauda (Sudan savanna) appeared to be unique; the few large positive correlations it had were with forest lcoations while all other correlations were very low or negative. Factor analysis was effective in classifying the testing sites into fairly more homogeneous groups. Depending on the materials evaluated and year of evaluation, two to four orthogonal factors accounted for the variations in the data (Table 9). Similar to the results of correlation analysis, Mokwa was either grouped with forest locations, or it stood alone as in the 1987 late OP trial. Usually, forest and transition locations loaded on the same factors. Also, Bagauda formed its own factor, except in the 1988 White Hybrid Trial where it was grouped with Samaru, Ife and Ilora.

Table 8. Environmental correlation coefficients for grain yield in the white Hybrid National Trials, 1987.

	IBADAN	IFE	AMAKAMA	FUNTUA	BADEGGI	BENIN	JOS	BAGAUDA	UYO	LANLATE	MOKWA
IBADAN	1.00										
IFE	0.67	1.00									
AMAKAMA	-0.16	0.13	1.00								
FUNTUA	0.58	0.41	-0.63	1.00							
BADEGGI	0.51	0.38	-0.54	0.86	1.00						
BENIN	0.16	0.60	0.34	0.23	0.27	1.00					
JOS	0.56	0.61	0.36	0.05	0.04	0.29	1.00				
BAGAUDA	0.20	0.01	0.17	0.31	0.21	-0.18	0.08	1.00			
UYO	0.40	0.57	0.03	0.65	0.69	0.76	0.25	0.18	1.00		
LANLATE	0.06	0.09	-0.67	0.41	0.33	-0.25	-0.49	-0.00	-0.21	1.00	
MOKWA	0.62	0.93	0.07	0.37	0.44	0.71	0.52	-0.21	0.55	0.13	1.00

AOV on the basis of locations within factors for 1987 White Hybrids and 1988 Late OPs showed that the G x E interaction was eliminated or, at least considerably reduced, by the grouping of sites using factor analysis (Table 10). Mean yield and ranking of the varieties seem to suggest a need to release OPs on ecological zone basis, but there appears to be no truly distinct forest and savanna hybrids (Table 11). Using the LSD values to test the means in Table 11, the best hybrids for each zone (factor) are :

(i) Forest/transition/southern Guinea savanna (Factors I & III): 8505-5, FE 86001, and 8321-18
(ii) Northern Guinea savanna (Factor II): 8505-5, 8505-2, 8505-3, and 8321-18
(iii) Sudan savanna (Factor IV): any of the hybrids.

Table 9. Summary of varimax rotated factors for locations used in the white hybrid and late O.P. Coordinated Maize Trials, 1987 and 1988.

	Factor I	Factor II	Factor III	Factor IV
1987 Late O.P.				
Locations loaded	Ib, Ft, Jos, Uyo	NCRI, Amak	Mokwa	Bag, Lan
% Total variance	32.2	31.6	18.5	17.6
Mean yield (t/ha)	3.42	4.07	4.9	2.8
Range (t/ha)	1.3-4.6	2.3-5.8	-	2.8-2.8
1988 Late O.P.				
Locations loaded	Ik, Mok, Ilora	Ife, Ft. Sam.	Bag	
% Total variance	37.0	34.4	28.5	
Mean yield	3.5	5.9	5.0	
Range	2.5-4.6	5.3-6.6	-	
1987 White Hybrids				
Locations loaded	Ib,Ife,Jos,Mok.	Amak,Ft,Bdgi,Lan	Benin,Uyo	Bag
% Total variance	29.7	28.1	27.3	14.9
Mean yield	4.5	3.8	4.0	4.2
Range	3.0-5.8	1.3-5.7	2.8-5.2	-
1988 White Hybrids				
Locations loaded	Bag, Ife, Ilora, Sam.	Mok, Ft, Ik.		
% Total variance	57.3	42.7		
Mean yield	4.9	4.4		
Range	3.0-5.8	2.5-6.7		

Ib = IBADAN, Ik = IKENNE, Amak = AMAKAMA, Mok = MOKWA, Ft = FUNTUA.
Bdgi = BADEGGI, Bag = BAGAUDA, Sam = SAMARU, Lan = LANLATE.

Table 10. Summary of AOV for grain yield combined across locations and for groups of locations (factors) from the 1987 white hybrid and the 1988 Late OP Coordinated Maize Trials^{+}.

Source of variation	Combined Df	Combined F-test	Factor I Df	Factor I F-test	Factor II Df	Factor II F-test	Factor III Df	Factor III F-test	Factor IV Df	Factor IV F-test
1987 White Hybrid Trial										
Location (L)	10	**	3	**	3	**	1	**	-	-
Variety (V)	8	**	8	**	8	*	8	**	8	**
L x V	80	**	24	NS	24	**	8	NS		
Error	262	-	96	-	95	-	47	-	24	-
1988 Late OP Trial										
Location (L)	6	**	3	**	1	**	-	-		
Variety (V)	8	**	8	**	8	**	8	NS		
L x V	48	**	24	**	8	NS		-		
Error	166	-	94	-	48		24	-		

+: ** = significant (P = 0.01)

Table 11. Mean yield (t/ha) and rank for each variety and each factor in the 1987 white hybrid and the 1988 late OP Coordinated Maize Trials.

No. Variety	Factor I		Factor II		Factor III		Factor IV	
1987 White Hybrid Trial	Yield	Rank	Yield	Rank	Yield	Rank	Yield	Rank
8505-5	5.23	1	4.47	1	4.51	2	3.60	7
FE 86001	5.10	2	3.39	9	3.67	8	4.53	3
Check-1 8321-18	4.79	3	4.13	4	4.70	1	4.94	2
8505-2	4.52	4	4.17	2	3.68	7	4.42	4
Check-2 IK83 TZSR-W-1	4.51	5	3.56	5	4.24	3	3.39	8
8505-9	4.45	6	3.52	6	3.84	6	3.30	9
8505-3	4.29	7	4.16	3	3.86	5	5.65	1
FE 86002	4.17	8	3.49	7	3.95	4	3.80	6
FE 86003	3.50	9	3.44	8	3.63	9	3.90	5
LSD, 5%	0.56	-	0.75	-	0.65	-	NS	
1988 Late O.P. Trial								
Check-1 Across 83 TZSR-W-1	4.77	1	5.56	8	4.39	9		
TZPB-SR	4.66	2	6.18	4	5.11	5		
DMR-LSR-W	4.33	3	6.22	3	4.65	7		
DMR-LSR-Y	4.03	4	5.94	5	5.44	1		
8540-SR	3.97	5	5.66	7	5.41	2		
Check-2 Fer 81 TZSR-Y	3.90	6	5.85	6	4.84	6		
Population 66-SR	3.82	7	5.27	9	5.39	3		
TZ Syn-1	3.74	8	6.23	2	4.60	8		
Guay 8443-SR	3.66	9	6.65	1	5.12	4		
LSD, 5%	0.54	-	0.68	-	NS			

Clearly, one can see that at least two hybrids are common to any two zones.

For the late OPs, however, the situation is different as shown in Fig. 4. Across 83 TZSR-W-1 seems to be distinctly a forest variety, whereas GUAY 8443-SR and TZ SYN-1 are more of savanna varieties. These OPs and perhaps others may be used as standard varieties to classify maize germplasm into zones of adaptation.

CONCLUSIONS

The yield potential of the presently available maize varieties in different agro-ecologies of Nigeria ranges from about 4 t/ha in the forest and forest-savanna (transition) zones to about 6 t/ha in the northern Guinea savanna. The yield potentials of the southern Guinea and Sudan savanna zones are similar, about 5 t/ha. The best hybrids showed an average of 23-30% yield advantage over the best OPs in the forest, transition and southern Guinea savanna ecologies.

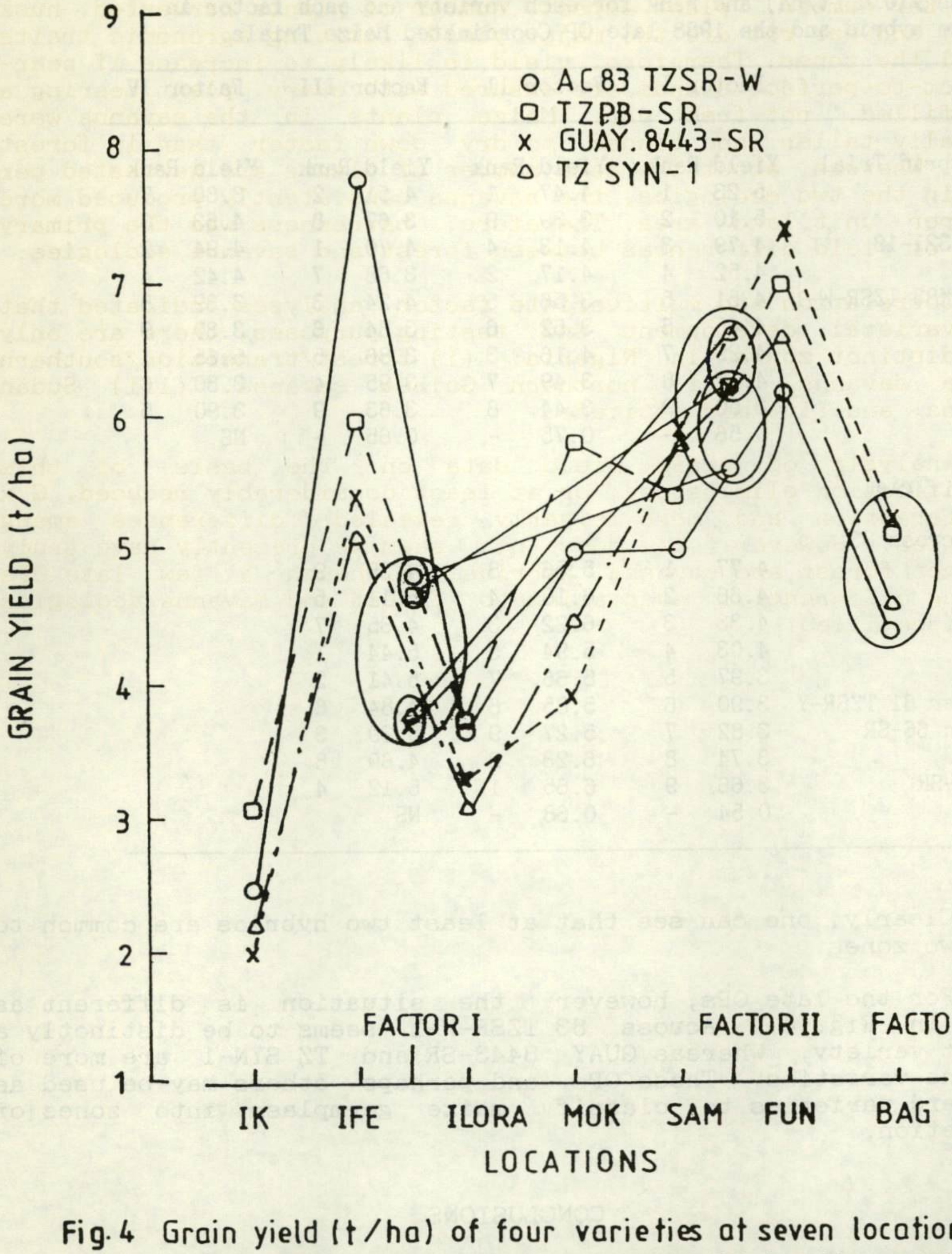

Fig. 4 Grain yield (t/ha) of four varieties at seven locations in the 1988 Late OP National Maize Trials. Mean yield for each variety as loaded on a factor are circled

Ear number, plant aspect, number of plants harvested, husk cover, and ear rot are the major yield limiting agronomic traits in all the zones. Therefore, yield is likely to increase if near-perfect-to-perfect stands are ensured with every plant bearing a well-filled, rot-free ear. Maize plants in the savanna were generally taller and tended to dry down faster than in forest zones. Whereas about the same number of plants are harvested per plot in the two ecologies, the savanna consistently produced more ears per unit land area. Therefore, barrenness was the primary cause of yield differences between forest and savanna ecologies.

Correlation and multivariate factor analyses indicated that for varietal development and testing purposes, there are only four distinct zones in Nigeria: (i) forest/transition/southern Guinea savanna, (ii) northern Guinea savanna, (iii) Sudan savanna, and (iv) mid altitude.

Analysis of grain yield data on the basis of this classification eliminated, or at least considerably reduced, G x E interaction and more clearly revealed differences among varieties. However, it does not seem we presently have truly distinct forest and savanna hybrids, although a few late OPs showing differential adaptation to forest and savanna ecologies were identified.

PART III

AGRONOMY/CROP PHYSIOLOGY

11. Millet/Cowpea Relay Cropping as Influenced by Cultivar and Nitrogen Fertilization.

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ABTRACT

Productivity of pearl millet (*Pennisetum americanum*) and cowpea could be influenced by cultivar and N fertilization. This paper presents the results of a field experiment that evaluated the response of five millet cultivars (Ex-Borno, Bristle Composite, SE2124, Dwarf Composite, and Nigerian Composite, in 1985, and Ex-Borno, SE. 360, SE. Composite, SE75 and SE13, in 1986), and two cowpea cultivars (Sampea 7 and 339-1-2) to four levels of N fertilization (0, 30, 60 and 90 kg N/ha).

Millet grain yield increased with increase in applied N up to a calculated economic optimum that varied from 73-91 and 58-72 kg N/ha in 1985 and 1986, respectively, depending on cultivar. Application of N to millet decreased grain yield of relay crop of cowpea in both years. Competitive effect of millet on the relayed cowpea generally reduced cowpea yield. The optimum N level for maximizing profits on sole crop millet was higher than that required to maximize profit for the millet/cowpea relay system. The need to base N fertilizer recommendation for millet/cowpea relay crop on the farmer´s priority for the components of the system is discussed.

RESUME

La productivité du mil perlé (*Pennisitum americanum*) et du niébé pourrait être influencée par le cultivar et l´engrais azoté. Cette communication présente les résultats d´un essai au champ qui a permis d´évaluer la réponse de cinq cultivars de mil (Ex-Borno, Bristle Composite, SE 2124, Dwarf Composite, et Nigerian Composite) en 1985, et Ex-Borno, SE 360, SE Composite, SE 75 et SE 13 en 1986), et la réponse de deux cultivars de niébé (Sampea 7 et 339-1-2) à quatre doses d´engrais azoté (0, 30, 60 et 90 kg N/ha).

Le rendement en grains du mil s´est accru en même temps que la dose d´engrais azoté a augmenté jusqu´à un optimum économique calculé qui variait entre 73-91 et 58-72 kg N/ha en 1985 et 1986, respectivement, dépendamment du cultivar. L´application de l´engrais azoté au mil a diminué le rendement en grains de la culture de relais du niébé au cours des deux années. L´effet compétitif du mil sur le niébé a généralement réduit le rendement du niébé. La dose optimale de l´engrais azoté en vue de maximiser les avantages au niveau de la culture du mil pure était plus élevée que celle requise pour maximiser les avantages au

niveau du système de culture intercalaire mil/niébé. La nécessité de fonder l´utilisation de l´engrais azoté pour la culture associée mil/niébé sur la priorité de l´agriculteur en ce qui concerne les composantes du système a fait l´objet de discussion.

INTRODUCTION

Cultivation of cowpea in relay crop with pearl millet (Pennisetum americanum (L.) K. Schum) is an important cropping practice among traditional farmers in the northern Guinea savanna agroecological zone of Nigeria. The photoperiod-insensitive gero millet, a principal staple food crop, is sown at the onset of the rains to mature in August (during the rainfall peak). As a minor crop, cowpea is sown into the millet in July/August, thus providing a unique opportunity for full utilization of the wet season.

Fertilizer requirements of 60 kg N, 30 kg P_2O_5, and 30 kg K_2O per hectare have been recommended for optimum grain production of millet in sole crop (Singh et al., 1983-. Generally, millet responds more to N than to P and K (Engelstad and Terman, 1966).

Fertilizer recommendation is also available for sole crop cowpea (IAR, 1985). About 36 kg P_2O_5 is recommended, but there is no requirement for N application, apparently because the crop fixes atmospheric N. However, effects of applied N on cowpea physiology and productivity have been documented.

For nodulating cowpea, there is a bried period of "N hunger" immediately after the shedding of the cotyledons but prior to effective N fixation (Minchin et al., 1981). During this period, a low dosage of applied N has been found beneficial (Ezidinma, 1964; Dart et al., 1977, Minchin et al., 1981; Rhoden et al., 1987) particularly when the level of soil organic matter is less than 2% (Agboola, 1978). High concentration of applied N, on the other hand, reduces nodule number and weight (Rhoden et al., 1987), symbiotic longevity (Minchin et al., 1981) and tends to replace the N fixation process altogether (Allos and Bartholomew, 1959). However, Eaglesham et al., (1977) found the crop assimilation of symbiotic N to be significantly higher than that of applied N. For the non-nodulated cowpea, no amount of applied N could compensate for the loss of symbiotic N; it produces fewer branches, peduncles and pods (Dart et al., 1977 ; Summerfield et al., 1977). It has been suggested that N application to cowpea is not economical, given the rising cost of nitrogen fertilizers and the lack of clear crop response (IAR, 1985).

Since pearl millet requires N fertilization for optimum yields, it was considered valuable to determine the fate of associated cowpea in the relay cropping system, with or without optimum N. Although current crop production technologies are based on the requirements of sole crops, the farmer traditionally grows his crops in mixtures. The present study examines the effects of cultivar and nitrogen fertilization on millet and cowpea in a relay cropping system.

MATERIALS AND METHODS

Experimental design

Field experiments were conducted during the wet seasons of 1985 and 1986 at the research farm of the Institute for Agricultural Research (IAR), Samaru (11°11´N; 7°38´E and 675 m above seal level), located int he northern Guinea savanna agroecological zone of Nigeria. The monomodal rainfall starts in May/June and terminates in September/October.

The soil is deep and imperfectly drained; the topsoil of fine sandy loam is formed over basement complex parent material. The clay content increases from about 13% at the surface to about 40% at 20-40 cm depth (Kowal, 1968).. In 1985, the soil had the following characteristics: pH, 5.87; N, 0.05%; 1.22% organic carbon; C.E.C., 14.28 meq/100g; Ca, 1.56 meq/100g; Mg, 0.58 meq/100g; available P, 11.2 ppm; and exchangeable K, 0.17 meq/100g. However, in 1986, the chemical soil analysis revealed pH, 5.6; 0.05% N; 0.4% organic carbon; C.E.C., 11,80 meq/100g; Ca, 2.8 meq/100g,; Mg, 0.62 meq/100g; available P, 18.4 ppm; and exchangeable K, 0.13 meq/100g. The site was under continuous fallow for three years before the study.

Experimental treatment and design

Experimental treatments comprised four levels of nitrogen fertilizer (0, 30, 60, and 90 kg/ha), five millet cultivars (Ex-Borno, Bristle Composite, SE2124, Dwarf Composite and Nigerian Composite, in 1985, and Ex-Borno, SE360, SE Composite, SE75 and SE13, in 1986) and two semi-erect cowpea cultivars (Sampea 7 and IAR 339-1-2). Ex-Borno and Sampea-7 are standard recommended varieties of IAR.

The experiment was laid out each year in a split-split plot design, with N on the main plot, millet cultivars on the subplot and cowpea cultivar on the sub-subplot, in three replicates. A subplot comprised 10, 10-m long ridges spaced 0.75 cm apart, the net plot being the eight inner ridges. The sub-subplot consisted of five, 10-m long ridges, 0.75 cm apart, with the three inner ridges serving as the harvest area.

Crop management

The field was ploughed, harrowed twice and ridged about a week before sowing. Millet was sown at 0.25 m spacing along rows and thinned to one plant per stand (53,333 plants/ha) about 10 days later. After anthesis of millet, cowpea was sown also at 0.25 m spacing in-between millet stands and about 5 cm from the centre of the ridge; seedlings were later thinned to one stand per hill (53,333 plants/ha). Millet and cowpea were sown on 15 June and 2 August, respectively, in 1985 and 17 June and 5 August, respectively, in 1986.

Fertilizer was applied just before millet was sown at the 60 kg N, 30 kg P_2O_5 and 30 kg K_2O per hectare, using calcium ammonium nitrate, single superphosphate, and muriate of potash, respectively. No fertilizer was applied directly to cowpea.

Three hoe-weeding operations were done at 2 weeks after planting of millet, at millet anthesis, and at 2 weeks after planting of cowpea.

Insect pests of cowpea were controlled by spraying a tank mixture of cypermethrin and dimethoate at the rate of 50 g a.i./ha and 500 g a.i./ha, respectively; three fortnightly sprays were applied, starting from the flowering stage.

Data collection

Data were collected on the grain yield and yield components of millet and cowpea. Harvesting of millet was on subplot basis as young cowpea plants were not expected to reduce yields of maturing millet plants. Cost and benefit analysis of N fertilizer application was based on information provided by the Department of Agricultural Economics and Rural Sociology of IAR, Ahmadu Bello University, Samaru. Millet and cowpea grains were valued at ₦1.5/kg and ₦2.5/kg, respectively, while N fertilizer was costed at ₦1.15/kg N.

RESULTS

Millet grain yield and yield components

Millet grain yield and yield components recorded in 1985 are presented in Table 1. Compared to check plots that received no nitrogen fertilizer, all levels of N fertilization significantly increased millet grain yield, but the difference between 60 and 90 kg N/ha was not significant. Ex-Borno outyielded significantly Bristle Composite and Dwarf Composite but not SE2124 and Nigerian Composite. Application of up to 60 kg N/ha had no significant effect on both threshing percentage and plant height; however, application of 90 kg N/ha significantly reduced the threshing percentage, although the plants were significantly taller. The effect of millet cultivar on threshing percentage was not significant but SE2124 produced some of the tallest plants while Dwarf Composite was the shortest. Ex-Borno and SE2124 produced significantly longer panicles than the other cultivars, but their grains were lighter than those of others. The N level x millet cultivar interaction significantly affected the thousand-grand weight.

Table 1. Effect of nitrogen fertilizer and millet cultivar on yield and yield components of millet (Samaru, 1985 wet season).

Treatment	Millet grain yield (kg/ha)	Threshing percentage (%)	Plant height (cm)	Panicle length (cm)	100-grain weigth (g)
N level (kg/ha)					
0	761	68	158	42	8
30	930	66	162	41	8
60	1072	65	162	42	9
90	1081	62	171	41	8
S.E.±	37.8	0.9	1.7	1.1	0.3
LSD (P=0.05)	130.7	3.1	5.9	ns	ns
Millet cultivar					
Ex-Borno	1036	66	175	44	8
Bristle Composite	896	66	173	40	9
S.E. 2124	974	63	192	43	8
Dwarf Composite	921	66	94	40	9
Nigerian Composite	976	65	182	41	9
S.E.±	32.6	1.9	5.1	0.7	0.3
L.S.D. (P = 0.05)	94.0	ns	14.8	2.7	1.0
Interaction					
N level x millet cultivar	ns	ns	ns	ns	*

ns = not significant; * = significant at 5% level of probability.

In 1986, the effect of N level x millet cultivar interaction on all parameters measured was not significant (Table 2).

Table 2. Effect of nitrogen fertilizer and millet cultivar on yield and yield component of millet (Samaru, 1986 wet season).

Treatment	Millet grain yield (kg/ha)	Threshing percentage (%)	Plant height (cm)	Panicle length (cm)	100-grain weight (g)
N level (Kg/ha)					
0	856	64	224	40	7
30	1159	60	226	39	7
60	1205	60	231	40	7
90	1225	60	240	43	7
S.E.±	35.0	0.8	3.4	1.0	0.3
L.S.D. (P = 0.05)	121.2	2.8	ns	ns	ns
Millet cultivar					
Ex-Borno	1075	61	221	39	6
S.E. 360	1022	60	243	44	7
S.E.Composite	999	59	223	38	7
S.E. 13	1286	64	231	41	7
S.E. 75	1176	60	234	40	8
S.E. ±	52.2	1.4	4.0	1.0	0.4
L.S.D. (P = 0.05)	150.7	ns	11.6	2.9	ns
Interaction					
N level x millet cultivar	ns	ns	ns	ns	ns

ns = Not significant.

However, grain yields of plots that received 30-90 kg N/ha were significantly higher than the yield of the unfertilized plot, although they were not significantly different from one another. Cultivar SE13 outyielded significantly Ex-Borno, SE360 and SE Composite. As in 1985, the effect of millet cultivar was not significant. While all levels of N significantly reduced the threshing percentage, they had no significant effect on plant height, panicle length and thousand-grain weight. Similarly, while the effect of millet cultivar on the hundred-grain weight was not significant, cultivar SE360 produced taller plants than the other cultivars, except SE75; it also produced longer panicles than others.

Cowpea grain yield and yield components

The effects of N fertilizer, millet and cowpea cultivars on grain yield and yield components of cowpea in 1985 are presented in Table 3. The main effect of millet cultivar on cowpea yield and yield components was not significant. However, all levels of applied N significantly decreased cowpea grain yield, compared to yield of plants that did not receive nitrogen fertilizer. The two cowpea cultivars gave statistically similar yields, but the effect of N level x cowpea cultivar interaction on cowpea grain yield was significant. Similarly, the effect of N level x millet cultivar on threshing percentage was significant. No other first order interaction was significant. Sampea 7 had significantly higher threshing percentage, more pods per plant, and larger grains than 339-1-2. None of the treatments affected the number of branches produced per plant.

As in 1985, the main effect of millet cultivar on cowpea yield and yield components in 1986 was not significant (Table 4). Compared to the yield of plots that did not receive nitrogen fertilizer, application of 30 kg N/ha did not significantly decrease cowpea agrain yield which was decreased significantly by higher doses (60 - 90 kg N/ha).

The two cowpea cultivars again produced similar grain yields. The effects of the N level x millet cultivar interaction on cowpea grain yield and on canopy height were significant. Also significant was the effect of N level x cowpea cultivar interaction on the hundred-grain weight. In 1986 also, Sampea 7 produced larger grains than 339-1-2. None of the treatments significantly affected threshing percentage and number of pods/plant. Sampea 7 cowpea produced more branches per plant than 339-1-2.

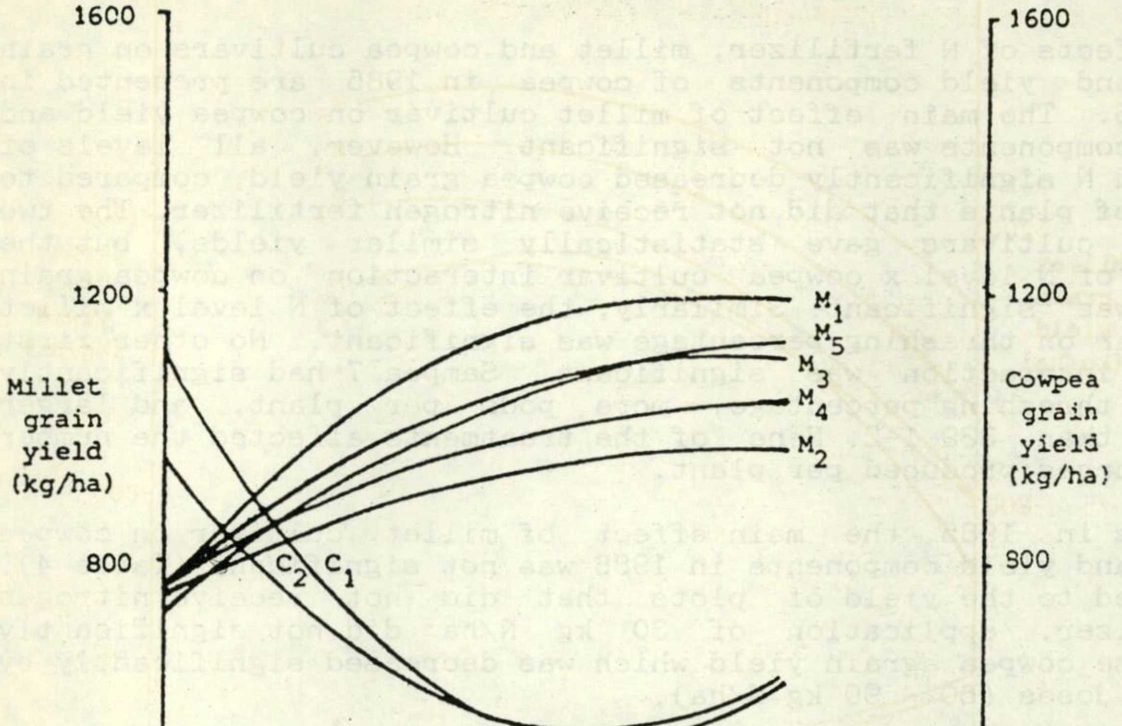
Overall comparison of response to N

The response curves of grain yields of millet and cowpea cultivars in relay crop as functions of N fertilizer applied to millet are presented in Figs. 1 and 2 for 1985 and 1986, respectively. All of the cultivars showed quadratic responses to N rates. Economic optimum N rates for each millet cultivar for each year were calculated from the equation (F.A.O. 1966):

$$Xopt = \frac{b-(q)/p}{2c}$$

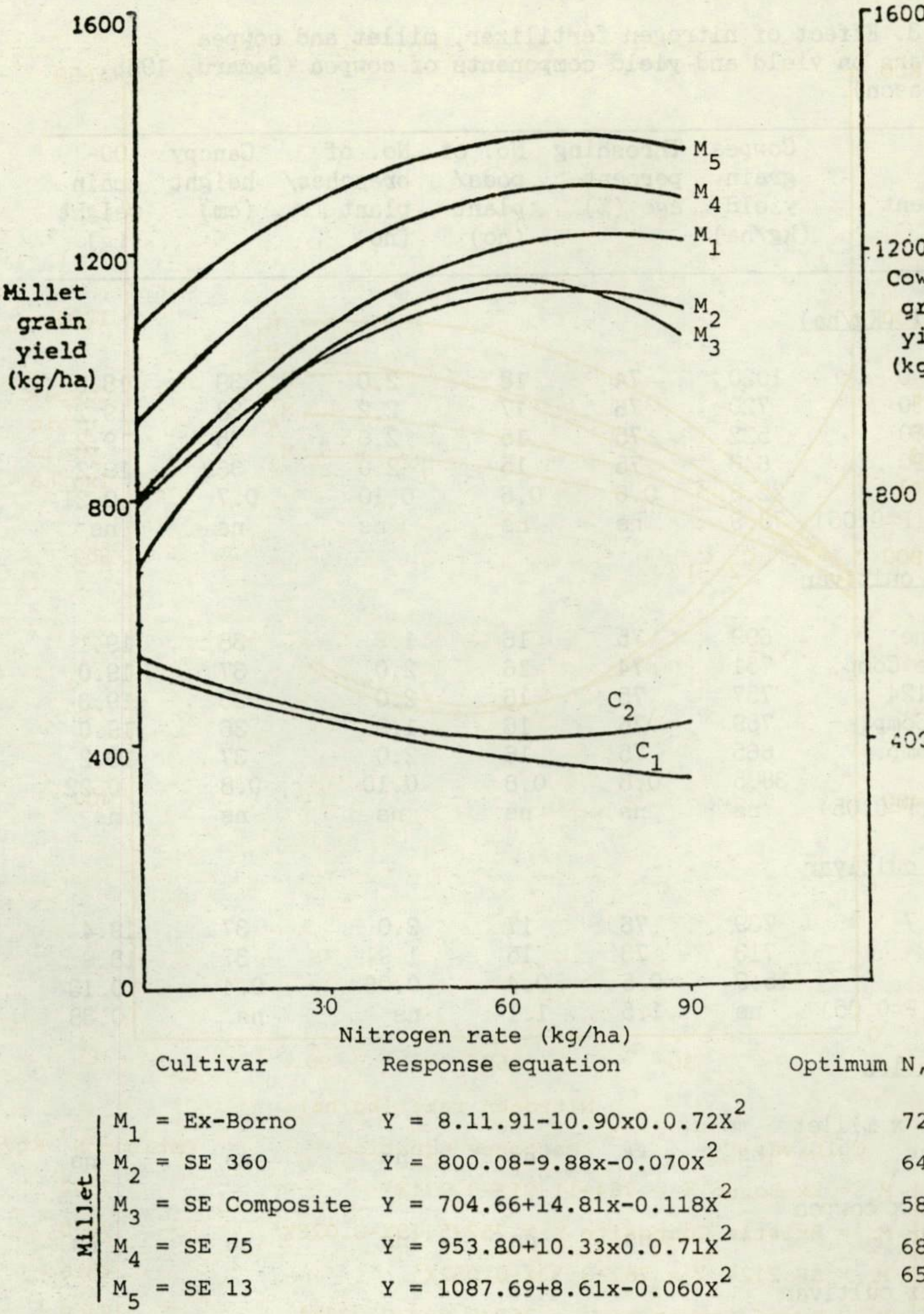
where : ´Xopt´ is the economic optimum level of N (kg/ha); ´b´ and ´c´ are the linear and quadratic coefficients of the response function; ´q´ is price of unit of fertilizer (Naira/kg N; and ´p´ is price of produce (Naira/ka grain).

The new millet varieties introduced into the experiment in 1986, particularly SE13, appeared more efficient in utilizing N fertilizer than Ex-Borno which was the top yielder in 1985.



	Cultivar	Response equation	Optimum N, Kg/ha
Millet	M_1 = Ex-Borno	$Y = 764+11.01X-0.071X^2$	73.2
	M_2 = Bristle Composite	$Y = 752+5.19X-0.028X^2$	79.0
	M_3 = SE 2124	$Y = 762+8.33X-0.052X^2$	75.6
	M_4 = Dwarf Composite	$Y = 762+5.86X-0.033X^2$	84.9
	M_5 = Nigerian Composite	$Y = 736+8.06X-0.038X^2$	91.17
Cowpea	C_1 = Sampea 7	$Y = 1101.91-17.15X+0.130X^2$	-
	C_2 = 339-1-2	$Y = 959.07-12.77X+0.104+X^2$	-

Fig.1: Response curves of grain yield of millet and cowpea cultivars in relay cropping as a function of N fertilizer (Samaru, 1985 wet season).



	Cultivar	Response equation	Optimum N, Kg/ha
Millet	M_1 = Ex-Borno	$Y = 8.11.91-10.90x0.0.72X^2$	72.4
	M_2 = SE 360	$Y = 800.08-9.88x-0.070X^2$	64.6
	M_3 = SE Composite	$Y = 704.66+14.81x-0.118X^2$	58.5
	M_4 = SE 75	$Y = 953.80+10.33x0.0.71X^2$	68.3
	M_5 = SE 13	$Y = 1087.69+8.61x-0.060X^2$	65.4
Cowpea	C_1 = Sampea 7	$Y = 521.96+2.97x-0.011X^2$	-
	C_2 = 339-1-2	$Y = 544.50-4.03x+0.025X^2$	-

Fig.2: Response curves of grain yield of millet and cowpea cultivars in relay cropping as a function of N fertilizer (Samaru, 1986 wet season).

Table 3. Effect of nitrogen fertilizer, millet and cowpea cultivars on yield and yield components of cowpea (Samaru, 1985 wet season).

Treatment	Cowpea grain yield (kg/ha)	Threshing percentage (%)	No. of pods/ plant (no)	No. of branches/ plant (no)	Canopy height (cm)	100-grain weight (g)
N level (Kg/ha)						
0	1020	74	18	2.0	39	18.9
30	720	76	17	2.2	38	19.2
60	522	75	15	2.0	35	19.2
90	643	75	15	2.0	36b	19.2
S.E.±	22.8	0.6	0.6	0.10	0.7	0.21
L.S.D (P=0.05)	78.9	ns	ns	ns	ns	ns
Millet cultivar						
Ex-Borno	699	75	16	1.9	38	19.1
Bristle Comp.	751	74	16	2.0	37	19.0
S.E. 2124	757	75	16	2.0	36	19.3
Dwarf Comp.	759	76	16	1.9	36	19.0
Nig. Comp.	665	75	16	2.0	37	19.2
S.E.±	38.5	0.8	0.8	0.10	0.8	0.22
L.S.D (P=0.05)	ns	ns	ns	ns	ns	ns
Cowpea cultivar						
Sampea 7	739	76	17	2.0	37	19.4
339-1-2	713	73	15	1.9	37	18.9
S.E.±	15.9	0.5	0.4	0.06	0.4	0.13
L.S.D (P=0.05)	ns	1.5	1.1	ns	ns	0.38
Interaction						
N level x millet cultivar	ns	**	ns	ns	ns	ns
N level x cowpea cultivar	*	ns	ns	ns	ns	ns
Millet x cultivar x cowpea cultivar	ns	ns	ns	ns	ns	ns
N level x millet cultivar x cowpea cultivar	**	ns	ns	ns	ns	ns

ns = Not significant; * = significant at 5% level of probability
** = significant at 1% of probability.

Table 4. Effect of nitrogen fertilizer, millet and cowpea cultivars on yield and yield components of cowpea (Samaru, 1986 wet season).

Treatment	Cowpea grain yield (kg/ha)	Threshing percentage (%)	No. of pods/ plant	No. of branches /plant	Canopy height (cm)	100-grain weight (g)
N level (kg/ha)						
0	524	68	13	2.1	42	17.0
30	471	67	12	2.1	41	17.5
60	360	68	12	2.1	40	17.3
90	370	66	10	1.5	38	17.1
S.E.±	32.3	1.2	1.0	0.07	0.9	0.14
L.S.D (P=0.05)	111.9	ns	ns	0.23	ns	ns
Millet cultivar						
Ex-Borno	462	69	13	2.0	42	17.4
S.E. 360	400	67	12	2.0	40	17.2
S.E. Comp.	464	70	12	2.2	40	17.4
S.E. 75	421	65	10	1.7	40	17.0
S.E. 13	411	67	10	1.9	40	17.2
S.E.±	30.6	1.8	0.9	0.10	0.7	0.25
L.S.D. (P=0.05)	ns	ns	ns	ns	ns	ns
Cowpea cultivar						
Sampea 7	422	67	12	2.1	40	17.8
339-1-2	441	68	11	1.8	41	16.7
S.E.±	16.4	1.0	0.6	0.10	0.7	0.12
L.S.D. (P=0.05)	ns	ns	ns	0.28	ns	0.34
Interaction						
N level x millet cultivar	*	ns	ns	ns	**	ns
N level x cowpea cultivar	ns	ns	ns	ns	*	ns
Millet cultivar x cowpea cultivar	ns	ns	ns	ns	ns	ns
N level x millet cultivar x cowpea cultivar	*	ns	ns	ns	ns	*

ns = Not significant; * = significant at 5% level of probability
** = significant at 1% of probability.

Economic analysis of fertilizer use

Tables 5 and 6 present the cost and return analysis of N fertilizer use for 1985 and 1986 wet seasons, respectively. In 1985, the results showed that use of N fertilizer resulted in loss of net income which was greatest when the millet cultivar, Bristle Composite, was grown. By contrast, in 1986, the use of N fertilizer in the production of all millet cultivars (except SE13 and SE Composite given 90 kg N/ha) increased net revenue, compared to that from the crop grown without N fertilizer.

Table 5. Cost and return in Naira (₦) of nitrogen fertilizer in millet/cowpea relay cropping (Samaru, 1985 wet season).

N (kg/ha)	Millet yield (kg/ha)	Cowpea yield (kg/ha)	Gross value product: Millet^{+} (₦)	Gross value product: Cowpea^{++} (₦)	Total gross value product (₦)	Cost of N fertilizer^{+++} (₦)	Net value product (₦)	Added income fertilizer use (₦)
				Ex-Borno				
0	769	934	1154	2335	3489	–	3489	–
30	1018	735	1527	1838	3365	35	3330	-159
60	1183	484	1775	1210	2985	69	2916	-573
90	1175	642	1763	1605	3368	104	3264	-225
				Bristle Composite				
0	765	1280	1148	3200	4348	–	4348	–
30	844	707	1266	1768	3034	35	2999	-1349
60	999	472	1499	1180	2679	69	2610	-1738
90	977	545	1466	1363	2829	104	2725	-1623
				SE2124				
0	759	981	1139	2453	3592	–	3592	–
30	974	849	1461	2123	3584	35	3549	-43
60	1067	567	1601	1418	3019	69	2950	-462
90	1096	630	1644	1575	3219	104	3115	-477
				Dwarf Composite				
0	764	954	1146	2385	3531	–	3531	–
30	900	649	1350	1623	2973	35	2938	-593
60	1003	653	1505	1633	3138	69	3069	-462
90	1019	781	1529	1953	3482	104	3378	-153
				Nigerian Composite				
0	745	950	1118	2375	3493	–	3493	–
30	916	659	1374	1648	3022	35	2987	-506
60	1107	431	1661	1078	2739	69	2670	-823
90	1137	619	1706	1548	3254	104	3150	-343

$^{+}$ = Millet grain at ₦1.5/kg; $^{++}$ = Cowpea grain at ₦2.5/kg;
$^{+++}$ = Nitrogen fertilizer at ₦1.15/kg.

Table 6. Cost and return in Naira (₦) of nitrogen fertilizer use in millet/cowpea cropping (Samaru, 1986 wet season).

N (kg/ha)	Millet grain yield (kg/ha)	Cowpea grain yield (kg/ha)	Gross value product Millet+ (₦)	Gross value product Cowpea++ (₦)	Total gross value product (₦)	Cost of N fertilizer+++ (₦)	Net value product (₦)	Added income from fertilizer use(₦)
				Ex-Borno				
0	818	478	1227	1195	2422	-	2422	-
30	1056	438	1584	1095	2679	35	2644	222
60	1224	387	1804	968	2804	69	2735	313
90	1203	543	1804	1358	3162	104	3058	636
				S.E.360				
0	793	486	1190	1215	2405	-	2405	-
30	1053	417	1580	1043	2623	35	2588	183
60	1116	343	1674	858	2532	69	2463	58
90	1124	352	1686	880	2566	104	2462	57
				S.E. Composite				
0	704	622	1056	1555	2611	-	2611	-
30	1044	565	1566	1413	2979	35	2944	333
60	1166	401	1749	1003	2752	69	2683	72
90	1080	269	1620	673	2293	104	2189	-422
				S.E.75				
0	889	459	1334	1148	2482	-	2482	-
30	1322	602	1983	1505	3488	35	3453	971
60	1157	339	1736	848	2584	69	2515	33
90	1334	283	2001	708	2709	104	2605	123
				S.E.13				
0	1079	576	1619	1440	3059	-	3059	-
30	1319	332	1979	830	2809	35	2774	-285
60	1360	332	2040	830	2870	69	2801	-258
90	1385	405	2078	1013	3091	104	2987	-72

+ = Millet grain at ₦1.50/kg; ++ = Cowpea grain at ₦2.50/kg;
+++ = Nitrogen fertilizer at ₦1.15/kg.

DISCUSSION

It is apparent from the data that application of N fertilizer increased millet grain yield up to an economic optimum that varied from 73-91 and 58-72 kg N/ha in 1985 and 1986, respectively. The differences in the two years were attributed to differences in the cultivars used. Singh and Thakare (1986) had similarly observed varietal differences in the response of millet to nitrogen rates. Generally, millet is responsive to N dressing but excess N causes lodging and, consequently, lower marginal yields. In the present study, lower levels of N fertilizer significantly increased grain yield in 1986 compared to 1985. Indeed, chemical analysis of the soil of the experimental site in 1986 revealed a lower C/N ratio (8.0) than that (24.4) in 1985. Since Giri and De (1979) found that a previous crop of cowpea increased grain yield of a subsequent, unfertilized millet crop by about 24%, the increased reserve of organic N in the present study probably came from the previously relayed cowpea crop.

It was also observed that application of N fertilizer to millet markedly decreased grain yield of the cowpea relay crop in both years. Eaglesham et al (1983) and Ofori and Stern (1986) have shown that fertilizer N application in excess of 25 kg N/ha reduces cowpea grain yield by inhibiting N fixation in cowpea.

The production function for millet has provided the basis for establishing the optimum rates of N fertilizer to maximize profits from the millet component of the millet/cowpea relay system. It has been ascertained that the optimum rate is generally close to the 60 kg N/ha currently recommended for sole crop of millet in Nigeria. However, this level of N fertilization does not necessarily maximize profits for the entire millet/cowpea system. The cost and return analysis of the whole system revealed no economic advantage to the use of N fertilizer in 1985. For 1986, however, application of N to millet gave additional net income for all millet cultivars, except cultivars SE13 (at all N rates) and SE75 (at 90 kg N/ha).

Considering the data obtained during the two years, it is tentatively concluded that application of N fertilizer at 30 kg N/ha is desirable in the context of the whole enterprise (i.e., millet/cowpea system). In a situation like this, which involves two crops, there will probably exist differential preference by farmers for the components of the system. Thus, for a farmer that places priority on millet, the choice of the level of N dressing should be close to the optimum. Where the premium is on cowpea grain, or where equal premium is given to grain of both crops, the N rate should be about 30 kg/ha.

The fore-going economic analyses have been based on the assumption that all additional inputs (e.g. costs of additional labour for applying fertilizer or increased weeding) as well as N fertilizers are readily available and that farmers have sufficient capital to purchase the optimum amounts. Very seldom are all these assumptions valid.

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12. Etude sur les Arrangements Spatiaux des Cultures dans le Système de Cultures Associées Sorgho-Niébé

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RESUME

Un essai sur l'arrangement spatial du sorgho et du niébé en association a été conduit à Longorola dans les conditions de culture pluviale. Les rendements en grains du sorgho ont été statistiquement équivalents. Cependant, en année de sécheresse, il a été observé chez le sorgho, la tendance à une baisse de rendement au fur et à mesure qu'on augmente la densité de niébé. L'arrangement spatial des cultures a eu une influence positive sur le rendement en grains du niébé. C'est la combinaison: une ligne de sorgho pour 4 lignes de niébé qui a donné les rendements les plus élevés de niébé pendant deux ans.

ABSTRACT

A trial on spatial arrangement of sorghum-cowpea mixed cropping system was conducted in 1986 and 1987 at Longorola in the rainy season. Sorghum grain yield in this trial was statistically the same each year. However, under drought conditions, sorghum grain yield tended to decline with increase in density of cowpea in the mixture. Certain spatial arrangements favourably influenced cowpea grain yield, thereby improving the productivity of the system. The 1:4 (one line of sorghum to four lines of cowpea) spatial arrangement gave the best yield advantage in the two years.

INTRODUCTION

L'association sorgho-niébé, pratique très ancienne se rencontre fréquemment dans les zones soudaniennes (600-1000 mm de pluie) du Mali.

Dans le système traditionnel de culture, les semences de ces deux plantes sont déposées simultanément dans le même poquet sur buttes, billons ou après grattage à la houe. Le sorgho est semé à la densité maximale (35.000 à 40.000 plants/ha), tandis que le niébé ne se rencontre que dans quelques poquets de sorgho avec une densité de 8.000 plants/ha (Serafini, 1982). Le niébé local, rampant, couvre par endroit le sol et végète sous les variétés locales de sorgho de haute taille (5 m de haut). Le niébé qui produit plus de fane que de grain, est récolté en premier lieu. Le paysan obtient un rendement plus ou moins complet de sorgho et une production supplémentaire de niébé.

Le système de culture tel que pratiqué n´est pas favorable à de bons rendements de niébé, qui a aussi son importance dans l´alimentation en milieu rural car utilisé particulièrement en période de soudure.

La présente étude a pour objectif, l´amélioration de la productivité du niébé sans porter préjudice à celle du sorgho à travers des arrangements spatiaux de cultures. Elle est conduite dans des conditions de culture pluviale.

MATERIELS ET METHODES

L´essai a été conduit durant les campagnes agricoles 1986 et 1987 à Longorola dans le sud du Mali. Les sols de cette localité sont ferrugineux tropicaux, lessivés à noyaux endurés et à carapace (Valet, 1988). Ils sont pauvres en matière organique et ont une faible capacité d´échange cationique (2,5 meg/100).

La pluviométrie moyenne annuelle est de 1200 mm concentrée en Juillet, Août et Septembre.

L´essai comportait quatre arrangements de cultures décrits ci-dessous disposés en blocs de Fisher à 4 répétitions.

T1 : le sorgho est semé à 75 cm x 50 cm (53333 plants/ha), le niébé à 225 cm x 150 cm (8.889 plants/ha). Ils sont tous démariés à 2 plants/poquet : arrangement 2:1, 2 lignes de sorgho, 1 ligne de niébé.

T2 : Le sorgho est semé à 75 cm x 50 cm (53.333 plants/ha), le niébé à 225 cm x 50 cm (26.667 plants/ha). Ils sont tous démariés à 2 plants/poquet : arrangement 2:1, 2 lignes de sorgho, 1 ligne de niébé.

T3 : Le sorgho est semé à 225 cm x 25 cm (53.333 plants/ha), le niébé à 75 cm x 50 cm (53.333 plants/ha) : arrangement 1:2, 1 ligne de sorgho, 2 lignes de niébé.

T4 : Le sorgho est semé à 150 cm x 25 cm (53.333 plants/ha), le niébé à 30 cm x 50 cm (133.332 plants/ha). Ils sont démariés à 2 plants/poquet : arrangement 1:4 , 1 ligne de sorgho, 4 lignes de niébé.

Les cultures pures des deux espèces étaient des traitements additionnels permettant la détermination de la surface équivalente relative.

Les variétés utilisées dans l´essai étaient le sorgho Malisor 84-1 à feuilles peu pendantes, semi-tardif et le niébé KN-1 à port érigé, précoce.

Comme le fait ressortir les arrangements de cultures , le sorgho a été semé à une seule densité celle de 53.333 plants/ha, tandis que la densité du niébé a varié selon les traitements. Les deux cultures ont été semées simultanément en Juillet pendant les années d´expérimentation.

Le niébé a été traité avec le Decis (Deltamethrine) à 0,50 l/ha dès l´apparition des premiers boutons floraux et par la suite, tous les 10 jours avec le Thimul 35 (Endosulfan) à 2 l/ha.

La parcelle expérimentale avait 4,5 m x 8 m de dimension. La fumure apportée aux cultures est à base de complexe NPK (200 kg/ha enfouis dans le sol, à la houe lors du semis) et d´urée (50 kg/ha) uniquement au sorgho lors de la montaison. Il y a eu deux sarclo-binages par année.

RESULTATS ET DISCUSSIONS

Nous avons enregistré en première année de l´essai, une hauteur de pluie normale : 1184,3 mm. Le sorgho a donné des rendements en grains statistiquement équivalents à travers les différents arrangements de cultures (Tableau 1).

Tableau 1. Rendement du sorgho et du niébé dans l´association à Longorola (kg/ha)

	1986			1987		
Traitements	Sorgho (kg/ha)	Niébé (kg/ha)	LER[£] Total (%)	Sorgho (kg/ha)	Niébé (kg/ha)	LER[£] Total (%)
T1	1192	35	105	2790	45	100
T2	1222	60	111	2470	110	100
T3	1488	220	163	1880	290	104
T4	1491	289	178	1890	365	115
Cultures pures	1211	525	-	2650	865	-
ES (±)*	133	27	-	250	30	-
dl	(9)	(9)	-	(9)	(9)	-
CV (%)	25	84	-	18	27	-

[£] LER = Rapport de surface équivalente relative

*ES = Erreur standard

Quant à la seconde année, la pluviométrie était déficitaire avec un total de 862,5 mm. Les rendements en grains de sorgho ont varié en fonction de l'arrangement des cultures (Tableau 1). Les arrangements de cultures 2:1 (2 lignes de sorgho pour 1 ligne de niébé) ont donné en moyenne 2.630 kg de grains de sorgho/ha. Les arrangements de semis qui avaient une ligne de sorgho pour deux ou quatre lignes de niébé ont donné un rendement grains moyen de 1.885 kg/ha. Ceci serait dû au fait que ces arrangements de cultures, tout en donnant de l'espace au niébé, accroissent la compétition entre poquets sur la ligne de sorgho.

En effet, la distance entre poquets est réduite pour obtenir une densité équivalente à celle de la culture pure de sorgho. Ces faibles rendements n'ont été enregistrés qu'en année de pluviométrie inférieure à la normale.

Sur le niébé: le rendement en grains de niébé a significativement varié d'une densité de semis à une autre.

Avec l'arrangement 2:1, on a obtenu jusqu'à 53 % d'augmentation de rendement de grains de niébé en passant de 8.889 plants/ha (225 cm x 150 cm) à 26.667 plants/ha (225 cm x 50 cm). Dans cet arrangement, le traitement phytosanitaire du niébé n'est pas facile après la montaison du sorgho. Le niébé a surtout souffert du manque de lumière qui a occasionné de faibles rendements. Un phénomène similaire avait été observé par Nambiar et al (1983) chez l'arachide dans les associations de cultures.

Dans les arrangements de semis 1:2 et 1:4, on a amélioré le rendement en grains du niébé de 22 % en passant de 53.333 plants/ha (75 cm x 50 cm) à 133.333 plants/ha (30 cm x 50 cm). Ces arrangements de cultures se prêtent aux opérations de traitements phytosanitaires du niébé. SINGH (1979) a également obtenu des résultats semblables en jouant sur l'arrangement de cultures sans réduction de rendement de la culture dominante.

Les différents arrangements de cultures ont tous donné des avantages de rendement. Mais le meilleur profit de l'association a été tiré de l'arrangement de semis 2 lignes de sorgho pour 4 lignes de niébé aussi bien en année humide qu'en année sèche. L'avantage de rendement est plus faible en année sèche qu'en année humide (15% contre 78% en année humide).

CONCLUSION

Dans l'arrangement de culture 2:1, le niébé qui semble beaucoup être concurrencé en lumière, a donné de faibles rendements. L'arrangement de culture 1:2 ou 1:4 qui présente plus d'espace dans les interlignes de sorgho, a permis au niébé d'exprimer ses meilleurs potentiels de rendements. Dans ces derniers arrangements de semis, le sorgho est apparu sensible au déficit pluviométrique.

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13. Intensification of Production in a Maize-Cassava Intercrop in Ghana

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ABSTRACT

Maize (*Zea mays* L.) intercropped with cassava (*Manihot esculenta* Crantz) is a widely known and accepted intercropping practice in Ghana. Cassava, however, is a long duration crop that occupies the land in the two rainy seasons in Ghana. This limits resource use by farmers. Cassava is also more susceptible to competition when interplanted into maize; up to 20% yield loss can be expected. To overcome these two constraints, two trials were planted in 1984. In one trial, cassava was cut back to 45 cm and maize planted into it in the minor rainy season. In the other trial, the effect of planting arrangement in the intercrop was studied.

Although there was drought during the minor rainy season of 1984, the results showed production of a second crop of maize with an acceptable yield loss in cassava. It was also shown that higher cassava tuber yields were obtained when two rows of cassava alternated with two rows of maize than when one row of one crop alternated with one row of the other.

RESUME

La Culture du maïs (*Zea mays* L.) en association avec le manioc (*Manihot esculenta* Crantz) constitue une pratique de culture associée largement répandue et acceptée au Ghana. Toutefois, le manioc est une culture à cycle long qui occupe la terre pendant les deux saisons pluvieuses au Ghana. Ceci limite les ressources utilisées par les paysans. Le manioc est également plus sensible à la compétition lorsqu´il est cultivé en association avec le maïs ; l´on peut s´attendre à des pertes de rendement allant jusqu´à 20 %. Pour surmonter ces deux contraintes, deux essais ont été semés en 1984. Dans l´un des essais, le manioc a été rétréci de 45 cm avant d´intercaler le semis du maïs au début de la saison pluvieuse. Dans l´autre essai, l´effet de l´arrangement des semis dans la culture intercalée a fait l´objet d´une étude.

Quoiqu´il y ait eu la sécheresse au début de la saison pluvieuse de 1984, les résultats ont montré la production d´une seconde récolte de maïs avec une perte de rendement relativement

faible au niveau du manioc. Il a été également montré que les rendements en tubercules du manioc sont plus élevés lorsqu'on alterne deux rangs de manioc avec deux rangs de maïs que lorsqu'on alterne un rang d'une récolte avec un rang d'une autre.

INTRODUCTION

Maize-cassava intercropping is widely known and accepted (Okigbo, 1978; Kumar and Hrishi, 1979, Moreno and Hart, 1979) and it is regarded as an efficient combination.

However, cassava is less competitive than maize when the two crops are intercropped; this results in up to 20% loss in yield. Cassava is also a long duration crop and does not allow the use of the land again by other crops after maize is harvested. In Ghana two rainy seasons occur in a year in the forest, the forest-savannah transition, and the coastal-savannah zones.

The study reported in this paper was done to determine how to overcome these two constraints in order to increase farmers' productivity of both maize and cassava in these three zones.

MATERIALS AND METHODS

Two trials were planted in 1984 at Kwadaso in the central forest zone of Ghana, on slightly acid clay loams. In each trial, the treatments were studied in a 2^4 factorial with confounding arrangement in two replicates, two blocks comprising a replicate. The two crops were planted in alternate rows, with cassava being planted within 8 days of sowing maize.

Trial 1

The aim was to evaluate the effect of row pairing on yields of intercropped maize and cassava. The treatments consisted of two maize varieties (Selection Precoz, 90-day maturity period and La Posta, 120-day maturity period); two levels of nitrogen fertilization (0 and 90 kg N/ha); two planting patterns (one or two rows of maize alternating with corresponding number of rows of cassava); and two cassava management systems (stems uncut till harvest, or stems cut back to 45 cm above soil level in the minor rainy season).

Trial 2

The aim was to determine the feasibility of planting maize during the minor (second) rainy season in the same cassava plot in which maize was grown in the main (first) rainy season. The treatments comprised two maize varieties (the same as those used in Trial 1); two maize planting densities (20 and 40 thousand plants/ha); two cassava planting densities (10 and 20 thousand plants/ha); and two levels of nitrogen fertilizer application (0 and 90 kg N/ha).

In the minor season, each cassava plot was divided into two parts; stems of one half were left intact while those of the remainder were cut back to 45 cm above soil level.

In each of the two trials, the long duration cassava cultivar, "Ankra", was used and no herbicides were applied.

RESULTS AND DISCUSSION

Trial 1

The effect of planting pattern on grain yield of intercropped maize was significant (Table 1). Thus, two rows of Selecion Precoz alternated with two rows of cassava produced significantly more grain yield than single row of maize alternated with single row of cassava, if nitrogen fertilizer was not applied. However, planting pattern had no significant effect on yield of Selecion Precoz that received 90 kg N per ha. By contrast, La Posta that received 90 kg N/ha gave more grain yield when two rows alternated with two rows of cassava than when one row alternated with one row of cassava. Unfertilized plots of La Posta gave similar yields, regardless of planting pattern.

Table 1. Yield of intercropped maize as influenced by maize variety, nitrogen fertilization and cropping pattern.

	Cassava-maize planting arrangement			
Maize variety	Single alternate rows		Two alternate rows	
	0 kg N/ha	90 kg N/ha	0 kg N/ha	90 kg N/ha
Selecion Precoz	2.9	3.0	3.4	3.3
La Posta	4.0	3.8	3.6	4.6

S.E. of difference between 2 means = 0.3

The data presented in Table 2 showed that the double-row planting arrangement produced about 36% more cassava tuber yield than the single-row planting arrangement. This result agrees with that of Almeida and Pereida (1984).

Table 2. Tuber yield and plant height of intercropped cassava as influenced by maize fertilization, planting pattern, and cutting back of cassava stem+.

Treatment	Treatment description	Tuber yield (weight basis) Mg/ha	Number of tubers per plant	Plant height (cm)
Maize variety	Selection Precoz	26.8 NS	2.5 NS	272 NS
	La Posta	27.1	2.6	265
Maize fertilization	0 kg N/ha	23.6*	2.2*	263 NS
	90 kg N/ha	30.3	2.9	274
Cropping pattern	1 alternate row	21.1**	2.1**	262 NS
	2 alternate rows	32.8	3.1	275
Cassava stem status	Uncut	30.2*	2.9*	303**
	Cut-back	23.7	2.2	234
S.E. of difference between 2 means		3.0	0.3	7

+: *, ** = significant at 5% and 1% level of probability, respectively; NS = non-significant.

On the other hand, cutting back cassava stem during the second rains reduced tuber yield by about 20% compared to yield of cassava with uncut stems. This result contradicts that of Okoli and Wilson (1981).

Trial 2

The yields of maize grown in the main rainy season (Table 3) were expected and compared favourably with those reported for monocropped maize by Larson and Hanway (1977). The minor rainy season in Ghana is characterized by several periods of drought. This largely accounts for the low yields of maize during that season (Table 3). However, it is noteworthy that some grains were produced during the minor season of 1984. The system should be studied further, especially as both the variety of maize and the application of fertilizer to the maize crop had significant effects on cassava tuber yields (Table 4).

Table 3. Yield of intercropped maize as influenced by maize variety, maize density, cassava density, and maize fertilization+.

Treatment	Treatment type/level	Main season grain yield (Mg/ha)	Minor season grain yield (Mg/ha)
Maize variety	Selecion Precoz	2.3**	0.8 NS
	La Posta	4.0	0.9
Maize density	20,000 plants/ha	2.6**	0.6**
	40,000 plants/ha	3.7	1.1
Cassava density	10,000 plants/ha	3.3 NS	0.9 NS
	20,000 plants/ha	3,1	0.8
Maize fertilization	0 kg N/ha	2.8*	0.5**
	90 kg N/ha	3.5	1.2
S.E. of difference between 2 means		0.29	0.11

+: *, ** = significant at P = 0.05 and P = 0.01, respectively; NS = non-significant.

Table 4. Yield of intercropped cassava as influenced by maize variety, maize density, cassava density, and maize fertilization+.

Treatment	Treatment type/level	Tuber yield of cassava with uncut stems (wet weight) (Mg/ha)	Tuber yield of cassava with cut-back stems (wet weight) (Mg/ha)
Maize variety	Selection Precoz	26.2**	20.2*
	La Posta	20.6	16.3
Maize density	20,000 plants/ha	24.1 NS	19.2 NS
	40,000 plants/ha	22.7	17.3
Cassava density	10,000 plants/ha	24.1 NS	18.7 NS
	20,000 plants/ha	22.7	17.8
Maize fertilization	0 kg N/ha	21.1*	17.2 NS
	90 kg N/ha	25.7	19.3
S.E. of difference between 2 means			

+: *, ** = significant at 0.05 or 0.01 level of probability; NS = non-significant.

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14. Adaptation du Niébé aux Zones Semi-Arides

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RESUME

Des études au champ ont été menées sous conditions pluviales à Bambey, Thilmakha et louga en 1987 et 1988. Elles avaient pour objectif de déterminer la réaction de 8 génotypes de niébé (<u>Vigna unguiculata</u> (L.) Walp.) en zones semi-arides. L´intensité de la sécheresse à Louga était de 0,65 et 0,49 % respectivement en 1987 et 1988. Les génotypes étaient divisés en sensibles, tolérants et résistants à la sécheresse sur la base de l´indice de sensibilité au stress appliqué au rendement et sur leur poids de 100 graines à Louga.

L´adaptation de la variété 58-57 aux zones semi-arides a été ainsi confirmée, les lignées IS86-275, IS86-283 et Mougne ont été identifiées comme tolérantes alors que TVx 3236, IS86-279 et IS86-239 sont sensibles à la sécheresse. Cependant, toutes ces lignées sont sensibles aux sécheresses de fin de cycle comme l´indique l´indice de sensibilité au stress basé sur le poids de 100 graines.

ABSTRACT

Field experiments were conducted under rainfed conditions at Bambey, Thilmakha, Louga, and Ndiol to study the performance of eight genotypes of cowpea in semi-arid zones of Senegal. Drought stress intensity index at Louga was 0.65 and 0.49% in 1987 and 1988, respectively. Tested genotypes were grouped into three categories : drought susceptible, drought tolerant, and drought resistant, based on their sensitivity index to drought stress and how the latter is related to grain yield and 100-kernel weight at Louga.

Based on the relationship between drought stress sensitivity index and grain yield, the adaptation of 58-57 to semi-arid zones was confirmed; lines IS86-275, IS86-283 and Mougne were identified as drought tolerant; and TVx 3236, IS86-275 and IS86-239 were drought susceptible. All these lines were, however, susceptible to the end of season drought, based on relationship between drought stress sensitivity index and 100-kernel weight.

INTRODUCTION

La culture du niébé (Vigna unguiculata (L.) Walp) au Sénégal est pratiquée en zone semi-aride. Cette zone est caractérisée par une saison de pluie qui dure 2 à 3 mois et est soumise à une forte demande évaporative (Dancette, 1979). Cette évaporation est plus élevée à Louga (570 mm) qu'à Bambey (490 mm). Avec un coefficient de végétation globale de 0,76, ceci donne des besoins en eau pour le niébé de 370 mm à Bambey et de 430 mm à Louga. Les moyennes pluviométriques des années sèches (1968-1985) étant de 247 mm à Louga et 476 mm à Bambey, les besoins en eau du niébé sont relativement faciles à satisfaire à Bambey, alors qu'à Louga, la culture devient aléatoire (Dancette, 1984). Des études ont été conduites pour estimer la fréquence de la sécheresse à différents stades de développement du niébé à Louga. Ainsi, les bilans hydriques ont été simulés en utilisant les informations sur la pluviométrie, la demande évaporative, le sol et les caractéristiques de la plante. Ces études ont montré que depuis 1968, les différentes variétés de niébé disponibles ont été soumises à de sérieuses conditions de sécheresse au stade de remplissage des gousses (Hall, 1986).

Le développement de variétés résistantes à la sécheresse était donc devenu une nécessité. Cet objectif a été poursuivi dans le passé par plusieurs autres programmes de sélection, mais les succès ont été très limités (Bruckner et Frohberg, 1987), non seulement à cause du manque de stratégies et de techniques de criblage appropriées (Blum et al., 1981), mais aussi de la non-identification de génotypes qui montrent clairement à des stades de développement précis, des différences de réponse (Hanson et al., 1980). C'est ainsi que des tests de tissus ont été utilisés (Sullivan, 1978), mais à cause de la multiplicité des facteurs de résistance et de leur interaction, ces efforts n'ont rencontré que peu de succès. L'amélioration génétique de la résistance au stress des plantes nécessite l'identification de mécanismes physiologiques significatifs pour ce caractère et leur utilisation comme critère de sélection (Blum et al., 1982).

Puisqu'il n'est pas encore possible de définir physiologiquement la résistance totale à la sécheresse (Blum et al., 1981), et que de simples tests de tissus n'ont pas encore été parfaitement mis au point (Fischer et Mauru, 1978), le rendement en grains et sa stabilité dans des zones à stress hydrique restent le principal critère de sélection dans plusieurs programmes d'amélioration variétale. Des rendements élevés sous stress peuvent résulter de l'esquive ou d'un haut potentiel productif plutôt que de mécanisme de résistance. Un indice de sensibilité à la sécheresse (S) qui donne une mesure de la résistance basée sur un minimum de perte de rendement sous stress comparé à des conditions optimales, a été utilisé pour caractériser la tolérance à la sécheresse de lignées de niébé nouvellement développées.

MATERIELS ET METHODES

Pendant l´hivernage de 1987, 38 nouvelles lignées ont été testées dans 3 essais à Bambey, Thilmakha et Louga, avec comme témoins 3 variétés vulgarisées (Mougne,TVx 3236 et 58-57). Le dispositif utilisé était en blocs complets randomisés à 4 répétitions. La parcelle était constituée de 4 lignes de 5 m de long avec des écartements de 50 cm x 50 cm pour les essais I, II et 50 cm x 25 cm pour l´essai III.

En 1988, un essai regroupant les 5 meilleures lignées des 38 de l´année précédente et les témoins 58-57, Mougne et TVx 3236, Ndiambour et CB5 a été mené à Bambey, Thilmakha et Louga. Des blocs complets randomisés avec "split" et répétés 4 fois ont été utilisés. La parcelle principale était constituée de la variété semée sur 12 lignes de 5 m de long dont 6 aux écartements de 50 cm x 50 cm et les 6 autres à 50 cm x 25 cm. Les semis ont été effectués entre le 19 et 21 Juillet en 1987 et entre le 30 Juillet et le 4 Août en 1988 dans toutes les localités.

Les rendements en grains ont été évalués sur les 2 lignes centrales de chaque parcelle en 1987, et sur les 4 lignes centrales de chaque sous-parcelle en 1988. Le poids de 100 graines a été calculé à partir d´échantillons de 500 graines.

Un indice de sensibilité au stress (S) a été utilisé pour caractériser la relative tolérance à la sécheresse du matériel testé. L´indice a été calculé indépendamment pour chaque essai en utilisant la formule présentée par Fischer et Maurer (1978). S = (1 - YD/YP)/D, où Y/P = rendement moyen (poids 100 graines) sous stress (à Louga), YP = rendement moyen (poids 100 graines) sous conditions favorables (à Bambey), D = intensité de la sécheresse = 1 - (moyenne YD de tous les génotypes/moyenne YP de tous les génotypes).

Cet indice de sensibilité au stress (S) des entrées a été calculé pour chacun des essais avancés I, II, III en 1987, et la moyenne des trois valeurs a été considérée pour les témoins 58-57, Mougne et TVx 3236. Les mêmes procédés de calcul ont été utilisés pour trouver l´intensité de la sécheresse (D) à Thilmakha et Louga en 1987 et pour les rendements des témoins.

RESULTATS ET DISCUSSIONS

Le cumul pluviométrique a été de 354 mm à Bambey en 1987. Ceci est inférieur aux besoins en eau du niébé dans cette zone (370 mm). Les taux de satisfaction moyens ont ainsi varié entre 84% et 91%. A Louga où les besoins sont de 430 mm, le cumul n´a été que de 348 mm, et les taux moyens de satisfaction de 62 à 75% (Diagne, 1988a). Cette variation est fonction de la répartition dans le temps des pluies et du type de variété. Les faibles taux de satisfaction ont été enregistrés par les variétés précoces et à floraison groupée (type Bambey 21), alors que celle à floraison étalée (type 58-57) avec des pointes de demande en eau moins élevées et plus échelonnées dans le temps ont été favorisées (Diagne, 1988a). Les conditions d´alimentation en eau ont donc globalement été plus favorables à Bambey qu´à Louga. En plus dans cette dernière localité, pendant la phase critique de floraison et de remplissage des gousses (entre 35 et 50 jours après semis), les taux de satisfaction ont été aussi faibles que ceux des années sèches 1981, 82, 83 (Dancette, 84). Les totaux pluviométriques en 1988 (635 mm à Bambey et 439 mm à Louga) ont été largement supérieurs à ceux des années sèches 1968-1985. Les besoins en eau ont été relativement bien satisfaits à Bambey (89 à 95 %) et à Louga (83 à 95%), (Diagne, 1988b).

Les rendements les plus élevés ont été obtenus en 1987 et 1988 à Bambey (Tableau 1), ainsi, cette localité a été considérée comme celle où on trouve les meilleures conditions de culture.

Tableau 1. Pluviométrie, rendement moyen et intensité de la sécheresse par localité.

Localité	Pluviométrie (mm)		Rendement (kg/ha)		Intensité du stress (D)	
	1987	1988	1987	1988	1987	1988
Bambey	353,8	635	1400,6	1773.6	-	-
Thilmakha	582,7	430	1002,9	829,5	0,29	0,53
Louga	348	439	480,8	892	0,71	0,50

Par contre, les plus faibles rendements de 1987 ont été enregistrés à Louga. En 1988, ceux de Louga (892 kg/ha) et Thilmakha (829,5 kg/ha) sont comparables. Ceci s´explique par le fait que l´intensité du stress (D) est plus élevée à Louga (0,65) qu´à Thilmakha (0,29) en 1987; alors que, comme le montre le Tableau 1, en 1988, cette intensité a été relativement la même à Louga (0,50) et à Thilmakha (0,53).

Ainsi, Louga a été classée comme une localité à stress avec rendements moyens représentant 34% et 50% respectivement en 1987 et 1988 de ceux de Bambey.

L´indice de sensibilité à la sécheresse (S) a donc été calculée pour chaque lignée. Une variété à sensibilité moyenne ou résistante à la sécheresse a une valeur de S égale à 1. Des valeurs de S inférieures à 1 indiquent une sensibilité moindre ou une plus grande résistance. Quand cette valeur est nulle (S= 0,0), traduisant un maximum de résistance possible, il n´y a pas d´effet de la sécheresse sur le rendement (Hall et Patel, 1985).

L'application de cet indice sur le rendement montre que la variété 58-57 est résistante à la sécheresse, que IS86-275, IS86-283, IS86-247 et Mougne sont moyennement résistantes alors que TVx 3236, IS86-279 et IS86-239 sont sensibles à la sécheresse (Tableau 2). La relative résistance à la sécheresse de 58-57 est conforme aux résultats précédents (Cissé, 1985) et à sa réputation d'être une variété adaptée aux zones semi-arides avec une pluviométrie inférieure à 300 mm (CILSS, 1985).

Tableau 2. Rendement moyen, indice de sensibilité à la sécheresse (S) Bambey et Louga.

Lignées	Rendement (kg/ha) à Bambey			Rendement (kg/ha) à Louga			Indice de sensibilité(S)	
	1987	1988	87-88	1987	1988	87-88	1987	1988
IS 86-275	1526	2150	1838	925	1051	998	0.69	1.02
IS 86-239	1936	2147	2041	600	1011	805	2.03	2.06
IS 86-283	1693	2090	1891	537	1012	777	1.00	1.02
TVx 3236	1574&	1811	1635	437&	594	477	1.09&	1.32
IS 86-279	1523	1728	1626	362	773	568	1.07	1.1
Mougne	1338&	1689	1426	550&	805	614	0.97&	1.04
58-57	1707	1527	1662	654&	1391	838	0.88&	0.18
IS86-247	1486	1477	1481	412	1088	750	1.06	0.58
CB5	-	1659	-	-	392	-	-	1.3
Ndiambour	-	1456	-	-	790	-	-	0.92
Moyenne			1773			892		
C.V. (%)			10			11		
PPDS (5%)			380			312		

& : Moyenne des essais avancés I, II, III.

Il y a eu peu de variations importantes dans la valeur de S d'une année à l'autre; c'est le cas de IS86-247 qui s'explique par le fait que l'hivernage de 1988 a généralement été plus favorable que celui de l'année précédente. Les valeurs de S de différents types de variétés peuvent varier quand elles sont soumises à des sécheresses de différentes intensités, ou de différents stades de développement de la plante, mais ces variations indiquent simplement qu'elles sont mieux adaptées à certains types de sécheresse et conditions du milieu (Hall et Patel, 1985).

L'effet de la sécheresse en fin de cycle, c'est-à-dire de la floraison au stade de remplissage des gousses a été apprécié en appliquant l'indice de sensibilité (S) au poids de 100 graines. Toutes les lignées utilisées sont fortement sensibles à la sécheresse pendant cette période (Tableau 3). Il y a eu des variations importantes sur les valeurs de (S) d'une année à l'autre pour les entrées Mougne, IS86-279, IS86-247. Ceci est dû au fait que l'hivernage 1988 a généralement été plus favorable. Des résultats similaires ont été obtenus par Turk (1979). En imposant des déficits hydriques dans un essai ou l'approvisionnement en eau était contrôlé, la taille des graines diminuait significativement en fonction de l'intensité du stress; des variations annuelles ont été également observées.

Tableau 3. Poids de 100 graines, indice de sensibilité à la sécheresse (S) à Bambey et Louga

Lignées	Poids de 100 graines à Bambey		Poids de 100 graines à Louga		Indice de sensibilité (S)	
	1987	1988	1987	1988	1987	1988
	(g)		(g)			
IS86-275	16,3	16,2	17,3	15,1	0,0	1,13
IS86-239	15,8	16,5	14,6	14,6	1,89	1,9
IS-86-283	23,3	23.0	21,4	21,1	2,04	1,38
TVx3236	12,2+	12,8	11,4+	10,5	1,52+	2,99
IS86-279	17,3	17,4	16,3	16,4	1,44	0,96
Mougne	15.0+	14,4	14,3+	15.0	2,07+	0.0
58-57	13.0+	13,5	11,6+	11,9	4,4+	1,96
IS86-247	16,5	15,7	15,7	16,6	1,21	0.0
CB5	-	20,2	-	18,1	-	1,73
Ndiambour	-	16,6	-	16,8	-	0,00
Moyenne	16,6		15,6			
C.V.	3,9		7,9			
PPDS (5%)	0,7		1,7			

\+ : Valeur moyenne des essais avancés I, II, III.

Si l'on considère le rendement des deux années à Louga, on constate que IS86-275, 58-57, et IS86-239 sont les plus productives dans cette zone sujette au stress, alors que TVx3236 et IS86-279 sont les moins productives (Tableau 1).

CONCLUSION

En utilisant l'indice de sensibilité à la sécheresse appliquée au rendement et la performance sous stress, l'adaptation de la variété 58-57 aux zones à pluviométrie déficitaire a été confirmée. Les nouvelles sélections IS86-275 et IS86-283 issues de croisement avec la variété 58-57 montrent une résistance moyenne à la sécheresse. Elles ne semblent donc pas avoir acquis entièrement les caractères de résistance à la sécheresse de 58-57. Il semble donc nécessaire de procéder à plusieurs croisements (back-cross) avec le parent résistant pour transférer son caractère "adaptation" à la sécheresse à ses descendants. Ceci confirme ainsi la nature quantitative de ce caractère (Quizenberry, 1982).

La bonne performance de IS86-239 à Louga semble être dûe à un potentiel productif élevé plutôt qu'à une résistance à la sécheresse. Sojka *et al*. (1981) ont observé chez le blé que des variétés ayant de haut rendement sous conditions favorables peuvent également avoir une bonne performance sous stress sans que ce soit dû à des mécanismes de résistance. Les deux critères utilisés ont montré que TVx3236 et IS86-279 sont sensibles à la sécheresse.

Toutes les variétés mises en essais sont sensibles aux sécheresses de fin de cycle. Turk (1979) a également montré qu'en plus de la diminution de la taille des graines, la sécheresse à ce stade provoque également une réduction considérable du nombre de gousses par m2. Ce dernier caractère a souvent été trouvé comme étant fortement corrélé au rendement du niébé (Imrie et Buttler, 1983, Kahn et Stoffela, 1985). Il semble donc nécessaire d'améliorer la résistance à la sécheresse pendant la floraison et le remplissage des gousses. L'indice de sensibilité à la sécheresse (S) peut constituer un outil considérable pour l'identification de génotypes résistants puisque la sélection basée sur des paramètres physiologiques avec des tests de tissus simples n'a eu qu'un succès très limité.

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15. Effect of Plant Density on Yield and Yield Components of Hybrid Maize in the Northern Guinea Savanna Zone of Nigeria

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ABSTRACT

Three maize hybrids (8321-21, 8321-18 and 8322-13) and an open pollinated check (TZSR) were evaluated at four plant densities (50,000 to 125,000 plants per ha) in 1987 and 1988 wet seasons at Samaru. The results showed that in 1988 the hybrid, 8321-21, significantly outyielded 8322-13 and the check (TZSR) by 55.5 and 68.3%, respectively. By contrast, in 1987 the grain yields of the cultivars were not significantly different from each other. In both years, the effect of various plant densities on grain yields were not significant. It appears that the current recommendation of 50 thousand plants per ha for open pollinated maize is also suitable for the three hybrids evaluated in the study.

Although the current recommendation of plant density (50,000 plants/ha) appears to be adequate for hybrid maize grain production, more needs to be done on plant arrangement (narrower rows) to improve on the rectangularity of the plants and for seed production.

RESUME

Trois hybrides de maïs (8321-21, 8321-18 et 8322-13) et un témoin à pollinisation libre (TZSR) ont été évalués à quatre densités (50000 à 125000 plantes par ha) au cours des saisons humides de 1987 et 1988 à Samaru. Les résultats ont montré qu´en 1988, l´hybride 8321-21 a nettement surpassé en rendement 8322-13 et le témoin (TZSR) de 55,5 et 68,3 % respectivement. Par contre, en 1987 les rendements en grains des cultivars ne présentaient pas de différence significative l´un de l´autre. Au cours des deux années, l´effet des différences de densités sur les rendements en grains n´était pas important. Il est apparu que la recommandation de 50000 plantes par hectare pour le maïs à pollinisation libre convenaient également aux trois hybrides évalués au cours de l´étude.

Quoique la recommandation actuelle à propos de la densité de (50000 plantes/ha) apparaisse appropriée pour la production du maïs hybride, beaucoup reste à faire au niveau de l´arrangement de la plante (des lignes plus serrées) pour la poursuite de l´amélioration de la rectangularité des plantes et pour la production des semences.

INTRODUCTION

Maize has recently become a very important cash crop in the Guinea savanna of Nigeria. A lot of work has been done in Nigeria with open pollinated varieties for which a plant density of 50 thousand plants/ha has been recommended (Ologunde and Egharevba, 1984). However, significantly higher yields at higher plant densities (70 to 100 thousand plants/ha) have been reported by workers in Kenya (Nadar, 1984) and India (Gurkirpal and Tajbakhsh, 1986), while in Nigeria, Kayode and Agboola (1981) reported positive response of open pollinated maize to spacing in three out of eight sites.

The introduction of hybrid maize with higher potential yield than open pollinated maize required plant population studies with the hybrids. The present study was done to determine the optimum plant density for maize hybrid grain production.

MATERIALS AND METHODS

Three maize hybrids (8321-21, 8321-18 and 8322-13) and an open pollinated check (TZSR) were evaluated at four plant densities, namely 50,000 (75 x 27 cm), 75,000 (75 x 18 cm), 100,000 (50 x 20 cm) and 125,000 (50 x 16 cm) plants ha^{-1} in 1987 and 1988 wet seasons on the Institute for Agricultural Research Farm at Samaru (Zaria) Nigeria in the northern Guinea savannaz zone. The experimental sites are loamy sand with good drainage and 0.03% total nitrogen. This trial was conducted under high soil fertility by applying N at 180 kg/ha and P and K at 60 kg/ha each. One half of N was applied at planting, while the other half was applied at 6 weeks after sowing (WAS); P and K were applied during land preparation. The trial was laid out in a randomised complete block design with three replications. Gross plot size was 30 m^2, the net plot being 15 m^2. The trial was sown on 30 and 24 June in 1987 and 1988, respectively. The seedlings were thinned to one plant per hill at 3 WAS. The plots were kept weed-free until hard dough stage. Observations taken per plot included grain yield, shoot height, number of days to 50% silking, 1000 grain weight, threshing percentage, cob length, kernel depth, and number of lodged plants.

RESULTS

Grain yield

A combined analysis of variance over years, hybrids, and plant density revealed that maize grain yields were significantly higher in 1988 than in 1987 (Table 1). However, hybrids did not yield significantly higher than the open pollinated variety, although 8321-21 and 8321-18 outyielded the check by 35.7%. The effect of plant density on grain yield was also not significant but 50,000 and 75,000 plants ha^{-1} recorded higher yields than 100,000 and 125,000 plants ha^{-1} (Table 1).

Table 1. Combined analysis of hybrid maize grain yield 1987/1988 at Samaru.

	Grain yield (t/ha)
Year	
1987	3.1
1988	3.9
LSD (P = 0.05)	0.7
Maize hybrid/variety	
8321-21	3.8
8321-18	3.8
8322-13	3.6
TZSR (Check)	2.8
LSD (P = 0.05)	NS
Plant density (000 ha^{-1})	
50	3.6
75	3.7
100	3.4
125	3.4
LSD (P = 0.05)	NS

In 1987, grain yields of the hybrids were not significantly different from each other; however both 8322-13 and 8321-18 yielded more than 8321-21. By contrast, in 1988, 8321-21 not only gave the highest yield but it also significantly outyielded both 8322-13 and the open pollinated check (Table 2).

Table 2. Interaction between year and hybrids on maize grain yield at Samaru in 1987 and 1988.

Maize hybrid or variety	Maize grain yields (t/ha) in: 1987	1988
8321-21	2.5	5.2
8321-18	3.6	4.1
8322-13	3.9	3.4
TZSR	2.5	3.1
LSD (P = 0.05)	1.5	

Compared to the check (open pollinated) variety, hybrids had no significant effect on shoot height, threshing percentage, cob length, kernel depth, and number of lodged plants (Table 3). Similarly, in both years, plant density had no significant effect on shoot height, number of days to silking, threshing percentage, kernel depth, and number of lodged plants per plot.

Table 3. Effect of plant density on hybrid maize performance at Samaru in 1987 and 1988 seasons.

Treatment	Grain yield (t/ha)		Shoot height (cm)		No. of days to silking		Threshing %	
	1987	1988	1987	1988	1987	1988	1987	1988
Hybrid								
8321-21	2.5	5.2	203.8	190.7	57.0	62.0	79.0	79.2
8321-18	3.6	4.1	209.8	204.1	58.0	62.0	75.5	77.0
8322-13	3.9	3.4	216.1	200.0	57.0	54.0	78.8	75.5
TZSR (Check)	3.0	3.1	218.8	201.7	57.0	64.0	66.9	73.6
LSD (P = 0.05)	NS	0.9	NS	NS	NS	3.1	NS	NS
Plant density (000/ha)								
50	3.6	3.6	219.5	192.5	57.0	61.0	78.7	78.0
75	3.6	4.3	209.2	204.8	57.0	60.0	76.3	76.8
100	2.6	4.2	212.5	204.8	57.0	59.0	75.3	72.9
125	3.2	3.6	207.3	194.4	58.0	61.0	69.9	77.6
LSD (P = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS

Interactions

The only significant interaction was that between year and hybrid. With the exception of 8322-18, hybrids performed better in 1988 than in 1987. The highest yield was recorded by 8321-21 in 1988 season while the poorest yield was recorded by TZSR (check) in 1987 (Table 2).

Correlations

Maize grain yield was positively and significantly correlated with threshing percentage, number of days to 50% silking, shoot height, cob length, kernel depth, and 1000-grain weight (Table 4).

Table 4. Coefficients of correlation (r) between various growth and yield components of hybrid maize in 1987 and 1988 seasons.

	Grain yield	Threshing %	No. of days to silking	Shoot height	Cob length	Kernel depth	1000 grain wt.	No.of lodged plants
Grain yield	1.0							
Threshing %	0.31**	1.0						
No. of days to silking	0.24*	0.19	1.0					
Shoot height	0.45**	0.14	-0.04	1.0				
Cob length	0.42**	0.33	0.28*	0.34**	1.0			
Kernel depth	0.36**	0.62**	0.15	0.20	0.62*	1.0		
1000 grain wt.	0.64**	0.53**	0.33	0.47	0.73**	0.47**	1.0	
No. lodged plants	-0.17	-0.05	-0.06	-0.12	-0.08	-0.08	0.12	1.0

DISCUSSION

The 1988 wet season was a more favourable season for maize production than that of 1987, probably because of a better distribution of rainfall in 1988. Hybrids 8321-21 and 8321-18 out-yielded the open pollinated check variety by about of 35.7%.

Although the effect of plant density on grain yield was not significant, 75 thousand plants/ha gave the highest yields. These findings agree with those of Nadar (1984) and Zaman (1987) but contradict those of Gurkirpal and Tajbakhsh (1986). The lower grain yields obtained at the highest plant density (125 thousand plants/ha) in the present study was probably related to competition by over-crowded plants; it could also be attributable to excessive shading of the lower leaves which, with suboptimal photosynthetic rates, would become virtually parasitic on the upper leaves as suggested by Army and Greer (1967).

CONCLUSION

Two maize hybrids (8321-21 and 8321-18) performed well in the northern Guinea savanna zone of Nigeria at densities of 50 to 75 thousand plants ha^{-1}.

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16. Effect of Planting Depth and Ridging on Maize Germination and Grain Yield at Kamboinse, Burkina Faso.

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ABSTRACT

The effects of shallow (3-5 cm) and deep (8-10 cm) planting on germination, grain yield, and yield components of several maize varieties were evaluated under a flat seedbed and simple ridging in a sandy loam soil (hyperthermic, oxic Plinthustalf) from 1979 to 1981. The experiment was over-planted (three seeds/hill) and thinned to one plant/hill.

There were no significant differences in grain yield and yield components between shallow and deep planting for varieties Jaune Flint de Saria, TZE-3, TZE-4, local Koudougou, and local Kamboinse; the only exception was that in 1979, grain yield of local Kamboinse was significanntly decreased by deep planting. Deep planting also significantly reduced germination in the 3 years. There were no significant differences in field germination, grain yield and yield components between planting on the flat and planting on the flank of simple ridges.

RESUME

Les effets du semis superficiel (3.5 cm) et profond (8-20 cm) sur la germination, le rendement en grains, et les composantes de rendement de plusieurs variétés de maîs ont été évalués au niveau des semis à plat et en simple billonnage dans un terrain sablonneux (hyperthermic, oxic Plinthustalf) de 1979 à 1981. L´essai a été semé avec un nombre exagéré de graines par poquet (trois graines/poquet) et réduit par la suite à une graine par poquet.

L´on ne notait aucune différence significative de rendement en grains et de composantes de rendements entre les semis superficiels et ceux profonds pour les variétés : Jaune Flint de Saria, TZE-3, TZE-4, local Koudougou, et Local Kamboinsé, la seule exception vient du fait que en 1979, le rendement en grains du local Kamboinsé s´est réduit de façon significative suite au semis en profondeur. Le semis en profondeur a également diminué de façon notable la germination au cours des 3 années. Il ne se présentait au champ aucune différence au niveau de la germination, du rendement en grains et des composantes de rendement entre le semis superficiel et semis sur le flanc des billons simples.

INTRODUCTION

Planting depth affects the ability of maize to emerge above the soil surface, depending on the elongation characteristics of the mesocotyl and coleoptile, soil moisture and soil temperature; under typical conditions in the U.S. Corn Belt the ideal depth is 5 cm (Aldrich et al., 1975). In temperate zones, low soil temperatures can be a limiting factor at planting time, while in lowland tropics high temperatures could be a matter of concern. Field experiments, however, provided little support for the hypothesis that, under Ibadan (Nigeria) conditions, temperatures in unmulched soil are sufficiently high to restrict grain yield in maize (Harrison-Murray and Lal, 1979). Badhoria et al. (1983) reported significantly higher emergence counts and greater emergence force for shallow (2 cm depth) planted than for deeper planted crops. Sanchez and Carballo (1983) compared three cultivars at planting depths of 4, 8 and 12 cm and found that percentage germination, radicle length, dry matter content, plant height, days to physiological maturity, and grain yield were not affected by sowing depth. An evaluation of 29 maize cultivars, sown at 3, 6 and 9 cm depth and kept at 25-30°C, showed that mesocotyl length varied with cultivar and responded to sowing depth more than coleoptile elongation; but, dwarf cultivars did not have shorter mesocotyls than other cultivars (Zheng and Wang, 1983). Elsahookie and Wassom (1984) compared 17 commercial hybrids and experimental crosses at four depths (5-30 cm) and found that grain yield was generally higher from plants established by deep sowing.

According to Jones and Wild (1975), mounding and ridging under low intensity farming are intended primarily to give an adequate depth of well drained soil for crop rooting. In their review of the effects of flat and ridge cultivation on water run off and erosion in West Africa, they concluded that the evidence is not conclusive and pointed out that field dimensions are critical for these evaluations, although ridges running down the slope always encourage erosion. According to Kowal and Kassam (1978), contour ridging may serve, in the absence of other soil conservation methods, to avoid large scale soil erosion. Flat cultivation is preferred where graded terraces, or other major conservation works, are present.

Dagg and Macarthey (1968), using large plots (0.8 ha), found no significant differences in maize grain yields between flat and ridge plantings in black, red and ash soils in Tanzania. According to Nicou (1981), for maize culture in West Africa, ridging before planting does not seem to be superior to other soil preparation methods; in fact, in mechanized agriculture, flat planting should be preferred over planting on ridges for higher tractor use efficency. However, higher maize grain yields were obtained with ridges than with flat planting in a trial conducted at Nsukka, Nigeria (Okigbo, 1972). By contrast, at Ibadan (Nigeria), Lal (1973) reported that maize yields at all planting dates were lowest for heaps and ridges and highest for plantings on the flat or in furrows.

Farmers in Central Burkina Faso generally plant maize after sorghum and millet, when the rains are better established and after a heavy (> 20 mm) rain. Because of the rapid drying of the topsoil and the risk of crust formation, planting depth should be such that soil moisture conditions around the seed are appropriate while favouring rapid seedling emergence. Little information is available on the best agronomic practices for maize production in the Sudan savanna zone of West Africa. This study evaluated the effects of shallow and deep planting, flat seedbed, and ridging on the germination, grain yield, and other plant characteristics of several maize varieties.

MATERIALS AND METHODS

The study was conducted at the Kamboinse Research Station of the Agricultural Studies and Research Institute (INERA) of Burkina Faso, located 12°28´N and 1°33´W at an elevation of 300 m. The soil is a sandy loam in the middle slope of a toposequence (0.7% slope), classified as hyperthermic, oxic Plinthustalf (USDA), plinthic Luvisol (FAO), or "Sol Ferrugineux Tropical lessivé hydromorphe à pseudoglay" (CPCS) (Smaling, 1985). Equilibrium infiltration rate was in the order of 5 cm/hour. The land had graded contour terraces separating strips 40-50 m wide.

Mean annual rainfall is 838 mm in one rainy season and potential evapotranspiration (PE) is 1805 mm (Virmani et al., 1980). Mean monthly rainfall, air temperatures, dependable precipitation (precipitation that can be expected in 3 out of 4 years) and PE are given in Table 1.

The experiment had a factorial combination of two seedbeds, three varieties and two planting depths as main plots, subplots and sub-subplots, respectively, in a split-splot plot arrangement with 4 replications. The seedbeds (S) were: planting on the flat (S1), i.e. traditional maize planting system in the area (although farmers normally grow maize only in compound plots); and planting on the flank of simple (non-tied) ridges (S2). The varieties were local Kamboinse (LKa), Jaune Flint de Saria (JFS), TZE-4, local Koudougou (LKo), and TZE-3 which have, respectively, 92, 90, 94, 82, and 92 days to physiological maturity. LKa was grown in all three years, JFS and TZE-4 only in 1989, and LKo and TZE-3 in 1980 and 1981. The planting depths were 3-5 cm (shallow), and 8-10 cm (deep).

Plots consisted of 5 rows, 0.75 m apart and 5 m long; main plots (S) were 18 m long. Density was 66,700 plants/ha in 1979 and 59,300 plants/ha in 1980 and 1981. The trial was planted with three seeds/hill while seedlings were thinned to one per hill at 16-17 days after planting (DAP). Grain yield was estimated from the three central rows.

Table 1. Longterm mean monthly rainfall (P), dependable precipitation (DP) potential evapotranspiration (PE), mean maximum (Ma) and minimum (Mi) air temperatures, monthly rainfall from 1979 to 1981, and rainfall from 10 days before planting (DBP) to harvest at Kamboinse, Burkina Faso.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual	10 DBP to harvest
P+(mm)	0	5	3	20	63	125	177	246	156	38	1	2	838	-
DP+(mm)	0	0	1	6	39	92	141	196	118	10	0	0	-	-
PE+(mm)	143	152	189	195	190	151	135	113	121	149	134	133	1805	-
Ma++(°C)	35.1	35.5	39.2	40.4	38.9	33.8	31.8	31.1	32.6	36.4	35.6	31.7	35.2	-
Mi++(°C)	14.7	16.9	19.9	25.2	27.3	23.8	23.2	22.2	22.7	23.2	18.7	13.0	20.9	-
Rainfall (mm)														
1979	0	0	2	0	83	160	146	212	166	18	4	0	791	537
1980	0	0	0	15	62	160	255	217	56	18	0	0	783	528
1981	0	0	0	30	56	78	180	170	173	3	0	0	690	528

+: Virmani *et al*. (1980); ++: data for 1980.

Compound fertilizer (14 N, 23 P_2O_5; 14 K_2O, 6 S, 1 B_2O_3) was broadcast before tractor plowing and harrowing or before ridging, at the rates of 400, 100 and 200 kg/ha in years 1, 2, and 3, respectively. All plots were tractor ridged and ridges were subsequently levelled by hand in S1 plots before planting. The experiment was conducted on the same land but all treatments were randomized each year. Planting was on July 16, 11 and 9, for years 1, 2, and 3, respectively. Primextra was applied (5 l/ha) at 0-3 DAP. Urea was side-dressed and incorporated in two equal split applications at about 3 and 5 weeks after planting (WAP), but there was only one application (at 26 DAP) in 1981. Plots were weeded and hand-hoe cultivated twice at about 2 and 4-5 WAP. Furadan 5G was applied to the soil (20 kg/ha) in 1980 at 10 and 19 DAP.

RESULTS AND DISCUSSION

Seed germination

Potential evapotranspiration from 3 days before planting to 12 DAP was about 65 mm while actual rainfall for the same period was 75, 194, and 47 mm for 1979, 1980, and 1981, respectively; the rainfall was relatively well distributed.

Average seed germination in the field was 80.0, 78.1 and 80.0% in 1979, 1980, 1981, respectively (Tables 2-4). Field germination percentage was significantly ($P = 0.05$) decreased by deep planting in the three years; in addition, visual observations indicated faster seedling emergence in shallow planted plots.

The only significant ($P = 0.05$) interactions were the variety x planting depth interaction in 1980 and 1981 and the seedbed x planting depth interaction in 1981. Percentage germination under laboratory conditions of local Kamboinse, local Koudougou, and TZE-3 was 95, 88 and 99% in 1980, and 83, 96 and 96% in 1981, respectively. As Table 5 shows, the decrease in field germination percentage associated with deep planting was more pronounced for those varieties with lower germination percentages (below 90%).

Table 2. Effect of seedbed, variety, and planting depth on maize grain yield and other crop variables in 1979. Underlined means are significantly different (P = 0.05) from one mean (---) or from the other two means (____)

	Seedbed		Variety+			Sowing depth(cm)			
Variable	Flat	Ridges	V1	V2	V3	3-5	8-10	Mean	%
Grain yield (Mg/ha)	3.75	3.85	3.69	3.86	3.84	3.94	3.65	3.80	10.5
Grain No. (Kernels/m²)	1980	1960	2020	1970	1910	2020	1910	1970	11.5
Kernel weight (mg/kernel)	189	197	183	196	200	195	191	193	6.4
Ears/plant	0.95	0.98	0.87	1.02	1.01	1.00	0.94	0.97	9.2
Germination (%), 14DAP++	77.3	82.6	82.1	81.0	76.8	85.3	74.6	80.0	25.5
Plant height (cm)	218	218	224	215	214	218	218	218	1.7
Days to 50% silking	49.6	50.1	50.8	48.5	50.2	49.3	50.3	49.8	2.3
Shelling (%), dry	83.0	82.8	84.4	83.9	80.4	82.9	82.9	82.9	0.8
Plants/m², at harvest	6.42	6.40	6.32	6.41	6.50	6.50	6.32	6.41	3.1
Lodging (%), 80 DAP	13.0	17.8	26.2	13.5	6.7	15.1	15.6	15.3	30.9

+: V1 = local Koudougou, V2 = Jaune Flint de Saria, V3 = TZE-4.
++: DAP = days after planting.

Table 3. Effect of seedbed, variety and planting depth on maize grain yield and other crop variables, 1980. Underlined means are significantly different (P = 0.05) from one mean (---) or from the other two means (___).

Variable	Seedbed		Variety+			Sowing depth(cm)		Mean	CV%
	Flat	Ridges	V1	V2	V3	3-5	8-10		
Grain yield (Mg/ha)	3.04	2.88	2.82	3.17	2.89	2.99	2.92	2.96	12.1
Grain no. (kernels/m^2)	2080	2080	2130	2070	2040	2080	2080	2080	10.2
Kernel weight (mg/kernel)	147	138	132	153	141	143	141	142	10.2
Ears/plant	1.01	1.00	0.98	1.04	1.01	1.00	1.01	1.01	3.6
Germination(%), 13DAP++	74.3	82.0	83.5	70.6	80.3	86.9	69.4	78.1	11.4
Plant height (cm)	249	241	270	227	238	248	242	245	5.1
Days to 50% silking	48.1	48.1	50.1	44.8	49.4	48.2	48.0	48.1	3.2
Plants/m^2, at harvest	5.64	5.75	5.81	5.44	5.85	5.80	5.59	5.70	4.3
Root lodging (arcsine), 76 DAP	17.5	19.8	20.9	14.5	20.5	19.4	18.0	18.7	39.0
Stem lodging (arcsine), 76 DAP	18.8	19.4	23.2	15.7	18.4	17.8	20.4	19.1	28.2

+: V1 = local Kamboinse, V2 = local Koudougou, V3 = TZE-3.

++: DAP = days after planting.

Table 4. Effect of seedbed, variety and planting depth on maize grain yield and other crop variables, 1981. Underlined means are significantly different (P = 0.05) from one mean (---) or from the other two means (___).

Variable	Seedbed		Variety+			Sowing depth(cm)		Mean	CV%
	Flat	Ridges	V1	V2	V3	3-5	8-10		
Grain yield (Mg/ha)	2.96	3.14	2.74	3.11	3.30	3.03	3.07	3.05	13.4
Grains no. (kernels/m^2)	1860	1950	1710	1900	2110	1900	1920	1910	13.8
Kernel weight (mg/kernel)	158	159	158	164	154	159	158	159	6.9
Ears/plant	0.94	0.97	0.89	0.98	1.00	0.96	0.95	0.96	7.0
Germination(%) 12 DAP++	77.9	82.0	64.3	86.2	89.4	85.2	74.8	80.0	5.1
Plant height (cm)	232	236	256	210	236	235	233	234	4.2
Days to 50% silking	48.5	47.4	51.4	43.4	49.2	47.9	48.1	48.0	2.1
Plants/m^2, at harvest	5.91	5.77	5.77	5.83	5.91	5.81	5.87	5.84	2.2
Lodging (arcsine),86 DAP	42.9	51.8	47.2	49.8	45.1	47.9	46.8	47.4	15.5

+: V1 = local Kamboinse, V2 : local Koudougou, V3 = TZE-3;
++: DAP = days after planting.

Table 5. Field germination (%) of three varieties as affected by planting depth at Kamboinse.

Planting depth (cm)	Year	Variety Local Kamboinse	 Local Koudougou	 TZE-3	LSD (P = 0.05)
3-5	1980	89.8	85.7	85.1	9.4
	1981	72.0	90.7	92.8	4.5
8-10	1980	77.2	55.6	75.5	9.4
	1981	56.6	81.7	86.1	4.5

Plant establishment

Plant densities at harvest were significantly (P = 0.05) different between planting depths in 1979 and 1980; among varieties in 1980 and 1981; and between seedbeds in 1981. Average differences in plant density among factor means were, however, very small in all cases (≤ 3,700 plants/ha) and of no practical relevance on grain yields. Rodriguez (1980) reported optimum densities for maximum grain yields of 60,000 to 80,000 plants/ha for early maturing varieties (about 50 days to 50% silking), and showed that Duncan's (1958) relationship between the logarithm of the yield per plant and plant density was applicable in the Sudan savanna and northern Guinea savanna zones of Burkina Faso. Carmer and Jackobs (1965) demonstrated that, if Duncan's model is appropriate, a change of 10% in the number of plants around the optimum density will cause a decrease of less than 1% of the maximum grain yield, whereas at 60% of the optimum density, grain yield will be about 90% of the maximum. In spite of the differences in percentage germination under field conditions reported in the present study, comparable densities were obtained under all treatments as a result of overplanting (3 seeds/hill) and thinning to one plant/hill. The lowest density was that of local Koudougou in 1980 (54,400 plants/ha).

Grain yields

In 1979, maize grain yields were significantly (P = 0.05) decreased by deep planting compared to shallow planting. There were also significant depth x seedbed and depth x variety interactions. The decrease in yield with deep planting was significant only with the local Kamboinse variety grown on ridges (Fig. 1) and was associated with a greater number of days to 50% silking and a smaller number of ears per plant, but not with a smaller plant density. In 1980 and 1981, however, deep planting had no significant effects on grain yields, days to 50% silking, and number of ears per plant. It appears that deep planting (8-10 cm) has no significant effect on grain yields provided that good plant stands are obtained by overplanting.

There were no significant differences in grain yields among varieties or between flat and ridge planting in any of the three years. Although there was no grain yield response to simple (open) ridges, experiments in adjacent plots (using similar fertilizer levels, planting dates and plant densities, etc) showed significant grain yield increases of 0.68, 0.86, and 0.78 Mg/ha in 1979, 1980, and 1981 respectively, due to tied ridges compared to flat, or simple ridge, planting (M. Rodriguez, unpublished data).

Other crop variables

There were no significant differences in grain number, kernel weight, ears per plant and plant height between planting depths or between seedbeds in 1979, 1980, and 1981. Deep planting had no effect on root, stem, or total lodging, but root lodging was significantly higher on ridges than on flat planting in 1980.

There were significant differences among varieties for some other variables. Perhaps the most interesting of these was the havest index (HI) which was estimated only in 1981 by taking 10 plants (under flat seedbed and shallow planting) from each variety. Local Koudougou, the earliest of the varieties tested, had a HI of 49.3% while comparable figures for local Kamboinse and TZE-3 were 40.2 and 36.8%, respectively.

CONCLUSION

Deep planting (8-10 cm) significantly decreased seed germination percentage under field conditions by an average of 12.9% per year, the effect being more marked when seed germinability under laboratory conditions was also relatively low (i.e., < 90%).

If maize is over-planted and thinned, good and similar plant densities could be obtained under both shallow (3-5 cm) and deep sowing; with only one exception, similar grain yields were also obtained under both planting-depth regimes.

If planting is such that thinning is not intended (either there is no over-planting, or the latter is done only to compensate for sub-optimum seed germinability), deep planting would result in lower plant stand. However, the effect of lower plant establishment on grain yields would be negligible, provided final plant density was close to the optimum density for maximum grain yield. In contrast, significant reduction in grain yield associated with low plant establisment occurs when seed germinability is low, or when other factors, e.g. pest damage, drastically reduce seedling establishment.

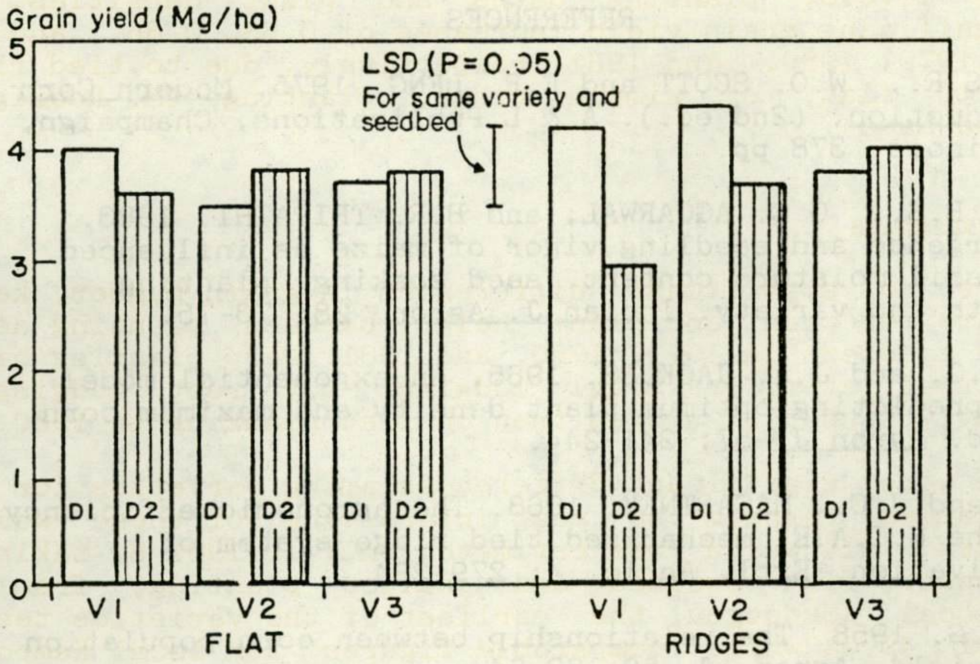

Fig.1 Maize grain yield as affected by seedbed, variety and planting depth, 1979. V1 = Local Kamboinsé, V2 = JFS, V3 = TZE-4, D1 = 3-5 cm, D2 = 8-10 cm.

No significant differences were found between planting on the flat and planting on simple (open) ridges in terms of seed germinability, grain yields, and yield components.

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17. Effects of Nitrogen Rate and Time of Application on Yield and Yield Components of Maize in the Northern Guinea Savanna Zone of Nigeria.

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ABSTRACT

Two open pollinated maize cultivars (TZSR and Samaru 84 TZESR-W) and a hybrid (8321-21) were tested at four nitrogen rates (90, 120, 150 and 180 kg N/ha) given either as a single dose at planting or twice as a split application in 1987 and 1988. Observations were taken on yield and yield components of maize.

Although there were no significant differences in grain yield among the three maize cultivars, Samaru 84 TZESR-W out-yielded TZSR and 8321-21 by 25-32% in 1987, while 8321-21 out-yielded TZSR and Samaru 84 TZESR-W by 9% in 1988. The effects of cultivars on several yield components were not significant; however Samaru 84 TZESR-W reached 50% silking about eight days earlier than TZSR and 8321-21. The rates of nitrogen had no significant effects on maize grain yields and yield components. Similarly, the time of nitrogen application did not significantly affect grain yield and yield components of maize.

RESUME

Deux cultivars de maïs à pollinisation libre (TZSR et Samaru 84 TZESR-W) et un hybride (8321-21) ont été expérimentés à quatre doses différentes d´engrais azoté (90, 120, 150 et 180 kg N/ha) soit en application unique au semis soit en deux applications séparées en 1987 et 1988. Les observations ont été faites sur le rendement et les composantes de rendement du maïs.

Quoiqu´il n´y ait pas de différence nettes de rendement en grains entre les trois cultivars de maïs, Samaru 84 TZESR-W a surpassé en rendement TZSR et 8321-21 de 25-32 % en 1987, alors que 8321-21 dépassait en rendement TZSR et Samaru 84 TZESR-W de 9 % en 1988. Les effets des cultivars sur plusieurs composantes de rendement n´étaient pas considérables ; toutefois, Samaru 84 TZESR-W a atteint 50 % de formation de soie environ huit jours plus tôt que TZSR et 8321-21. Les doses d´engrais azoté n´ont pas d´effet important sur les rendements en grains du maïs et sur les composantes de rendement. De même, le temps d´application de l´engrais azoté n´affecte pas de façon significative le rendement en grains et les composantes de rendement du maïs.

INTRODUCTION

Maize cultivation has been on the increase in the last few years in the savanna zones of Nigeria. This was subsequent to the report by Kassam et al. (1975) that in several respects maize performed much better in the savanna zone than in the forest zone; later, several agricultural development projects convincingly demonstrated that higher maize grain yields are attainable in the savanna than in the forest zone.

The local sourcing of raw materials by agro-allied industries in Nigeria stimulated large scale maize production. Consequently, maize is currently produced on a sizeable proportion of land hitherto used in the production of sorghum and millet. The increased maize production has resulted in increased application of fertilizers, especially nitrogen fertilizer. The current recommendation is split application (one half at planting and the other at 6 weeks after sowing) of 120 kg N per ha (Ologunde and Egharevba, 1984). However, significant grain yield responses have been reported at 150 kg N/ha in both the rain forest zone (Lucas, 1986) and the savanna zone (Amorowa et al., 1987).

The study reported in this paper was done to determine the effects of the rate and time of application of N on maize yield and yield components.

MATERIALS AND METHODS

Two open pollinated maize varieties (TZSR and Samaru 84 TZESR-W) and one hybrid (8321-21) were sown on 23 June, 1987 and 20 June, 1988 at the Institute for Agricultural Research Farm at Samaru (Zaria), Nigeria, in the northern Guinea savanna zone. The soil is loamy sand with good drainage, the N content being 0.05%. The four levels of N (90, 120, 150, and 180 kg ha^{-1}) studied were supplied as calcium ammonium nitrate. Each rate was given either as a single dose at planting or as a split application, one half at planting and the other at 6 weeks after sowing (WAS). The trial was planted in a randomized complete block design with three replicates. Basal application of phosphorus (60 kg P_2O_5 per ha) and potassium (60 kg K_2O ha^{-1}) were given during land preparation. Inter- and intra-row spacings were 0.75 and 0.27 m, respectively; the gross plot was 27 m^2, while the net plot was 18 m^2.

Plants were thinned to one plant per hill at 3 WAS. The plots were kept weed-free until hard dough stage. Observations taken included grain yield, shoot height, number of days to 50% silking, 1000-grain weight, threshing percentage, cob length, kernel depth, and number of lodged plants.

RESULTS

Grain yield

The effect of cultivars on grain yields in both 1987 and 1988 was not significant (Table 1). However, in 1987, Samaru 84 TZESR-W outyielded 8321-21 and TZSR by 25.0 and 31.6%, respectively; in 1988, hybrid 8321-21 yielded 9% more than the open pollinated varieties.

Although time of N application had no significant effect on maize grain yield, split application gave 14-15% higher grain yields in both years. Similarly, the effect of rate of N application was both non-significant and inconsistent.

Growth characters

In both years, TZSR was significantly taller than both 8321-21 and Samaru 84 TZESR-W, but the differences between these two cultivars, though statistically significant, were inconsistent. By contrast, time and rate of N application did not significantly affect shoot height in both years. In both 1987 and 1988, Samaru 84 TZESR-W (an early maturing cultivar) silked significantly earlier than the other two cultivars. By contrast, the rate and time of N application had no significant effect on the number of days to 50 % silking (Table 1).

Table 1. Effect of rate and time of N application on maize grain yield, shoot height, number of days to 50% silking, and threshing percentage, in 1987 and 1988 at Samaru.

Treatment	Grain yield (t/ha)		Shoot height (cm)		No. of days to 50% silking		Threshing percentage	
	1987	1988	1987	1988	1987	1988	1987	1988
Cultivar								
TZSR	2.0	2.2	183.3	221.6	59.0	64.0	80.1	76.5
Samaru 84								
TZESR-W	2.5	2.2	187.3	156.0	53.0	52.0	76.0	80.9
8321-21	1.9	2.4	154.2	175.4	63.0	63.0	78.2	78.1
LSD (P = 0.05)	NS	NS	13.5	12.8	2.2	0.8	NS	NS
Time of N application								
All N at planting	2.0	2.1	173.4	181.4	59.0	60.0	78.8	77.6
1/2 N at planting & 1/2 at 6 WAS	2.3	2.4	176.4	187.3	58.0	60.0	77.4	79.5
LSD (P = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS
N rate (kg ha^{-1})								
90	1.7	2.2	173.0	189.2	58.0	50.0	78.1	78.7
120	2.0	2.5	163.7	183.1	59.0	59.0	77.2	78.4
150	2.5	2.2	179.6	183.4	58.0	60.0	76.6	77.2
180	2.4	2.3	183.4	181.7	58.0	60.0	80.5	79.8
LSD (P = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS

Yield components

The effects of maize cultivar, and of time and rate of N application on threshing percentage in both seasons were not significant (Table 1). Although in each year, the effect of maize cultivar on 1000-grain weight was significant, no consistent trend was established for the two years. Thus, in 1987 the 1000-grain weight of Samaru 84 TZESR-W was significantly higher than that of 8321-21 while the reverse situation was obtained in 1988. In both years the effects of cultivar on cob length, kernel depth, and number of lodged plants were significant (Table 2).

Table 2. Effect of rate and time of N application on 1000-grain weight, cob length, and number of lodged plants in 1987 and 1988 at Samaru.

Treatment	1000-grain weight (g)		Cob length (cm)		No. of lodged plants	
	1987	1988	1987	1988	1987	1988
Cultivar						
TZSR	217.7	249.7	16.2	16.3	3.0	19.0
Samaru 84 TZESR-W	229.9	203.4	16.4	14.6	8.0	21.0
8321-21	208.3	239.8	15.6	16.6	5.0	17.0
LSD (P = 0.05)	16.4	12.7	NS	1.2	2.7	NS
Time of N application						
All N at planting	217.7	228.1	16.1	15.9	5.0	19.0
1/2 N at planting & 1/2 at 6 WAS	219.8	233.8	16.0	15.8	6.0	19.0
LSD (P = 0.05)	NS	NS	NS	NS	NS	NS
N rate (kg/ha)						
90	209.9	221.7	16.1	15.3	6.0	21.0
120	214.0	239.8	15.9	16.0	3.0	21.0
150	222.1	235.4	16.2	15.8	7.0	19.0
180	229.2	227.0	16.1	16.2	5.0	14.0
LSD (P = 0.05)	NS	NS	NS	NS	NS	NS

Interactions

The maize cultivar x time of N application interaction had significant effects on the number of lodged plants in 1987 and on the number of days to 50% silking in 1988. Similarly, the effect of cultivar x rate of N application interaction on number of days to 50% silking in 1988 was significant.

Correlations

Maize grain yield was significantly and positively correlated with threshing percentage, shoot height, cob length, kernel depth, 1000-grain weight, and number of lodged plants per plot (Table 3).

Table 3. Coefficients of correlation (r) between grain yield correlated and yield components of three maize cultivars at Samaru in 1987 and 1988.

Grain yield	1.0							
Threshing %	0.25*	1.0						
No. of days to silking	0.32**	-0.19	1.0					
Shoot height	0.43**	0.16	-0.64**	1.0				
Cob length	0.32**	0.09	0.24*	0.31**	1.0			
Kernel depth	0.26*	0.13	0.22	0.23	0.30**	1.0		
1000 grain wt	0.52**	-0.08	0.49**	0.55**	0.50**	0.47**	1.0	
Lodged plants	0.39**	-0.01	0.24*	0.31**	0.09	0.12	0.20	1.0
	Grain yield	Threshing %	No. of days to silking	Shoot height	Cob length	Kernel depth	1000 grain wt.	Lodged plants

**Significant at 1% level of probability; *significant at 5% level of probability.

DISCUSSION

The 1988 growing season was generally more favourable for maize production than that of 1987, most probably because of better rainfall distribution in 1988 compared to 1987, during which poor rainfall distribution resulted in waterlogging of fields in August. However, Samaru 84 TZESR-W, an early maturing cultivar, escaped the waterlogging and, consequently, performed better than the other two cultivars in 1987.

The time of nitrogen application, a critical factor in maize production, should take into account the N requirements of the critical stages of maize growth and development. Closely related to timing of N application is the rainfall distribution and intensity. The results of the present study showed that split application of N had 14-15% yield advantage over single dose application at planting, although the differences were not significant. However, given the scarcity and cost of fertilizer, as well as labour for its application, split application of N to a large farm is unlikely to be economic.

The recommended N rate for the northern Guinea savanna zone of Nigeria is 120 kg N/ha^{-1}. The non-response to the rates of N used in the present study was probably related to the fact that soil N content of the sites used in both years was 0.05%, in addition to the fact that the lowest N rate studied was relatively high.

CONCLUSION

The three maize cultivars used in the present study gave similar grain yields, but the hybrids performed marginally better than the open pollinated cultivars in 1988 during which the weather conditions were favourable.

Split application of nitrogen resulted in a non-significant increase in grain yield that was unlikely to be economic.

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18. Effects of Simple and Tied Ridging and Earthing on Grain Yield and Lodging of Maize in an Oxisol at Farako-Bâ, Burkina Faso

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ABSTRACT

Maize culture in the northern Guinea savanna may face drought stress problems during the growing season, as well as excess moisture conditions at the peak of the rainy season. Lodging caused by high winds is also a common problem. This study evaluated the effects of eight systems of flat cultivation, ridging and earthing, with and without tying every other furrow, on maize grain yield, yield components, and lodging in a gravelly sandy loam to sandy clay loam (isohyperthermic, tropeptic Eutrustox).

There were no significant differences in grain yields among the treatments, neither in 1983 and 1984 (rather dry years) nor in 1985 (a very wet year). It was concluded that in these soils in the northern Guinea savanna, and under medium/high fertilizer application, there seems to be no grain yield advantage of planting on ridges (simple or tied), nor of earthing (simple or tied) over flat cultivation. Late earthing tended to decrease root lodging whereas early earthing did not. Ridging did not have a consistent effect on root lodging. No significant differences were found in the soil chemical properties of samples taken in furrows of simple and tied ridges.

RESUME

La culture du maïs dans la savane nord Guinéenne peut être confrontée à des problèmes de sécheresse au cours de la campagne agricole, ainsi qu'aux conditions d'humidité excessive en pleine saison pluvieuse. La verse due aux vents forts est également un problème commun. Cette étude a évalué les effets de huit systèmes de binage du plat : billonnage et buttage, avec ou sans cloisonnement à chaque deux sillons, sur le rendement en grains du maïs, les composantes de rendement, et sur la verse au niveau d'un sol en terrain gravelleux et sablonneux et en terrain sablonneux et argileux (isohyperthermic, tropeptic Eutrustox).

Il n´y a pas eu de différences significatives de rendements en grains entre les traitements, ni en 1983 et 1984 (années plutôt sèches) ni en 1985 (année très arrosée). Il a été conclu qu´au niveau de ces sols de la savane nord Guinéenne et qu´avec une application moyenne et élevée d´engrais, il ne semble y avoir aucun avantage de rendement en grains ni au niveau des semis sur billons (simples ou cloisonnés), ni au niveau du buttage (simples ou cloisonnés). Par rapport au binage à plat, le buttage tardif avait tendance à réduire la verse de la racine alors que le buttage précoce n´en avait pas. Le billonnage n´avait pas un effet consistant sur la verse de la racine. Aucune différence considérable n´a été remarquée au niveau des propriétés chimiques du sol des échantillons pris à partir des sillons des billons simples ou cloisonnés.

INTRODUCTION

The northern Guinea savanna zone of West Africa has an annual rainfall of 900-1300 mm and the length of the rainy season is 130-190 days (Jones and Wild, 1975). Rainfall greatly exceeds potential evapotranspiration during part of the growing season (Kowal and Kassam, 1978) and excess moisture conditions may occur. Although the risk of drought stress is less than in the Sudan savanna zone, maize may experience drought stress if dry spells occur during the growing season (Kowal and Kassam, 1973). Surface configuration may affect water infiltration and runoff characteristics as well as crop performance. Previous work in West Africa, comparing flat and ridged seedbeds, has given conflicting results (Okigbo, 1972; Lal, 1973; Jones and Wild, 1975; Kowal and Kassam, 1978; Nicou, 1981). Little information is available on the effects of earthing on maize, although Nicou (1981) reported no significant effect on maize yield.

Tied ridges have been very effective in reducing runoff and increasing soil moisture and maize yields in the Sudan savanna (Rodiguez, 1987; Hulugalle and Rodriguez, 1988). Large yield responses of cotton to tied ridges have been observed in ferruginous soils in the northern Guinea savanna (Lawes, 1961).

This study was undertaken to evaluate the effect of ridging and earthing, with and without tying of every other furrow, on maize grain yield and lodging in a ferrallitic soil (Oxisol) in northern Guinea savanna of Burkina Faso.

MATERIALS AND METHODS

The Farako-Bâ Research Station of the Agricultural Studies and Research Institute (INERA) of Burkina Faso, where this study was conducted, is located 11°06´N and 04°23´W at 405 m elevation. Mean annual rainfall is 1083 mm and potential evapotranspiration (PE) is 1705 mm (Virmani et al., 1980). Monthly rainfall, PE and air temperatures, and dependable precipitation (precipitation that can be expected in 3 out of 4 years) are presented in Table 1. The topsoil texture was sandy loam to sandy clay loam; average gravel content in the top 20 cm was 46.7%, decreasing to 38.9% at 20-40 cm depth. The soil was classified as a isohyperthermic tropeptic Eutrustox (USDA), orthic Ferralsol, petroferric phase (FAO), and "sol ferrallitique faiblement desaturé, remanié, induré moyennement profond" (CPCS); the B horizon is massive and overlies a petroferric horizon at 90 cm depth (Smaling, 1985).

Soil chemical properties are presented in Table 2 (average of 4 samples taken in November 1983, in plots planted on the flat). Cumulative infiltration, measured with a double ring infiltrometer, was 328 mm after 150 minutes. Water infiltration rates were : 30.9 cm/h from 0-10 min., 10.5 cm/h from 110-120 min., and 9.3 cm/h from 140-150 min.; these indicate the good infiltration characteristics of this soil. Soil bulk density (after correction for gravel content) was 1.31 and 1.28 g/cm^3 at 0.5 and 20-25 cm depth, respectively.

Table 2. Soil properties (0-10 cm) at Farako-Bâ, 1983.

				Exchangeable cations (me/100g)							
pH (H_2O)	Organic C(%)	Total N(%)	Bray-1 P(ppm)	Ca	Mg	Mn	K	Na	Total acidity	Exchangeable Al	Gravel (%)
5.0	0.74	0.045	11.9	0.37	0.30	0.11	0.21	0.18	0.42	0.32	43.2

The experiment consisted of 8 ridging and earthing treatments in a latin square arrangement:

T1 : Planting on the flat; no earthing.
T2 : Planting on the flat; earthing at 35 days after planting (DAP).
T3 : Planting on the flat; earthing at 70 DAP.
T4 : Planting on the flat; earthing and tying of every other furrow at 35 DAP.
T5 : Planting on the flat; earthing at 35 DAP but tying of every other furrow at 70 DAP.
T6 : Planting on the side of ridges.
T7 : Planting on the side of ridges; earthing at 35 DAP.
T8 : Planting on the side of ridges tied every other furrow; earthing at 35 DAP.

Table 1. Longterm mean monthly rainfall (P) and dependable precipication (DP); potential evapotranspiration (PE), mean maximum (Ma) and minimum (Mi) air temperatures, monthly rainfall from 1983 to 1985, and rainfall from 10 days before planting (DBP) to harvest at Farako-Bâ, Burkina Faso.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual	10 DBP to harvest
P+(mm)	0	3	25	44	106	141	207	277	205	58	13	1	1083	
DP+(mm)	0	0	8	27	69	111	137	227	165	21	0	0	–	–
PE+(mm)	145	155	185	173	162	131	123	116	117	137	128	133	1705	–
Ma++(°C)	33.2	35.3	36.4	35.8	34.2	31.4	29.5	29.2	30.2	32.4	33.6	33.0	32.8	–
Mi++(°C)	15.3	17.3	21.4	23.4	23.5	21.7	21.1	20.9	20.6	20.6	16.7	14.4	19.7	
Rainfall (mm)														
1983	0	0	4	31	122	104	166	194	131	3	0	0	755	565
1984	0	0	21	16	102	104	123	274	157	13	7	0	817	637
1985	0	0	40	7	112	290	272	429	169	57	0	0	1376	903

\+ Virmani *et al*. (1980)

++ Sivakumar and Gnoumou (1987).

Maize was planted on the same land in 1983, 1984 and 1985. Soil preparation was by tractor plowing in 1983 and by hand-hoeing thereafter. Ridging and earthing were done with hand hoe to a height of 25-30 cm. Rows were perpendicular to the slope and small ditches were dug along the alleyways to allow free drainage of open furrows. At the end of the rainy season, all furrows in plots with tied ridges were reopened. All plots were levelled with hand-hoe at the start of the following rainy season and treatments were re-randomized every year.

Compound fertilizer (14 N, 23 P_2O_5, 15 K_2O, 6 S, 1 B_2O_3) was broadcast and incorporated before planting at the rates of 300, 200, and 300 kg/ha in years 1, 2, and 3. Urea was side-dressed, banded and incorporated, in equal split applications at 35-37 DAP and 51-54 DAP, at the rates of 250, 100, and 200 kg/ha/crop in years 1, 2, and 3, respectively. Primextra (5 l/ha) was applied only in 1983. Plots were hand weeded and cultivated 2 to 3 times at about 15, 35, and 55 DAP. Carbofuran was applied to the soil in years 1, 2, and 3 at planting, 29 DAP, and 1 DAP, respectively, at the rates of 0.8, 4.0, and 0.8 kg/ha active ingredient. In 1985 there was a second application of 0.8 kg/ha a.i. carbofuran at 57 DAP. Plots consisted of 6 rows, 5 m long and 0.75 m apart. Maize was planted at a density of 53,300 plants/ha, placing 3 grains/hole and thinning to 1 plant/hill. Planting dates were June 23, 25, and July 7, in years 1, 2 and 3 respectively, to varieties TZPB (1983) and SAFITA-102 (both about 110 days to physiological maturity).

There was no reopening of tied furrows and no levelling of ridges after harvest of the 1985 maize crop. No crop was planted in 1986. Soil samples were taken in November 1986 between the two central rows of treatments 1, 6, and 8, in four replications, at 0-20 and 20-40 cm depth. (There were cross ties between the two central rows of treatment 8.)

RESULTS AND DISCUSSION

Differences in plant density at harvest were significant (P = 0.01) only in 1983, but they were always very small and did not affect grain yields. Lowest and highest densities were 51,700 and 53,200 plants/ha in 1983; 51,700 and 53,200 in 1984; and 53,000 in 1985 (CVs were 1.5, 2.5, and 0;6%, respectively). Maize streak virus incidence was low (9.6% in 1984 and 0.9% in 1985).

Grain yields

Mean grain yields were 3.15, 3.25, and 2.69 Mg/ha and there was no significant (P = 0.05) differences among treatments in any year (Table 3). Both 1983 and 1984 were rather dry years, whereas 1985 was wet, the total rainfalls for the 3 years being 75 and 127%, respectively, of the longterm average (Table 2). Therefore, from the point of view of maize grain yield (under medium/high fertilizer regime) in relation to planting on the flat and keeping a flat seedbed, there appears to be no advantage of early (35 DAP) or late (70 DAP) earthing, earthing with early (35 DAP) or late (70 DAP) tying of every other furrow, planting on the flank of ridges, planting on the flank of ridges and early earthing, or planting on the flank of ridges tied every other furrow. The lack of yield response to simple ridges is somewhat surprising since this is the practice commonly followed by farmers in the area. It is commonly assumed that one of the purposes of ridging in the northen Guinea savanna is to improve drainage and reduce the risk of waterlogging. This view is not supported by results of the present study, done under medium/high fertilizer regime, but it should also be tested under a low fertility level. Other reasons advanced for ridging are to gather topsoil around the plants when soil fertility is low and to facilitate weed control ; these could not be evaluated in this study.

Although the plot and ridge length was only 5 m, similar results are to be expected from larger plots. If the purpose of ridges is to improve drainage, this is more easily achieved with short ridges and, in addition, open furrows were connected to small ditches down the slope along the alleyways. If the purpose of ridges is to slow down runoff and improve water infiltration, short ridges would be less effective than long ones, but in such a case there should be a response to tied ridges. In this study, there was no effect, positive or negative, of tied ridges on grain yield.

Visual observations at Farako-Ba indicated that old termite hills had surface crusting problems and were more prone to drought stress. A separate replicated experiment was conducted in 1984 on plots affected by old termite hills, to compare simple and tied earthing of all furrows at 34 DAP. Maize grain yields were 2.94 and 3.24 Mg/ha, respectively (S.E. = 0.13 Mg/ha), the effect of tied earthing being greater in those plots with higher clay content.

The main soil types in the northern Guinea savanna are the leached ferruginous soils; ferrallitic soils have better structures and have better drainage than the former (Jones and Wild, 1975). Therefore, the results of this study cannot be generalized to all of the northern Guinea savanna. Fournier (1967) reported yield responses of groundnuts and millet (average of 4 years data) to tied ridges at Niangoloko, Burkina Faso, in a soil with 90% sand, under a mean annual rainfall of 1137 mm. Matlon and Koning (1986) also reported a sorghum grain yield response to tied ridges at Koho, in the northern Guinea savanna zone of Burkina Faso.

Yield components and other crop variables

Average grain number was 1740, 1780, and 1440 kernels/m^2 in 1983, 1984 and 1985, respectively, but there were no significant differences among treatments in any year. Kernel weight was significantly ($P = 0.05$) different among treatments only in 1984 (Table 3), but no consistent pattern was found. There were no significant differences among treatment in respect of ear number.

Average plant height was 223, 186, and 210 cm in 1983, 1984 and 1985, respectively, with significant ($P = 0.05$) differences among treatments only in 1985 when planting on ridges (T6, T7, and T8) gave an average height of 227 cm against 200 cm for flat cultivation (T1). There were significant ($P = 0.05$) differences in 1983 among treatments in the number of days to 50% silking which was higher in treatments involving planting on ridges (70.6 days) than in flat planted treatments (67.5 days); no significant differences were observed in 1984 and 1985.

Stem lodging (percentage of stalks broken below the ear node) and root lodging (percentage of plants inclined from the base at an angle of 45° in relation to the vertical), after angular transformation, are presented in Table 4. There were significant ($P = 0.05$) differences among treatments in stem and root lodging in 1983 and in root lodging in 1984. Lodging values were very low in 1985 (0.4 and 2.7 for stem and root lodgings, respectively), probably because counts were made very early (73 DAP) and not 7-10 days before harvest, as in previous years; it could also be attributed to the second carbofuran application. The data suggest that late earthing (70 DAP) tends to reduce roots lodging compared to early earthing (35 DAP). Ridging had no consistent effect on stem lodging. Nicou (1981) reported no effect of earthing on maize lodging.

Table 3. Maize grain yields and kernel weights as affected by simple and tied ridging and earthing at Farako-Bâ, from 1983 to 1985.

Treatment	Grain yields (Mg/ha)				Kernel weight (Mg/kernel)			
	1983	1984	1985	Mean	1983	1984	1985	Mean
T1. Planting on the flat (PF); no earthing	3.13	3.36	2.48	3.00	181	190	172	181
T2. PF; earthing 35 DAP	3.36	3.38	2.70	3.15	187	184	171	181
T3. PF; earthing 70 DAP	3.16	3.14	2.39	2.90	177	179	167	174
T4. PF; earthing and tying every other furrow 35 DAP	3.20	3.48	2.82	3.17	182	186	175	181
T5. PF; earthing 35 DAP; tying every other furrow 70 DAP	3.41	3.10	2.65	3.05	189	178	165	177
T6. Planting on side of ridges (PR)	2.87	3.35	286	3.03	171	188	164	174
T7. PR; earthing 35 DAP	3.04	2.96	2.64	2.88	182	180	167	176
T8. PR; tied every other furrow; earthing 35 DAP	3.04	3.22	2.95	3.07	175	175	174	175
Mean	3.15	3.25	2.69	3.03	181	182	169	177
C.V. %	15.0	15.8	19.1	-	7.9	5.5	10.2	-
F test (P = 0.01)	0.356	0.487	0.386	-	0.213	0.046	0.846	-
S.E. of means	0.167	0.182	0.182	-	5.0	3.5	6.1	-

Table 4. Effect of simple and tied ridging and earthing on stem and root lodging of maize (after angular transformation) at Farako-Bâ, 1983 and 1984.

Treatment	Stem lodging			Root lodging		
	1983	1984	Mean	1983	1984	Mean
T1	14.1	3.4	8.8	15.3	30.4	22.8
T2	20.3	4.5	12.4	13.3	34.4	23.8
T3	12.2	6.5	9.4	9.8	13.3	11.6
T4	16.5	5.5	11.0	25.2	31.9	28.6
T5	15.7	6.1	10.9	19.2	34.6	26.9
T6	15.1	5.8	10.4	17.1	27.7	22.4
T7	10.0	3.8	6.9	20.2	32.5	26.4
T8	13.9	4.1	9.0	20.4	31.4	25.9
Mean	14.7	5.0	9.8	18.8	29.5	24.2
C.V. (%)	38.3	116.5	-	37.0	30.6	-
F test (P=0.01)	0.041	0.938	-	0.003	<0.001	-
S.E. of means	2.0	2.0	-	2.5	3.2	-

Soil analysis

Ridge height was about 20 cm at the time soil samples were taken. The sampling depths of 0-20 and 20-40 cm do not, therefore, have the same meaning in relation to the original flat soil surface when comparing ridged plots with those planted on the flat. There is a confounding effect of soil depth differences with treatment-induced changes in soil properties and, strictly speaking, soil analysis values under flat planting (T1) are not directly comparable with those under ridges. The comparison of most interest is that between simple ridges (T6) and tied ridges (T8).

There were no significant differences between simple and tied ridges (Table 5) for any of the soil properties measured. Although tied ridges virtually eliminate runoff and, therefore, more water percolates through the profile than under simple ridges, no changes in soil chemical properties in the furrows were detected after two years of continuous tied ridges, with 1376 mm of rainfall in 1985 and 948 mm in 1986. Although tied ridges did not increase maize yields in this type of soil, they did not depress them either and the possibility of using tied ridges for runoff and/or erosion control could be considered. Longer term studies would be needed to evaluate changes in soil properties.

Particle-size analysis in flat plots, from 0-20 and 20-40 cm depths, showed a decrease in sand with depth (6% against 45%, S.E. = 3.1) and an increase in clay (21% against 40%, S.E. = 2.1.).

Values in Table 5 are based on data from three replications. Data from the fourth replication were deleted because some samples fell on an old termite hill and had higher values of pH (5.1), organic C (0.97%), total N (0.079%), exchangeable bases (5.52 mg/100g), and clay content (44%), in the top 0-20 cm than the other samples.

CONCLUSIONS

In relation to flat cultivation, no significant differences in grain yield were obtained by planting on ridges or by early or late earthing. Tying of every other furrow at 0, 5, or 10 weeks after planting did not affect grain yields in dry and wet years. Thus, in these gravelly Oxisols (ferrallitic soils) in the northern Guinea savanna, under medium/high fertilizer regime, either excess moisture conditions during the rainy season did not seem to be a problem for maize culture, or they were not alleviated by planting on ridges, or by earthing. Late earthing (10 weeks after planting) tended to reduce root lodging, while early earthing (5 weeks after planting) did not reduce it. Ridging did not have a consistent effect on root lodging.

There were no significant differences in soil chemical properties of samples taken in furrows of simple and tied ridges at 0-20 and 20-40 cm depths.

Table 5. Soil properties as affected by treatment and depth; samples taken between rows at Farako-Bâ.

			Treatment				Soil depth		
Property	Mean	CV %	Flat	Simple ridges	Tied ridges	LSD (P=0.05)	(cm) 0-20	20-40	LSD (P=0.05)
pH (H_2O)	4.6	2.3	4.7	4.4	4.6	0.25	4.6	4.5	NS+
Organic C (%)	0.50	19.3	0.42	0.56	0.52	NS	0.57	0.42	0.11
Total N (%)	0.052	10.6	0.046	0.058	0.051	0.007	0.055	0.048	0.006
Bray-1 P (ppm)	3.3	30.5	4.3	3.1	2.5	NS	4.5	2.1	1.2
Exch. Ca (me/100g)	0.97	19.5	0.51	1.20	1.20	NS	0.95	0.99	NS
Exch. Mg(me/100g)	0.68	19.8	0.55	0.78	0.72	NS	0.59	0.77	0.16
Exch. Mn (me/100g)	0.04	47.9	0.04	0.05	0.04	NS	0.06	0.03	0.02
Exch. K (me/100g)	0.21	24.7	0.15	0.20	0.28	0.08	0.23	0.19	NS
Exch. Na (me/100g)	0.18	7.9	0.18	0.18	0.18	NS	0.18	0.17	NS
Total acidity(me/100g)	0.97	58.6	0.99	1.01	0.90	NS	0.90	1.04	NS
Exch. Al (me/100g)	0.78	65.2	0.81	0.79	0.75	NS	0.74	0.82	NS
CEC (me/100g)	3.05	22.6	2.42	3.42	3.31	0.76	2.91	3.19	NS
Base saturation (%)	67.6	16.9	58.5	71.1	73.1	NS	68.2	67.0	NS
Gravel, 2 mm (%)	42.8	17.2	42.1	43.1	43.4	NS	46.7	38.9	NS

+NS = non-significant (P = 0.05).

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19. Effects of Planting Date and Varietal Maturity on Seed Production and Storability of Maize in Ghana.

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ABSTRACT

Seed quality and storage problems are closely associated with pre-harvest field weathering. Time of planting, generally, determines when to harvest, thereby influencing the extent of field deterioration. To determine optimum dates for planting maize for seed, maize varieties with three different maturity periods (early, medium, and late) were planted at various dates in the forest, the forest-savanna transitional zone and the Guinea savanna zone. At maturity, seed yields were recorded. Subsequently, laboratory studies on seed viability, infection by fungi, and damage by storage insects were conducted. In the forest and the transitional zones, the highest seed yields were obtained from the April plantings but seeds from later sown maize had the lowest incidence of infection by fungi. A similar trend was obtained in the Guinea savanna zone.

RESUME

Le critère de qualité des graines et les problèmes de conservation sont étroitement liés à l´altération au champ de la pré-récolte. La période de semis détermine généralement la période de récolte, influençant ainsi le degré de l´altération au champ. Pour déterminer les dates optimales pour le semis du maïs pour les semences, des variétés de maïs avec trois différentes périodes de maturité (précoce, intermédiaire et tardive) ont été semées à différentes dates dans la zone de forêt, dans la zone de transition forêt-savane et dans la zone de savane Guinéenne. A la maturité, des rendements en semences ont été enregistrés. Par la suite, des études ont été menées au laboratoire sur la viabilité semencière, sur l´infection cryptogamique, et sur les dégâts causés par les insectes de stockage. Dans les zones de forêt et de transition, les rendements en graines les plus élevés ont été enregistrés sur les semailles d´avril mais le maïs semé plus tard montrait la plus faible incidence d´infestation cryptomagique. Un caractère similaire a été obtenu au niveau de la zone de savane Guinéenne.

INTRODUCTION

In a successful seed programme, high quality seeds of improved crop varieties are often available in sufficient quantities for supply to farmers. Seed quality problems normally arise in the field and continue during storage. Deterioration of seed after maturation, but before harvest, is a serious seed production problem, especially in the humid tropics.

Deterioration begins as soon as the seed reaches functional maturity and continues, at varying rates, until the seed is completely dead. Mondragon and Potts (1974) reported that germination of seeds subjected to ambient environmental conditions in the field declined significantly 4 weeks after physiological maturity. Optimum planting dates for respective varieties would expose the crop to weather conditions favourable for seed development and maturation.

The objectives of the study reported below were, therefore, to determine the effects of both planting date and maize variety maturity period on seed yield, harvest losses, seed viability at harvest, and the incidence of major field-to-store fungi and insects; the effects of ecological environment on seed production were also studied.

MATERIALS AND METHODS

The three white dent maize varieties used in the study were SAFITA-2, Aburotia, and Dobidi with maturity periods of 90, 105, and 120 days. The five planting dates in the forest and transition zones were mid March, late March, mid April, late April, and mid May, while those in Guinea savanna were late May, mid June, late June, mid July, and late July. The experimental design was split plot (with four replications) in which planting dates constituted the main plots, while maize varieties comprised the sub-plots.

Laboratory procedures

Germination test. For each subplot, 50 seeds were tested using blotter paper method. Germination was recorded at 4 and 7 days after planting.

Seed health testing. Fifty seeds were sampled from each subplot and planted on moist blotter paper in petri dishes (10 seeds per petri dish). The plates were incubated at 26°C for 7 days under an alternating cycle of 12 hours of near ultraviolet light and 12 hours of darkness. The seeds were then examined under the low power of a compound microscope and the incidence of microflora recorded.

Seed damage caused by storage insect pests. Two hundred grams of seeds of each treatment were stored in separate kilner jars. Emerging insect pests and damaged seeds were recorded after three months of storage.

RESULTS AND DISCUSSION

Seed production in the forest zone

Seed yield. The differences among seed yields of maize varieties were highly significant as were the differences among seed yields of maize sown at various planting dates; the variety x planting date interaction was also significant.

Seed germination. Germination percentages of seeds harvested from maize sown at various planting dates were significantly different from each other (P = 0.01), the maize variety x planting date interaction being also highly significant. For example, germination percentage of mid March-sown maize was 52 while that of maize sown in mid-May was 79. The lower viability of seeds of early-sown maize was associated with higher incidence of field and storage fungi (Table 1).

Seed infection caused by the ear-rot fungus(*Fusarium moniliforme*). The effects of planting date, variety and variety x planting date interaction on the incidence of infection by the ear-rot fungus (*Fusarium moniliforme*) were significant (P = 0.01); the earlier the planting, the higher the incidence of infection. The higher levels of infection in the seeds from earlier planted maize probably contributed to their lower germination percentages. Simpson and Stone (1935) and Cadwell (1972) reported a negative correlation between the viability of cotton seed exposed in the field and the amount of rainfall during the exposure period. In the present study, infection percentages for the early, medium, and the late maturing varieties were 15, 18, and 8, respectively. It appears that seeds of the late maturing variety merely escaped infection.

Seed infection by storage fungi. The effect of planting date, variety, and variety x planting date interaction on the incidence of infection by storage fungi (*Aspergillus flavus* and *A. terreus*) were significant (P = 0.01); the later the planting date the lower the incidence of infection, while the earlier the maturity period the higher the incidence of infection.

Damage caused by field-to-store insects.. The number of, and the incidence of grain damage by, storage insect pests after three months of storage are summarized in Table 2. Generally, the later the maturity period of maize, the higher the levels of infestation and damage by these insects, particularly *Sitophilus zeamais*.

Table 1. Effects of planting date and maize variety maturity period on seed yield, germination percentage and incidence of seed infection by fungi in the forest zone of Ghana.

Maize variety maturity period (days)	Planting date	Seed yield (kg/ha)	Seed germination (%)	Incidence of seed infection (%) by:		
				Fusarium moniliforme	*Aspergillus flavus*	*Aspergillus terreus*
90	Mid March	1321.9	64.0	40.0	58.0	9.0
90	Late March	1450.6	51.0	20.0	29.0	11.0
90	Mid April	1069.3	60.0	3.0	7.0	1.0
90	Late April	2657.4	66.0	6.0	1.0	0.0
90	Mid May	994.9	83.0	6.0	11.0	1.0
105	Mid March	1882.5	50.0	72.0	16.0	6.0
105	Late March	1298.9	49.0	9.0	6.0	1.0
105	Mid April	2636.2	66.0	3.0	3.0	0.0
105	Late April	2559.5	78.0	3.0	9.0	0.0
105	Mid May	2063.1	78.0	4.0	9.0	1.0
120	Mid March	968.2	40.0	8.0	1.0	0.0
120	Late March	2656.6	65.0	4.0	2.0	0.0
120	Mid April	2914.6	77.0	6.0	8.0	1.0
120	Late April	3618.7	78.0	6.0	9.0	2.0
120	Mid May	1589.1	75.0	18.0	4.0	0.0
Mean		1978.8	65.2	13.8	11.3	2.0
LSD (0.05)		954.1	10.6	13.0	9.1	4.0
CV (%)		34.1	11.8	66.8	57.0	15.0

Table 2. Effects of varietal maturity period on the incidence and damage by field-to-store insects in the forest zone of Ghana.

		No. of insects per 200 seeds		
Maize variety type	Incidence of damaged seeds (%)	*Sitophilus zeamais*	*Cryptolestes* spp.	*Carpophilus* spp.
90-day white dent	6.1	26	3	0
105-day white dent	17.8	87	12	3
120-day white dent	45.2	255	19	9

Seed production in the transitional zone

Seed yield. The effect of planting date on seed yield was significant (P = 0.01); the later the planting date, the higher the seed yield. For example, mid March planted maize yielded 603.9 kg/ha, while mid May sown maize yielded 2683.7 kg/ha.

Seed germination. The germination percentages of seeds from maize sown in mid March and late March were significantly lower than those of maize sown between mid April and mid May (P = 0.05).

Seed infection caused by the ear-rot fungus Fusarium moniliforme). The effects of planting date, maize variety and planting date x variety interaction on the incidence of infection by *Fusarium moniliforme* were significant; grains from mid March sown maize had significantly higher incidence of infection than grains from maize sown on the other dates (P = 0.05), while grains of medium maturity periods had the highest incidence of infection (Table 3).

Seed infection by storage fungi. Seeds from mid March sown maize had significantly (P = 0.05) higher incidence of infection by *Aspergillus flavus* than seeds of maize sown at the other planting dates.

Seed damage caused by field-to-store insects. The incidence of grains damaged by insects and the species of storage insect pests associated with the damage are summarized in Table 4. Grains of the late maturing variety sustained the greatest damage.

Seed production in the Guinea savanna

Seed yield. The effects of maize variety and variety x planting date interaction on seed yield were significant (P = 0.05); the late maturing variety produced the highest seed yield, while late May-sown maize produced the highest seed yield (Table 5).

Seed germination. The differences in germination percentages of seeds from maize sown at the first four sowing dates (late May-mid July) were not significant; by contrast, seeds of maize sown at the last sowing date (late July) had significantly (P = 0.05) lower germination percentage than those of any of the earlier sown maize.

Seed infection caused by *Fusarium moniliforme*. The effect of planting date on the incidence of infection by *F. moniliforme* was significant (P = 0.05); grains from late May sown maize had the highest incidence of infection.

Seed infection caused by storage fungi. Planting date, maize variety and planting date x variety interaction significantly (P = 0.05) affected the incidence of seed infection by *Aspergillus flavus*, grain from later sown maize having the highest incidence of infection. Also, the incidence of infection in grains of the early maturing variety was significantly lower than that of either the late or the medium maturing variety (Table 5).

Table 3. Effects of planting date and maize variety maturity period on seed yield, germination percentage, and incidence of seed infection by fungi in the transitional zone of Ghana.

Maize variety maturity period (days)	Planting date	Seed yield (kg/ha)	Seed germination (%)	Incidence of seed infection (%) by		
				Fusarium moniliforme	*Aspergillus flavus*	*Aspergillus terreus*
90	Mid March	558	58.0	55.0	3.0	1.0
90	Late March	1825	54.0	32.0	20.0	3.0
90	Mid April	2422	75.0	11.0	6.0	0.0
90	Late April	3059	75.0	4.0	8.0	1.0
90	Mid May	2667	69.0	9.0	20.0	1.0
105	Mid March	584	43.0	26.0	47.0	7.0
105	Late March	1827	69.0	6.0	13.0	0.0
105	Mid April	2504	72.0	5.0	8.0	0.0
105	Late April	3233	65.0	6.0	10.0	0.0
105	Mid May	2744	84.0	6.0	19.0	1.0
120	Mid March	669	41.0	17.0	16.0	2.0
120	Late March	2768	52.0	12.0	2.0	0.0
120	Mid April	2571	71.0	6.0	1.0	0.0
120	Late April	2642	75.0	13.0	21.0	0.0
120	Mid May	2641	82.0	5.0	21.0	1.0
	Mean	2182	65.5	14.2	14.8	1.4
	LSD (0.05)	948	14.5	13.5	21.9	2.8
	CV %	30.7	16.1	67.5	109	148

Table 4. Effects of maize variety maturity period on the incidence of, and damage by, field-to-store insects in the transitional zone of Ghana.

Maize variety type	Incidence of damaged seed (%)	No. of insects per 200 seeds		
		Sitophilus zeamais	*Cryptolestes* spp.	*Carpophilus* spp.
90-day white dent	9.9	11	1	0
105-day white dent	15.2	95	30	0
120-day white dent	54.3	237	9	1

Seed damage caused by field-to-store insects. Only *Sitophilus zeamais* was detected on maize stored in the Guinea savanna. The incidence of damaged seeds was relatively low and was not significantly (P = 0.05) influenced by the variety of maize (Table 6).

CONCLUSIONS

To minimize field deterioration of seed, it is important to plant maize at optimum sowing dates for respective maize varieties in various ecological zones. The results of the present study suggest the following planting dates for maize of different maturity periods in three ecological zones in Ghana.

Maize variety maturity type	Optimum sowing date:		
	Forest zone	Transition zone	Guinea savanna
Early maturing	Late April	Late April	Mid June
Medium maturing	Mid-late April	Late April	Mid June
Late maturing	Mid April	Mid April	Late May

Table 5. The effects of planting date and maize variety maturity period on seed yield, germination percentages, and incidence of seed infection by fungi in the Guinea savanna zone of Ghana.

				Incidence of seed infection (%) by:		
Maize variety maturity period (days)	Planting date	Seed yield (kg/ha)	Seed germination (%)	*Fusarium moniliforme*	*Aspergillus flavus*	*Aspergillus terreus*
90	Late May	1347.9	88.0	28.0	16.0	8.0
90	Mid June	1665.3	82.5	26.0	16.0	2.0
90	Late June	1795.6	75.5	28.0	24.0	5.0
90	Mid July	779.7	77.5	9.0	20.0	4.0
90	Late July	1063.1	62.0	19.0	21.0	7.0
105	Late May	1821.8	83.0	43.0	24.0	14.0
105	Mid June	1551.3	71.5	22.0	12.0	24.0
105	Late June	2312.5	73.0	29.0	31.0	10.0
105	Mid July	1093.7	75.5	11.0	75.0	22.0
105	Late July	1258.5	46.5	12.0	49.0	16.0
120	Late May	3922.1	77.3	30.0	25.0	4.0
120	Mid June	3417.8	66.0	11.0	18.0	4.0
120	Late June	1827.1	64.3	14.0	36.0	2.0
120	Mid July	2368.1	60.5	14.0	44.0	11.0
120	Late July	990.7	61.0	30.0	32.0	4.0
	Mean	1881.0	70.5	21.5	29.2	8.9
	LSD (0.05)	881.9	23.5	17.5	21.5	20.7
	CV %	33.2	23.5	51.7	52.0	165.3

Table 6. Effects of maize varietal maturity period on the incidence of, and damage by, field-to-store insects in the Guinea savanna zone of Ghana.

Maize variety type	Incidence of damaged seeds (%)	No. of insects per 200 seeds		
		Sitophilus zeamais	Cryptolestes spp.	Carpophilus spp.
90-day white dent	2.4	8	0	0
105-day white dent	3.9	9	0	0
120-day white dent	3.6	4	0	0

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PART IV

CROP PROTECTION

20. Pouvoir Pathogène et Mode d´Action de *Macrophomina phaseolina (Tassi) Goïd*, Parasite du Niébé, (*Vigna unguiculata* (L.) Walp.) au Niger.

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RESUME

Macrophomina phaseolina provoque sur le niébé plusieurs types de dégâts : fontes de semis, pourriture des racines et des tiges, flétrissement en végétation, altérations des gousses et des graines et mort des plantes. Le champignon a une croissance très rapide et envahit tous les tissus des racines et des tiges, ainsi que le révèlent les coupes histologiques. Par ces coupes, on met également en évidence la localisation des différents organes du parasite, ainsi que les dommages subis par les cellules. Un parallèle est fait entre la manifestation extérieure des symptômes et la progression du parasite dans les tissus.

ABSTRACT

Macrophomina phaseolina induces several symptoms in cowpea; these include : seed, root and stem necrosis; seedling mortality; and wilting and death of older plants. The fungus grows rapidly and invades all root and stem tissues, as demonstrated by histological studies which also facilitated a study of structures formed by the parasite during host invasion as well as a study of the damage done at cellular level to the host. A correlation was established between the manifestation of external disease symptoms and the progress of the parasite through the host plant tissues.

INTRODUCTION

Macrophomina phaseolina (Tassi) Goid (Sphaeropsidales) est aujourd´hui un des parasites les plus destructeurs du niébé au Niger. Depuis 1981, il a été régulièrement signalé dans les principales zones de production comprises entre les isohyètes 300 mm au nord et 700 mm au sud (ADAM, 1986).

La gravité des dégâts de ce champignon se traduit par l´importance des pertes qu´il occasionne et la vaste gamme de plantes cultivées qu´il colonise. Ainsi, des pertes atteignant parfois 100% ont été enregistrées en 1981, 1982, 1984 dans plusieurs stations, d´abord sur le niébé, puis sur l´arachide, le sorgho, le sésame, l´oseille, etc... (ADAM, 1986).

Sur le niébé, qui a été retenu pour cette étude, divers symptômes sont observés au champ chez les agriculteurs : fontes de semis, flétrissement, pourriture des racines et des tiges, pourriture sèche des gousses et des graines et finalement mort de la plante (ADAM, 1986).

L´évolution des symptômes a été étudiée expérimentalement au champ, après inoculation artificielle.

Pour mettre en évidence le mode d´action parasitaire, nous avons réalisé des inoculations artificielles in vitro et examiné des coupes histologiques de plantules infectées.

MATERIEL ET METHODES

Etude des symptômes au champ

Des graines de quatre variétés de niébé (TN88-63, TN3-71, IT82E-18, IT82E-60) ont été artificiellement inoculées par trempage pendant 1 heure dans une suspension de sclérotes de M. phaseolina. Elles sont ensuite semées sur de petites parcelles fortement infestées par des cultures répétées de niébé sensible et contaminé.

Après la levée, les plantules sont arrosées une fois par semaine. Les symptômes sont enregistrés et décrits durant tout le cycle du développement de la plante.

Etude in vitro du mode d´action

Des graines de la variété de niébé TN88-63 sont désinfectées au Mercryl Laurylé ; après rinçage à l´eau distillée stérile, elles sont mises en germination sur eau gélosée à 2% en boîtes de Pétri.

Les plantules saines de 3 jours sont repiquées en tube à essais, de 3 cm de diamètre et 16 cm de hauteur, contenant 20 à 40 ml de milieu glucosé et gélosé stérile de Murashige et Skoog (1962, cités par BATCHO, 1981), sans phytohormones.

Quatre jours après repiquage, quand les plantules sont installées, on les inocule par dépôt d´un fragment mycélien d´une culture de Macrophomina phaseolina au pied de la plantule.

On arrête l´infestation par fixation après 0 heure (témoin), 24 heures, 48 heures, 72 heures, et 96 heures, de contact entre le parasite et son hôte. La fixation est réalisée à la Navachine et la coloration à l´hématoxyline.

RESULTATS

Description des symptômes au champ

De nombreux types de symptômes sont constatés chronologiquement :

- Les fontes de semis ; ("charcoal rot") : les graines ou les plantules sont envahies et détruites en un temps record. Sur les plantules, la pourriture, franchement noire, apparaît le plus souvent au niveau des cotylédons, puis tout l´hypocotyle s´affaisse et la plantule meurt. Des sclérotes et des pycnides peuvent apparaître sur la lésion. Ces fontes de semis durent jusqu´à 2 ou 3 semaines après le semis.
- La pourriture des racines: M. phaseolina infecte les plantes par les racines qui sont détruites progressivement et qui noircissent.
- Le flétrissement est un des symptômes le plus caractéristique : il commence par quelques folioles puis quelques branches et finalement se généralise à toute la plante qui meurt dans les 4 à 5 jours. Pendant ce temps, les plantes voisines sont contaminées les unes après les autres et subiront le même sort.
- La pourriture cendrée des tiges:("Ashy stem blight"): elle fait suite au flétrissement ou apparaît par endroit sur la plante au niveau du collet ou des branchettes terminales. Elle est parfois bien localisée sur les points de ramifications puis se généralise. Elle est typique sur les plantes âgées, entre la floraison et la maturité. Généralement, de nombreux sclérotes et des pycnides proéminentes sont visibles sur les lésions.
- Affection des gousses et des graines : lors de la fructification, les gousses et les graines peuvent être envahies par les attaques tardives. Elles sont alors gris noir, petites et tapissées de sclérotes et parfois de pycnides noires. M. phaseolina envahit donc tous les organes aériens, sauf les feuilles, sur lesquels il provoque divers faciès maladifs et des dégâts considérables.

Mode d´action du parasite in vitro :

Ce champignon étant tellurique (ROGER, 1953), nous avons recherché les voies par lesquelles il atteint et contamine les gousses et les graines, ainsi que les branchettes terminales.

Deux hypothèses peuvent être formulées à ce niveau :

- Soit la contamination des gousses est réalisée par contact direct avec le sol infesté ou par projections sur ces organes de fragments de sol infesté à l'occasion des pluies.

- Soit le champignon évolue dans la plante, par voie intercellulaire jusqu'à atteindre ces organes.

Nous avons examiné cette seconde hypothèse, qui, en outre, expliquerait le flétrissement progressif décrit ci-dessus, résultat d'une probable invasion du système vasculaire.

Lorsque l'inoculation se fait en même temps que le repiquage des plantules en tubes, la croissance du champignon est si rapide qu'il envahit et détruit ces plantules avant leur installation. En effet, M. phaseolina émet ses premiers filaments mycéliens entre 6 et 10 heures après inoculation et a une croissance très rapide entre 30 et 35°C.

Nous avons donc laissé les plantules s'installer pendant 4 jours avant d'inoculer les tubes.

Au bout de 24 heures, le parasite est en pleine phase végétative, son mycélium est encore hyalin et couvre la surface du milieu de culture. Les plantules ne manifestent aucun symptôme. La coupe des tissus ne révèle pas la présence du parasite.

Au bout de 48 heures d'inoculation, le mycélium amorce la coloration noire caractéristique, avec formation des premiers sclérotes. Les coupes histologiques indiquent un début d'installation du champignon dans le parenchyme cortical, au niveau des espaces intercellulaires.

Après 72 heures d'inoculation, la plantule manifeste nettement les symptômes : début de pourriture des racines et du collet, jaunissement ou flétrissement des feuilles. Les différentes assises cellulaires sont atteintes, y compris la zone médullaire. Les sclérotes et le mycélium contribuent à écarter les cellules et à endommager leur structure.

Au bout de 96 heures, le flétrissement atteint son maximum et la plupart des plantules meurent. La tige montre le symptôme typique d'"Ashy stem blight", ainsi que de nombreux sclérotes et des pycnides en surface. Les coupes histologiques montrent que le parasite a atteint tous les tissus, les cellules sont dégénérées et vidées de leur contenu. En plus du mycélium et des sclérotes, les pycnides formées écartent fortement les tissus pour apparaître en surface. Une coupe de ces pycnides révèle des pycniospores caractéristiques du champignon : elles sont unicellulaires et plus ou moins elliptiques.

DISCUSSION

L'inoculation artificielle réalisée pour cette étude a permis de provoquer les symptômes décrits chez les agriculteurs, donc de bien confirmer la responsabilité de M. phaseolina dans les dégâts enregistrés.

La contamination des graines par l'inoculum ou la culture de semences saines sur sol infesté suffisent à créer la maladie.

Des études antérieures (ADAM, 1986), avaient mis en évidence que les semences et le sol étaient les principales sources d'inoculum de M. phaseolina.

Cela nous amène aux constats suivants :

- Dans la plupart des pays producteurs de niébé, et à l'occasion des échanges de ressources génétiques, les semences de niébé ne font pas l'objet de contrôle particulier en vue de la détection des germes infectieux qu'elles porteraient, et notamment l'inoculum de M. phaseolina. Il est donc prévisible, si des dispositions ne sont pas prises, que ce champignon se propage, à travers les semences, dans toutes les zones de production. Les zones sahéliennes semi-arides, en particulier, lui offrent des conditions climatiques très favorables températures moyennes comprises entre 30 et 35°C, sécheresse fréquentes (ADAM, 1987). Ce sont donc des zones à haut risque (si elles ne sont pas encore envahies).
- Il a été mis en évidence (ADAM, 1986) que les sols agricoles du Niger hébergent les sclérotes de ce parasite. Cet inoculum est fourni au sol par les résidus d'hôtes multiples. ADAM (1986) a aussi démontré que les isolats de ces différents hôtes ont sensiblement la même agressivité sur le niébé. On peut donc craindre que ce champignon devienne rapidement abondant et endémique dans toute zone infestée où les conditions favorables sont réunies car, les sclérotes, principale forme de conservation de M. phaseolina, ont une grande longévité dans le sol (DHINGRA et SINCLAIR, 1978).

En ce qui concerne le mode d'action cellulaire de ce champignon redoutable, les coupes hitologiques apportent une vision complémentaire ; en plus de la destruction des racines, (DHINGRA et SINCLAIR, 1978), les flétrissements progressifs et rapides observés sont aussi dûs à l'invasion de tous les tissus des tiges, de la périphérie à la zone médulaire. Les cellules et le système vasculaire sont détruits.

La progression du mycélium se fait en longueur et explique au moins en partie la colonisation des pédoncules, des gousses et des graines. Seuls les tissus foliaires semblent épargnés pour des raisons encore inconnues.

Cette invasion intercellulaire (et même intracellulaire) des tissus pourrait orienter la recherche de méthodes de lutte vers des fongicides systémiques. De tels produits pourraient reprimer l´inoculum éventuel des semences, celui venant du sol, et grâce à des traitements périodiques, maîtriser les infections successives en végétation.

CONCLUSION

Ce travail a permis de décrire les principales manifestations du M. phaseolina sur le niébé dans les conditions du Niger. Cela aiderait donc à un diagnostic rapide de la maladie.

La contamination des semences suffit à déclencher la maladie. Cette contamination est réalisée naturellement dans les champs. Il est donc urgent que les mesures soient prises en vue de l´analyse et du contrôle des semences de niébé destinées aux producteurs et aux chercheurs, en vue de limiter ou éviter la propagation de M. phaseolina d´une zone à une autre d´un même pays, d´un pays à un autre. Dans la pratique, cela est évidemment très difficile.

La mise au point de fongicides systémiques pourrait, à court terme, constituer une solution pour neutraliser les infections en cours de végétation.

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21. Lutte Contre le Grand Capucin du Maïs, Prostephanus truncatus Horn (Coleoptère Bostrichidae) Dans les Greniers Traditionnels au Sud du Togo.

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RESUME

L´efficacité de quatre insecticides de formulation EC a été testée contre le grand capucin du maïs et contre d´autres parasites de stock dans les greniers traditionnels au Sud du Togo. La matière active Deltaméthrine (2 ppm) et le mélange Fenvalerate (7,5 ppm) + Fenitrothion (37,5 ppm) ont contrôlé d´une façon satisfaisante pendant plus de 10 mois tout le spectre de charançons. La problématique de l´estimation des pertes des épis de maïs stockés en spathe a été entièrement discutée.

L´importance de la quantité de farine provenant des dégâts s´est révélée être un indice sûr pour l´appréciation de l´infestation du maïs par le grand capucin. Une corrélation étroite existe entre la quantité de la farine d´une part et la perte en matière sèche, le nombre de *P. truncatus* et l´ensemble de charançons d´autre part. Les connaissances acquises en milieu rural nous guideront dans les essais ultérieurs.

ABSTRACT

The efficacies of EC formulations of four insecticides against *Prostephanus truncatus* and some storage insect pests in the traditional granaries of Southern Togo were tested. The traditional maize granaries were sprayed with the following insecticides : permethrin (7.5 ppm), deltamethrin (2 ppm), fenvalerate + fenithrotion (7.5 + 37.5 ppm), cyfluthrin + fenithrotion (0.3 + 12 ppm). The results showed that deltamethrin or fenvalerate + fenithrotion treatments gave satisfactory control of the storage pests for 10 months. The problem of assessing insect pest damage on stored maize cobs with husks is discussed.

The proportion of flour lost due to insect pest damage during storage was found to be reliable index of maize grain damage by *P. truncatus*. There was a positive correlation between the quantity of flour lost in storage, and the number of *P truncatus* together with the maize weevil.

INTRODUCTION

Le grand capucin du maïs (Prostephanus truncatus) fut découvert en Janvier 1984 à Djagblé (12 km au Nord-Est de Lomé), dans un grenier de maïs (Krall, 1984).

Au Sud du Togo, le maïs est habituellement conservé en spathe et en couches superposées sur une plate-forme en bois couverte de paille. Ce type de grenier sert en même temps de plates-formes de séchage aux épis de maïs dont la teneur en eau des grains se situe généralement entre 25 et 30 % au moment de la conservation.

P. truncatus se multiplie plus rapidement dans le maïs en spathe que dans le maïs égrené (Cowley et al., 1980). Ce parasite traverse facilement les spathes de maïs qui constituent généralement un rampart solide pour l'attaque des autres parasites de stock comme Sitophilus sp. Les pertes causées par P. truncatus dans les greniers traditionnels sont estimées à 45 % environ après 8 mois de conservation (Pantenius et Schulz, 1986).

L'adoption de nouvelles méthodes de conservation de maïs telles que le stockage du maïs-grain ensaché avec traitement insecticide par les paysans se développe très timidement pour les raisons suivantes :

- les greniers traditionnels représentent un élément de prestige pour leur propriétaire ;
- le despathage, l'égrenage et le traitement insecticide constituent une besogne supplémentaire ;
- manque d'argent disponible pour l'achat de sacs ;
- accroissement du risque de vol ;
- augmentation dans certaines circonstances de l'auto-consommation ;
- manque de magasins appropriés pour le stockage du maïs-grain ;
- difficultés de séchage.

Toutes ces contraintes nous ont conduit à étudier la possibilité d'application dans les greniers traditionnels des insecticides de formulation EC pour lutter contre P. truncatus et les autres parasites de stock.

METHODE

Les essais ont été menés entre octobre 1985 et septembre 1986 à Gbonvé chez un paysan. Les échantillons ont été évalués au laboratoire à Cacaveli.

Les insecticides testés sont :

- 5 % Fenvalerate + 25 % Fenitrothion ("Sumicombi")
  7,5 ppm + 37,5 ppm
- 2,6 % Cyfluthrine + 100 % Fenitrothion
  ("Bayer FL 3393/3") - 0,3 pp + 12 ppm
- 25 % Permethrine ("Ambush") - 7,5 ppm
- 1,2 % Deltaméthrine ("Decis") - 2,0 ppm.

Les doses d´application des produits ont été plus élevées que celles recommandées par les firmes car les produits appliqués sur les spathes n´entraient pas en contact direct avec les grains ; le risque de résidus élevés sur les grains de maïs n´était donc pas à craindre. Chaque traitement fut répété trois fois.

Les épis de maïs (500 kg) ont été traités avec 80 % de bouillie insecticide de la variante correspondante puis disposés en couches superposées dans chacun des quinze greniers traditionnels de 1,5 m de diamètre. Le reste de la bouillie insecticide (20 %) fut appliqué sur la paroi externe de chaque grenier dans lequel dix épis, marqués et artificiellement infestés de vingt adultes sexés de <u>P. truncatus</u> furent ensuite introduits de la façon suivante :

- deux à la base de la plate-forme,
- quatre dans les 5ème et les 19ème couches de chaque grenier comprenant 25 couches d´épis au total.
  <u>P. truncatus</u> a un sex-ratio de 1/1.

Cent épis furent ensuite prélevés de chaque grenier comme échantillon standard. Ces échantillons tout comme d´autres échantillons ultérieurs pour analyse ont été prélevés de la couche supérieure du grenier selon la méthode décrite par Pantenius (1986).

- Division de la surface de prélèvement en quatre secteurs
- Subdivision des secteurs en sous-secteurs internes et externes
- Prélèvement de 15 et 10 épis respectivement dans les sous-secteurs externes et internes.

Cette méthode du poids des échantillons (PME) a l'avantage de permettre la détermination quantitative de la perte sans avoir pour base le grain unitaire qu'on ne retrouve pas dans toute infestation avancée de cet insecte. P. truncatus dévore généralement le grain entièrement en laissant un amas de farine de telle sorte qu'on ne peut plus retrouver la silhouette des grains, ce qui supprime toute possibilité d'estimation de pertes au moyen de méthodes connues telles que :

- Méthodes de comptage et du pesage (MCP) des grains (Anon, 1969) ;
- Méthode du poids volumique standard (MPVS) des grains, d'après Adams et Schulten (1978) ;
- Méthode du poids de mille grains (MPMG), d'après Proctor et Rowley (1983).

Le premier prélèvement d'échantillon a été fait trois mois après l'installation de l'essai, les suivants mensuellement. Chaque échantillon de 100 épis a été fumigué au PH3 aussitôt après prélèvement pour tuer les charançons, puis après le despathage et l'égrenage des épis sont effectués, la farine et les charançons sont tamisés (à l'aide des tamis à mailles de 1 et 3 mm). Les grains et la farine ont été ensuite pesés, et la portion de farine estimée en pourcentage du poids total initial, les charançons dénombrés par espèces.

La teneur en eau des grains a été mesurée avec un humidimètre (Pfeuffer HOH-Express Type HE 30). L'écart-type et la moyenne ont été calculés à partir des trois répétitions de chaque variante. Nous avons déterminé les pertes en poids par les méthodes de la pesée des échantillons (Pantenius C.U. et Schulz F.A. 1986; Pantenius, 1987) et de la détermination de la proportion de farine.

RESULTATS

Le pourcentage de farine en début de conservation était nul car aucune attaque au champ des épis en spathes par P. truncatus n'a encore été signalée au Togo et les pertes occasionnées au champ par les autres charançons et espèces de lépidoptères ont été négligeables.

Perte en poids sec

La perte en poids estimée selon la méthode de la pesée des échantillons a donné les résultats suivants:

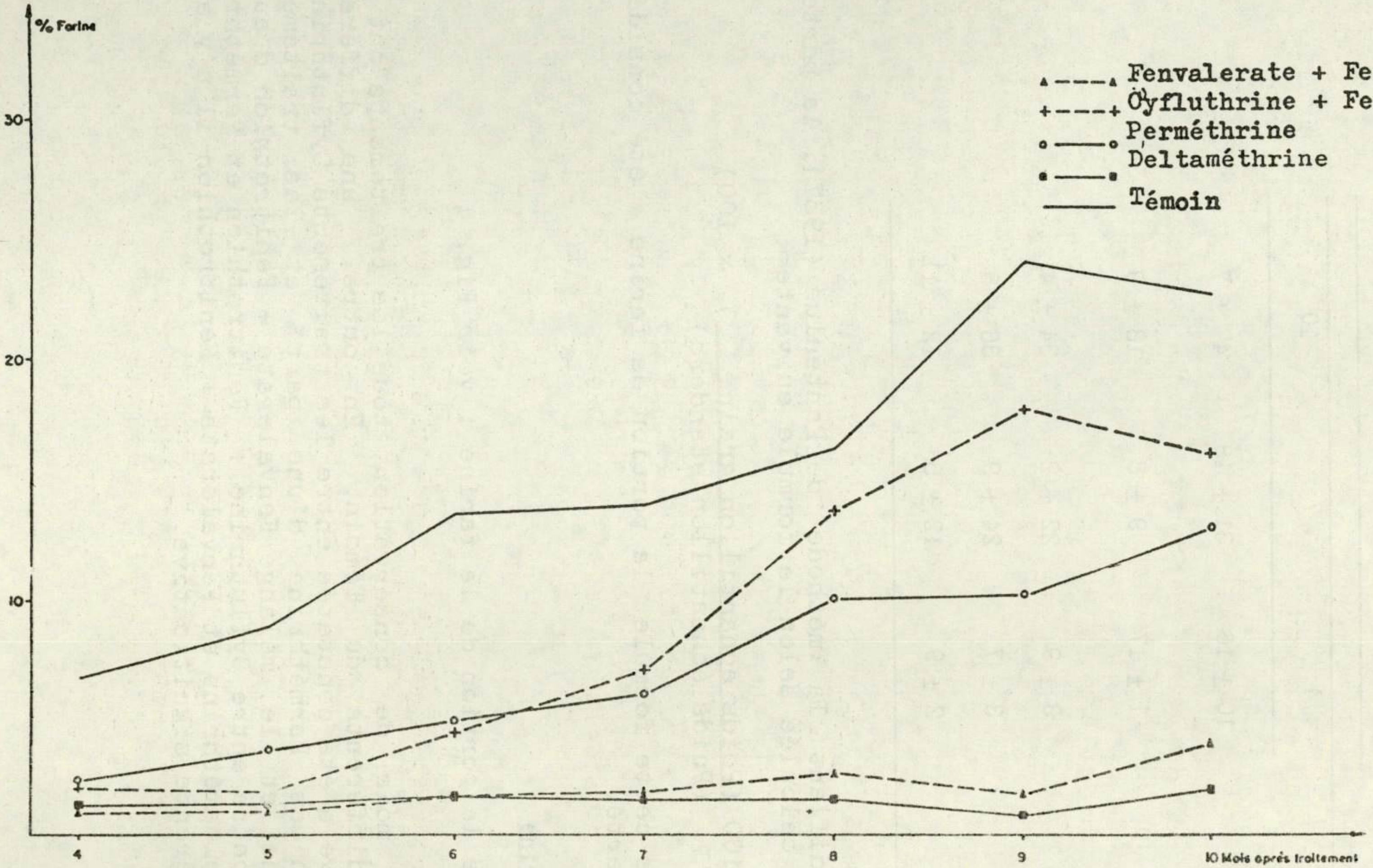

Fig. 1. Production de farine pendant le stockage

Tableau 1. Evolution de la perte en poids sec (%) (moyenne de trois répétitions).

Traitement	Intervalle entre prélèvement et traitement (mois)		
	4	7	10
Témoin	10 ± 16	31 ± 18	47 ± 7
Fenvalerate + Fenitrothion	1 ± 17	9 ± 8	18 ± 9
Cyfluthrine + Fenitrothion	3 ± 9	22 ± 2	34 ± 4
Perméthrine	3 ± 7	24 ± 9	36 ± 8
Deltaméthrine	2 ± 9	12 ± 5	12 ± 11

En modifiant la méthode de Panténius (1987), la perte en poids a été calculée selon la formule suivante :

$$100\ (\frac{\text{Poids échantillon grain}}{\text{(Poids échantillon standard)}})\ \times 100)$$

D´après cette formule, la portion de farine a été considérée comme une perte.

Portion de farine

Evolution de la portion de la farine : voir Fig. 1

A dix mois de conservation, tous les traitements ont été nettement différents du Témoin. En outre, une différence significative a été constatée entre les traitements Cyfluthrine + Fenitrothion et Perméthrine d´une part, et les traitements Deltaméthrine et le mélange Fenvalerate + Fenitrothion d´autre part. Par contre entre Cyfluthrine + Fenitrothion et Perméthrine ou entre Deltaméthrine et Fenvalerate + Fenitrothion il n´y a eu aucune différence significative.

Nombre de P. truncatus

Tableau 2. Développement de la populatiion de P. truncatus (imagos/100 épis, moyennes de 3 répétitions).

Traitement	Intervalle de temps entre le traitement et le prélèvement (Mois)		
	4	7	10
Témoin	3491 ± 1002	9199 ± 1302	4073 ± 2210cd
Fenvalerate + Fenitrothion	46 ± 35a	191 ± 21a	905 ± 203a
Cyfluthrine + Fenitrothion	246 ± 178a	4679 ± 1302	4612 ± 631bc
Perméthrine	596 ± 589a	2364 ± 624	3252 ± 832bd
Deltaméthrine	19 ± 17a	47 ± 16a	22 ± 12a

Les chiffres suivis d´une même lettre ne sont pas significatifs à $P < 0,05$.

La population de P. truncatus dans les greniers témoins a été la plus élevée entre les 5ème et 8ème mois, puis a rapidement décru, probablement par manque de nourriture. Le développement de la population du P. truncatus dans les divers traitements a été par contre très lent : le nombre de P. truncatus a peu progressé jusqu´à la fin de l´essai (traitements Cyfluthrine + Fenitrothion et Perméthrine) ou est resté presque constamment à un niveau bas (traitement Fenvalerate + Fenitrothion) ou extrêmement bas (traitement Deltaméthrine). Le coefficient de corrélation entre le nombre de P. truncatus et la quantité de farine (pour un pourcentage de farine entre 0,1 et 15 % était de 0,86. La population de P. truncatus a brusquement décliné pour les valeurs de portion de farine supérieures à 15 %.

Tous les quatre traitements ont été efficaces et statistiquement différents du témoin au 7ème mois de conservation. La variante Cyfluthrine + Fenitrothion était le moins efficace, les autres traitements Deltaméthrine et Fenvalerate + Fénitrothion - les plus efficaces. Après 10 mois de stockage, les traitements Fenvalerate + Fenitrothion et Deltaméthrine avaient des différences significatives par rapport au témoin et aux traitements Cyfluthrine + Fenitrothion et Permethrine (décroissement de la population du témoin).

Nombre de charançons : leur infestation a été naturelle

Tableau 3. Développement de la population totale des charançons (imagos/100 épis, moyennes de 3 répétitions).

Traitement	Intervalle de temps entre le traitement et le prélèvement (mois)		
	4	7	10
Témoin	5267 ± 1417	11917 ± 1387	12125 ± 6262a
Fenvalerate + Fenitrothion	2661 ± 1404a	2538 ± 599b	5978 ± 1930a
Cyfluthrine + Fenitrothion	2405 ± 778a	7783 ± 1784a	12089 ± 1064a
Perméthrine	3117 ± 1563a	6390 ± 2399a	10640 ± 2746a
Deltaméthrine	2896 ± 895a	1675 ± 270a	1810 ± 665a

Les chiffres suivis d´une même lettre ne sont pas significatifs à $P < 0,05$.

Sur le témoin le nombre maximum des charançons a été enregistré au 8ème mois de conservation avec un taux d´accroissement continu. Dans les traitements Cyfluthrine + Fenitrothion et Perméthrine, la population totale des charançons a constamment progressé du 6ème mois de conservation jusqu´à la fin de l´essai. Dans les traitements Fenvalerate + Fenitrothion et Deltaméthrine, la population des charançons s´est maintenue à un niveau constant pendant respectivement 9 et 10 mois. Le coefficient de correlation entre le nombre total de charançons et la quantité de farine était de 0,97 (pour un pourcentage de farine situé entre 0,1 et 17 %); la population des parasites a rapidement décru pour des valeurs de portion de farine supérieures à 17 %.

Outre P. truncatus, les espèces suivantes de charançons, par ordre d´importance, étaient responsables des pertes post-récolte : Sitophilus spp., Tribolium spp., Palorus subdepressus, Cathartus quadricollis et Carpophilus spp. (les premiers mois de conservation), Cryptolestes spp. (vers la fin de la période de conservation).

Après 4 et 7 mois de conservation, tous les traitements étaient statistiquement différents du témoin. Au 7ème de conservation, les variantes Fenvalerate + Fenitrothion et Deltaméthrine étaient significatifs par rapport aux traitements Cyfluthrine + Fenitrothion et Perméthrine. A 10 mois de conservation seule la variante Deltaméthrine étaient efficace.

DISCUSSION

Détermination des pertes

Les méthodes traditionnelles de détermination de la perte en poids (Harris et Linblad, 1978) est fondée sur la comparaison d'un épi endommagé par un parasite à un épi sain. Dans le cas de P. truncatus l'application de ces méthodes donne des estimations de pertes non représentatives des dégâts réels à cause de la particularité de ses dommages engendrant une destruction souvent complète de l'épi en cas d'une attaque sévère. La méthode de poids des échantillons préconisée par Pantenius (1987), consistant à comparer respectivement 100 épis avec un échantillons standard externe, apparaît théoriquement plus prometteuse bien qu'elle ne manque pas de lacunes en pratique :

- enregistrement de pertes négatives
- fluctuation des données au sein des traitements entraînant des valeurs élevées de l'écart-type
- impossibilité d'enregistrer un accroissement continu des pertes pour une longue période de stockage.

Les causes possibles, relatives à ces résultats sont entre autres :

1. l'inégale répartition des différents calibres d'épis dans le grenier, ce qui rend l'échantillon de 100 épis non représentatif.

2. l'irrégulière infestation au sein du grenier ; les données de pertes ainsi obtenues ne sont pas représentatives de l'ensemble du grenier car le prélèvement ne s'effectue que dans la couche supérieure du grenier.

3. certaines erreurs subjectives telles que la préférence pour des épis grand ou petits lors du prélèvement ; le prélèvement de 100 épis devrait être mieux standardisé pour éviter de telles erreurs.

Par conséquent, la discussion sur l'amélioration de la méthode de poids des échantillons par augmentation du nombre des épis par prélèvement et/ou par modification de la technique de prélèvement reste ouverte.

Les méthodes d'estimation des pertes dûes à P. truncatus considèrent la quantité de farine issue des dégâts comme éléments de calculs, éliminant ainsi, tout comme la méthode du comptage et de la pesée, de potentielles sources d'erreur. En outre elle est pratique, car les pertes ne sont plus calculées en fonction du poids de la matière sèche, ce qui rend superflues les mesures de la teneur en eau.

La portion de farine reflète principalement les pertes causées par P. truncatus. Cette portion donc se situe en dessous de la perte totale qui cumule aussi les dégâts causés par d'autres parasites, la farine consommée et la farine non recueillies lors des prélèvements des échantillons pour le maïs en spathe.

La portion de farine, comme paramètre des pertes dues aux attaques par P. truncatus en spathe devrait servir selon nous de base pour les essais ultérieurs.

Efficacité des produits testés

Les résultats montrent que l'application de la Deltaméthrine ou de Fenvalerate + Fenitrothion sur les épis en spathe dans les greniers traditionnels aux doses indiquées maintient le maïs, pendant une période de 10 mois dans un état acceptable pour la consommation humaine.

A partir du 7ème mois, la variante Deltaméthrine s'est avérée plus efficace que le mélange. Les matières actives Perméthrine et Cyfluthrine + Fenitrothion ont été jusqu'au 5ème mois de conservation satisfaisants. Cependant leur application en milieu rural dans le Sud Togo ne peut être recommandée que dans des cas exceptionnels, car leur efficacité se dégrade significativement dans le temps. Les grains du témoin (non traité) étaient inconsommables et pouvaient tout au plus servir comme aliment de bétail.

Comme difficultés inhérentes à la vulgarisation de la méthode décrite on peut citer le manque d'appareils de traitement et de récipients appropriés de mesure pour la pulvérisation ; en outre les paysans éprouvent beaucoup de difficultés pour calculer les doses, la concentration etc. Le concours des services d'encadrement des paysans serait très souhaité pour remédier à cette lacune.

Du point de vue toxicologique, la méthode est relativement sécurisante, car la matière active est surtout appliquée sur les spathes et n'entre pas en contact direct avec les grains : en cas de surdosage donc, aucun danger de résidus n'est à craindre. La méthode décrite ne peut cependant pas prétendre être meilleure aux traitements alternatifs tels que le stockage en sacs du maïs préalablement traité avec un insecticide en poudre.

L'avantage de cette méthode de pulvérisation réside cependant dans le fait que, concernant spécialement le Sud du Togo, les structures de stockage traditionnelles peuvent être maintenues, ce qui facilitera l'acceptation de la méthode par le groupe-cible. Dans un essai ultérieur la technique d'application sera simplifiée (application de la solution insecticide sur les épis à l'aide d'un pinceau artisanal) afin d'adapter cette méthode au milieu rural.

Les essais ultérieurs feront l'objet d'autres publications.

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22. Importance de l´Association Mil/Niébé dans les Relations entre Bruchidius atrolineatus (Coleoptera bruchidae) et sa Plante Hôte Vigna unguiculata (L.) Walp. dans un Agrosystème Sahélien au Niger.

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RESUME

Les travaux ont porté sur l´effet de l´association du mil et du niébé sur l´infestation des gousses du niébé (Vigna unguiculata (L.) Walp) par Bruchidius atrolineatus pic. L´étude de la contamination des gousses par les pontes de B. atrolineatus montre que: sous canopée dense, on ne note pas de différence entre l´infestation des gousses du niébé associé au mil et celles de la culture pure ; il en est de même pour le nombre moyen d´oeufs par gousses. Sous une canopée moins importante, ces résultats ne changent pas. Sous une canopée insignifiante (mil à maturité) où le niébé associé au mil est tout aussi exposé que le niébé en culture pure, il n´y a guère de différence entre les deux systèmes de culture pour ce qui concerne la contamination des gousses par les pontes.

Par contre, l´étude du développement larvaire de la bruche montre une plus forte mortalité au cours du développement de B. atrolineatus dans la culture pure. Effectivement, si la ponte a lieu sur les gousses formées sous canopée peu importante ou insignifiante, le taux d´émergence des bruches n´est pas différent de celui de la culture pure. Sous une canopée dense, le taux d´émergence des bruches est plus élevé dans la culture associée. L´association avec le mil crée donc des conditions favorables au bon développement des bruches constituant ainsi un grand inconvénient du système actuel de culture.

ABSTRACT

The effect of millet/cowpea intercropping on infestation of cowpea pods by Bruchidius atrolineatus was studied. A study of pod infestation by eggs of B. atrolineatus showed that in dense crop canopy, the incidence of egg-infested pods as well as the average number of eggs per pod in cowpea intercropped with millet were not significantly different from those in sole crop cowpea. Similar results were obtained for different crop canopy regimes (with respect to the above two insect egg characteristics) including the canopy regime obtained after the millet crop had been harvested, thereby exposing intercropped cowpea to ambient conditions similar to those in pure stand cowpea.

In contrast, other results have revealed high bruchid larval mortality in pure crop cowpea compared to any situation in intercropped cowpea. Also the rate of bruchid larval emergence was much higher in intercropped cowpea under dense canopy than in sole crop cowpea. However, under less dense crop canopy, the rate of bruchid larval emergence from infested pods of intercropped cowpea was similar to that in sole crop cowpea. It appears, therefore, that under dense crop canopy, intercropping cowpea with millet, creates favourable conditions suitable for the development of B. atrolineatus.

INTRODUCTION

De nombreux travaux ont démontré l'importance de l'hétérogénéïté de la végétation sur la répartition des populations d'insectes phytophages (Perrin, 1980 ; Altieri et Letourneau, 1982; Andow, 1982). Selon Kayumbo et al. (1976), les populations de Ootheca bennioseni et d'hémiptères Coreidae seraient beaucoup plus faibles dans l'association maïs-niébé que dans une monoculture de niébé.

Des résultats analogues ont été observés chez la bruche Acanthoscelides obtectus dans l'association maïs-haricot par Labeyrie et Maison, (1954) ; et Parfait, (1986).

Plusieurs théories ont été avancées par ces auteurs pour expliquer le fait que la plante recouverte était moins attaquée par les insectes phytophages.

Certains auteurs pensent que la canopée dense formée par la plante recouvrante rendrait plus difficile la découverte de la plante hôte en créant une barrière physique (Tahvanainen et Root,1972; Feeny,1976; Risch,1980) ou en créant un masquage chimique (Hill,1977 ; Uvah et Coaker,1984).

Pour d´autres, la canopée dense en modifiant les caractéristiques microclimatiques pourrait perturber l´activité reproductrice des insectes phytophages (Andow,1982) ou servirait de refuge aux entomophages augmentant ainsi le parasitisme au niveau de la culture associée (Root,1973 ; Dempster et Coaker, 1974; Way,1977).

Au Niger, le niébé (Vigna unguiculata (L.) Walp.) est cultivé surtout en association avec le mil (Pennisetum americanum). Cette association suscite un intérêt au niveau du niébé où on note de fortes attaques d´insectes de la famille des Bruchidae, particulièrement Bruchidius atrolineatus Pic. et Callosobruchus maculatus F.

Nous avons entrepris dans la présente étude une comparaison de situation (en ce qui concerne la ponte et le développement de B. atrolineatus) dans deux systèmes différents de cultures: l´un de culture pure (niébé seul) et l´autre de culture associée (niébé/mil).

MATERIEL ET METHODES

Les études ont été réalisées de 1982 à 1984 dans une zone de culture traditionnelle (mil/niébé) couvrant plus de 5 hectares et située dans le campus universitaire de Niamey. Les terrains expérimentaux ont une superficie de 200 m² (20 m x 10 m). La variété de mil 3/4 HK, et la variété de niébé TN88-63 ont été utilisées dans les deux types de cultures. En culture pure, les poquets de niébé sont séparés par des intervalles de un mètre. Dans les terrains de culture associée, l´écart entre un poquet de mil et un poquet de niébé voisin d´une même rangée est de 0,50 m.

Les gousses sont numérotées dès leur apparition au niveau des poquets et leur contamination par les pontes de B. atrolineatus est suivie régulièrement tous les quatre jours jusqu´à la récolte. D´autres paramètres tels que le parasitisme par les cophages (Uscana lariophaga) et les entomophages (Bruchocida vuilleti), ou les orifices de sortie des bruches adultes, sont également notés. Le stade de maturation de la gousse tel que défini par Alzouma et Huignard (1981), la longueur de la gousse et le nombre de graines apparentes sont enregistrés aussi.

RESULTATS ET DISCUSSIONS

Des travaux antérieurs (Alzouma, 1981; Alzouma et Huignard, 1981) ont montré que les populations adultes (mâles et femelles aptes à se reproduire) de *B. atrolineatus* apparaissent dans les cultures à la fin de la saison des pluies lorsque le niébé commence à fructifier. Durant la journée, les bruches se réfugient dans les épis de mil dont elles consomment le pollen, mais dès le début du crépuscule, les insectes voltigent vers les plants de niébé au niveau desquels les femelles déposent leurs oeufs sur les gousses en voie de maturation. Cette activité de ponte se poursuit pendant toute la période de formation et de maturation des gousses, et au moment des récoltes on peut constater que la plupart des gousses portent déjà des trous d´émergence de bruches adultes.

Etude de la contamination des gousses par les pontes de *B. atrolineatus*

L´analyse globale des résultats obtenus en 1983 et 1984 (Tableau 1) au niveau des trois sites d´étude montre qu´il n´y a pas de différences significatives en ce qui concerne les pontes entre la culture pure et la culture associée. Les pourcentages de gousses attaquées (gousses ayant reçu des oeufs avant la récolte) sont très élevés (supérieurs à 80% et constants d´une année à l´autre et d´un site expérimental à un autre). Toutefois, l´analyse de la distribution des gousses en fonction du nombre d´oeufs qu´elles reçoivent au niveau de chaque poquet, fait ressortir une certaine variabilité. Les premières gousses formées sont les plus contaminées et elles reçoivent plus d´oeufs à la récolte que les gousses formées plus tardivement.

Tableau 1. Ponte de *B. atrolineatus* dans les terrains expérimentaux en 1983 (1) et 1984 (2-3) en culture associée (CA) et en culture pure (CP). Valeurs X^2 non significatives à P 0.05 1 ddl (3,8).

Terrains	Nombre de gousses étudiées	Nombre de gousses attaquées(%)	Test X^2	Nombre d´oeufs	Nombre d´oeufs/ gousses attaquées
CA (1)	276	230 (83,3)	0,67	1.935	8,4
CP (1)	786	615 (78,2)		6,172	10,03
CA (2)	413	336 (81,4)	0,94	2.433	7,2
CP (2)	1.081	996 (92,0)		8.013	8,05
CA (3)	630	560 (89,0)	0,33	4,519	8,06
CP (3)	1.979	1.846 (93,3)		11.384	6,16

Analyse des pontes de B. atrolineatus dans la culture associée en fonction de l´évolution de la canopée de feuilles de mil

Nous avons distingué trois périodes.

a) Une période A (31 Août au 9 Septembre), durant laquelle le niébé se trouve sous une canopée dense de feuilles de mil, la luminosité y est supposée plus faible et les variations thermiques plus amorties.

b) Une période B (9-21 Septembre), où le mil commence à se déssécher et la canopée de feuilles de mil devient moins importante au dessus du niébé.

c) Une période C (21 Septembre au 8 Octobre), où la situation devient identique dans les deux cultures.

Les résultats observés en culture associée sont comparés à ceux obtenus durant les mêmes périodes en culture pure.

- Au cours de la période A (Tableau 2), il n´apparait pas de différences dans les deux types de cultures tant en ce qui concerne le pourcentage de gousses portant des oeufs (à la fin du stade 2) que le nombre moyen d´oeufs sur les gousses. La comparaison des pourcentages de gousses contaminées donne un $X^2 < 3,8$ non significatif à p 0,05 1 ddl. Pour les nombres moyens, le test "t" donne des valeurs non significatives également.

Tableau 2. Etude des pourcentages de gousses contaminées et du nombre moyen d´oeufs par gousse dans les deux types de cultures effectifs de gousses étudiées). (Résultats obtenus en 1983).

	Gousses à la fin du stade 2		Gousses à la fin du stade 4	
	Culture pure n = 33	Culture associée n = 87	Culture pure n = 336	Culture associée n = 84
Pourcentage de gousses contaminées	96	86	98,4	92
Valeurs du X^2	0,86 NS		0,81 NS	
Nombre moyen d´oeufs par gousse attaquée	11,2±2,5	8,9±4,2	15,6±3,4	14,9±4,2
Valeur du test "t"	1,2 NS		0,7 NS	

- Au cours de la période B (Tableau 3), les valeurs obtenues tant pour le test X² que pour le test "t" ne sont pas significatives comme dans le cas de la période précédente.

Tableau 3. Etude des pourcentages de gousses contaminées et du nombre moyen d'oeufs par gousse dans les deux types de cultures (n = effectifs de gousses étudiées). (Résultats obtenus en 1983).

	Gousses à la fin du stade 2		Gousses à la fin du stade 4	
	Culture pure n = 185	Culture associée n = 83	Culture pure n = 177	Culture associée n = 73
Pourcentage de gousses contaminées	67,4	47	91,8	84,2
Valeur du X^2	3,8 NS		0,11 NS	
Nombre moyen d'oeufs/gousse attaquée	3,7±0,4	4,8±0,7	6,7±0,4	8,7±1,5
Valeur du test "t"	1,8 NS		0,9 NS	

- Au cours de la période C (Tableau 4), les pourcentages de gousses contaminées évoluent de la même manière dans les deux types de cultures. Mais des différences entre les nombres moyens d'oeufs par gousse apparaissent aux stades 2 et 4 de saturation des gousses. Ces différences sont probablement dûes aux écarts dans les effectifs de gousses observées dans les deux types de cultures, la production de gousses étant nettement plus faible en culture associée dans nos conditions expérimentales.

Tableau 4. Comparaison des pourcentages de gousses contaminées (Test X^2) et des nombres moyens d'oeufs par gousse (test "t") dans les deux types de cultures (n = effectifs de gousses étudiées). (Résultats obtenus en 1983).

	Gousses de stade 2		Gousses de stade 4	
	Culture pure n = 130	Culture associée n = 30	Culture pure n = 123	Culture associée n = 30
Pourcentage de gousses contaminées	31	22,3	68,2	86,6
Valeur du X^2	0,15 NS		1,06 NS	
Nombre moyen d'oeufs/gousse attaquée	1,6±2,3	4,1±1,2	5,5±2,4	0,6±0,3
Valeur du test "t"	2,35		2,65	

Ces résultats montrent que la présence de mil en floraison et servant en plus de site refuge et de site alimentaire, n'a aucune influence sur la découverte des gousses de niébé par les femelles pondeuses de B. atrolineatus. Il est probable que les bruches très actives soient capables de se dissiper dans tous les terrains environnants, quelle que soit la composition de la biocenose.

Influence de la canopée des feuilles de mil sur le développement de B. atrolineatus

L'analyse des facteurs de mortalité susceptibles d'influencer le développement de B. atrolineatus montre que les facteurs climatiques semblent jouer un rôle prépondérant bien que difficile à quantifier, sur la mortalité élevée qu'on observe au cours du développement de B. atrolineatus. Cette mortalité très importante dans les deux types de cultures est significativement plus élevée en culture pure comme l'indique les résultats observés au cours de trois années d'étude (Tableau 5).

Table 5. Analyse des taux d'émergence des bruches adultes dans les deux types de cultures au cours des trois années successives (* : X^2 significatif à P 0,05).

	Taux de survie des bruches en culture pure	Taux de survie des bruches en culture associée	Valeur du X^2
1982 (terrains 1 et 2)	0,17	0,29	43,7*
1983 (terrains 3 et 4)	0,17	0,21	6,4*
1984 (terrains 7 et 8)	0,33	0,37	7,2*

Nous avons procédé à une analyse comparative du développement de B. <u>atrolineatus</u> par période comme dans le cas des pontes. Les résultats obtenus au Tableau 6 montrent que :

Les gousses formées au début (période A) présentent un taux d'émergence plus élevé dans la culture associée que dans la culture pure. En culture associée, la ponte et la première partie du développement ont lieu sous la canopée de mil et dans ces conditions, la mortalité au cours du développement est réduite. L'analyse des facteurs de mortalité à différentes phases du développement montre que les variations observées ne sont pas liées au parasitisme des oophages et des parasites larvaires, ni aux pertes d'oeufs par avortement des gousses.Il semble que c'est essentiellement les différences entre les conditions microclimatiques règnant dans les deux types de cultures qui expliquent ces résultats.

Lorsque la ponte a lieu sur des gousses formées plus tardivement, (périodes B et C), les taux d'émergence ne sont plus significativement différents dans les deux types de cultures.

Table 6. Comparaison des taux de parasitisme et des taux d´émergence dans les terrains 5 et 6 en fonction de la date de formation des gousses (et de l´état de la canopée de mil en culture associée).

Date de formation des gousses	Gousses A (31/8 au 9/9)	Gousses B (11/9 au 21/9)	Gousses C (21/9 au 8/10)
A.			
Nombre de gousses suivies	310	170	135
Nombre d´oeufs pondus	4.628	978	566
Fréquence d´oeufs perdus par avortement de gousses	0.04	0,02	0
Taux de parasitisme dû aux oophages	0,05	0,05	0,10
Taux de parasitisme dû à <u>Bruchocida</u> sp.	0,04	0,06	0,04
Nombre d´adultes obtenus et taux d´émergence des adultes	697 0,15	166 0,17	175 0,31
B.			
Nombre de gousses suivies	93	104	33
Nombre d´oeufs pondus	1.268	356	311
Fréquence d´oeufs perdus par avortement de gousses	0,03	0,04	0
Taux de parasitisme dû aux oophages	0,07	0,06	0,10
Taux de parasitisme dû à <u>Bruchocida</u> sp.	0,04	0,04	0,06
Nombre d´adultes obtenus et taux d´émergence des adultes	329 0,26	76 0,21	91 0,29

DISCUSSION ET CONCLUSION

Dans nos conditions d'étude et avec les variétés utilisées, il n'apparaît pas de différences en ce qui concerne les pontes déposées sur les gousses de niébé dans un système de culture pure ou dans la culture associée, bien que le mil au-dessus du niébé semble attirer les adultes de B. atrolineatus. Le mil ne paraît pas non plus représenter un obstacle particulier à B.atrolineatus pour découvrir les sites de pontes (gousses) et se disperser dans les terrains voisins. Ces résultats diffèrent de ceux qu'observent Labeyrie et Maison (1954) chez Acanthoscelides obtectus dans l'association maïs-haricot. Mais cette différence peut s'expliquer par les modes d'activités assez différents des deux espèces de bruches. En effet, B. atrolineatus est un insecte à activité crépusculaire, et l'ombrage de la canopée ne doit pas beaucoup l'influencer. Par contre, A. Obtectus est beaucoup plus actif lorsqu'il est placé à la lumière (Zachariae, 1958).

Par contre, dans nos conditions d'étude, l'association mil/Niébé semble avoir un léger effet sur la mortalité, qui est moins élevée pendant la période où le mil recouvre le niébé.

La canopée de mil amortirait les variations de température et créerait dans la culture associée un microclimat favorable ici au développement des bruches, et non à la prolifération de parasites comme cela a été signalé par ailleurs (Root, 1973).

Les résultats que nous avons obtenus au cours de ces trois années, en utilisant les mêmes variétés de mil et de niébé, et les mêmes techniques culturales, montrent que l'association culturale peut se révéler défavorable pour le niébé d'un point de vue agronomique à deux niveaux :

- Au point de vue des rendements en gousses (Wien et Nanju, 1976 ; Maréchal, 1985 ; Alzouma, 1987)
- Au niveau des pertes dûes aux bruches puisque la canopée dense du mil crée un microclimat favorable à un meilleur développement larvaire des bruches.

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23. Seed and Pod Wall Resistance of Cowpea Varieties to Attack by the Cowpea Storage Beetle, Callosobruchus maculatus (F.) (Coleoptera : Bruchidae).

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ABSTRACT

Damage caused by the cowpea storage beetle, Callosobruchus maculatus (F.), to threshed and unthreshed seeds of eight cowpea varieties (Ife Brown, IT82D-524-1, IT82D-600-5, IT81D-1137, IT82D-703, VITA-7, IT82D-716, and TVu 2027) stored for 3 months was determined. Unthreshed seeds of all varieties were less damaged by C. maculatus than threshed ones. Among the threshed seeds, damage caused by the bruchid was highest in Ife Brown and lowest in IT82D-716 and TVu 2027. When the seeds were stored in pods, Ife Brown had the highest damage, while the lowest was observed in IT82D-524-1, IT82D-600-5 and VITA-7; pod walls of these three varieties were tougher than those of the other varieties.

RESUME

Les dégâts causés par les coléoptères des stocks de niébé, Callosobruchus maculatus (F), aux récoltes décortiquées et non décortiquées de huit variétés de niébé (Ife Brown, IT 82D-524-1, IT82D-600-5, IT 81D-1137, IT82D-703, VITA-7, IT82D-716, et TVu 2027) conservées pendant 3 mois ont été évalués. Les récoltes non-décortiquées de toutes les variétés ont subi peu de dégâts de la part de C. maculatus que celles décortiquées. Parmi les récolte décortiquées, les dégâts causés par les bruches étaient les plus élevés au niveau de Ife Brown et les plus faibles au niveau de IT82D-716 et TVu 2027. Lorsque les récoltes étaient conservées avec leur gousses, Ife Broown présentait les dégâts les plus importants, alors que IT82D-524-1, IT82D-600-5 et VITA-7 enregistraient les dégâts les plus faibles. Les enveloppes de ces trois variétés étaient plus épaisses que celles des autres variétés.

INTRODUCTION

Cowpea forms a major component of many African diets due to its high protein content. The crop is thus grown in many parts of Africa where the seeds may be stored either in the threshed or unthreshed form, depending on locality. The major problem the peasant farmer faces in storing cowpea is damage caused to the seeds by the cowpea storage beetle, Callosobruchus maculatus (F.) (Coleoptera : Bruchidae) (Caswell, 1961 ; Booker, 1965). The damage caused in storage could reach 100%, if the insect is not controlled.

Application of insecticides has been the usual method of controlling C. maculatus in storage. Nevertheless, peasant farmers, who produce the bulk of the crop, have no access to insecticides or may be unwilling to use them due to several factors, such as prohibitive cost of the insecticides and farmers´ lack of knowledge of application skills (Taylor and Webley, 1979). In view of these constraints, several cowpea varieties which require no insecticide for storage, because they possess physical and chemical properties that render them resistant to attack by C. maculatus, have been developed by plant breeders; such properties include tough pod wall and high level of trypsin inhibitor in the seed (Gatehouse et al., 1979; Caswell, 1984). This study was conducted to evaluate the resistance of seed and pod wall of some cowpea varieties to attack by C. maculatus.

MATERIALS AND METHODS

Dry pods of Ife Brown (susceptible seed check), IT82D-524-1, IT82D-600-5, IT81D-1137, IT82D-703, VITA-7, IT82D-716, and TVu 2027 (resistant seed check) were fumigated with phostoxin tablet for 3 days in an air tight metal drum. The fumigated pods were aerated to remove the phosphine gas, and conditioned to the laboratory environment (temperature, 21-29°C; relative humidity, 63-84%) for 30 days. Samples of the pods were taken from each variety and threshed, while the hardness of pod wall was determined with a penetrometer (Owusu-Akyaw, 1987). Moisture content of the seeds and of the pod wall of the varieties ranged from 11.1-11.5% and 7.3-8.0%, respectively.

Five hundred grams of the threshed seeds of each variety were put into a 750-ml kilner jar. Two pairs (two males and two females) of 0- to 1-day-old adult C. maculatus were introduced into each jar which was then covered with a lid lined with a nylon cloth consisting of 400 square holes/cm². The jars were arranged on shelves in the laboratory which had been disinfested with Kelthane^R MF (an acaricide).

One kilogram of the pods of each variety was put into a calico bag. Fifty pairs of 0- to 1-day-old adult C. maculatus were introduced into each bag, the open end of which was then tied with a twine. The bags were arranged on shelves in the laboratory disinfested as described above.

RESULTS AND DISCUSSION

Figure 1a shows the damage caused by C. maculatus to threshed seeds, and to seeds in pods (unthreshed seeds) of the test varieties stored for three months. For each variety, the bruchid caused much greater damage to threshed seeds than to those in pods.

Among the threshed seeds, the highest damage occurred in Ife Brown, while IT82D-716 and TVu 2027 sustained the lowest damage. These results agree with those of Singh (1977) who reported that Ife Brown was highly susceptible, while TVu 2027 was resistant to damage by C. maculatus. Gatehouse et al., (1979) attributed the bruchid resistance in seeds of TVu 2027 to their relatively high levels of trypsin inhibitor which retards bruchid development; Ife Brown seeds contain low levels of the inhibitor. Thus, it appears that the low damage caused by C. maculatus to seeds of IT82D-716 (which was developed using TVu 2027 as a donor parent) was probably due to their high content of trypsin inhibitor which adversely affected development of the insect.

In the case of seeds in pods, the highest damage was again observed in Ife Brown. However, seeds of IT82D-524-1, IT82D-600-5, and VITA-7 (the threshed seeds of which were highly damaged by the insect) were virtually not damaged when stored in pods. Data from the penetrometer measurements indicated that IT82D-524-1, IT82D-600-5, and VITA-7 had tougher pod walls than any of the other varieties (Figure 1a). In addition, pod wall toughness was negatively and significantly ($P = 0.01$) correlated ($r^2 = -0.74$) with percentage of damaged seeds stored in pods. The lower damage caused by C. maculatus to unthreshed seeds of the varieties with tougher pod wall could be attributed to the fact that tough pod wall creates a barrier which prevents damage by the insect to the seeds inside the pods (Caswell, 1984). The lower level of pod shattering in IT82D-524-1, IT82D-600-5 and VITA-7 than in Ife Brown (Figure 1b) would complement pod wall resistance to bruchid damage in these three varieties of cowpea.

In the present study, resistance to C. maculatus was detected either in the seed or on the pod wall. Therefore, in developing bruchid-resistant varieties a conscious effort should be made to combine both forms of resistance into one cultivar. Cowpea varieties with both characters would probably possess multiple resistance against several biotypes of C. maculatus.

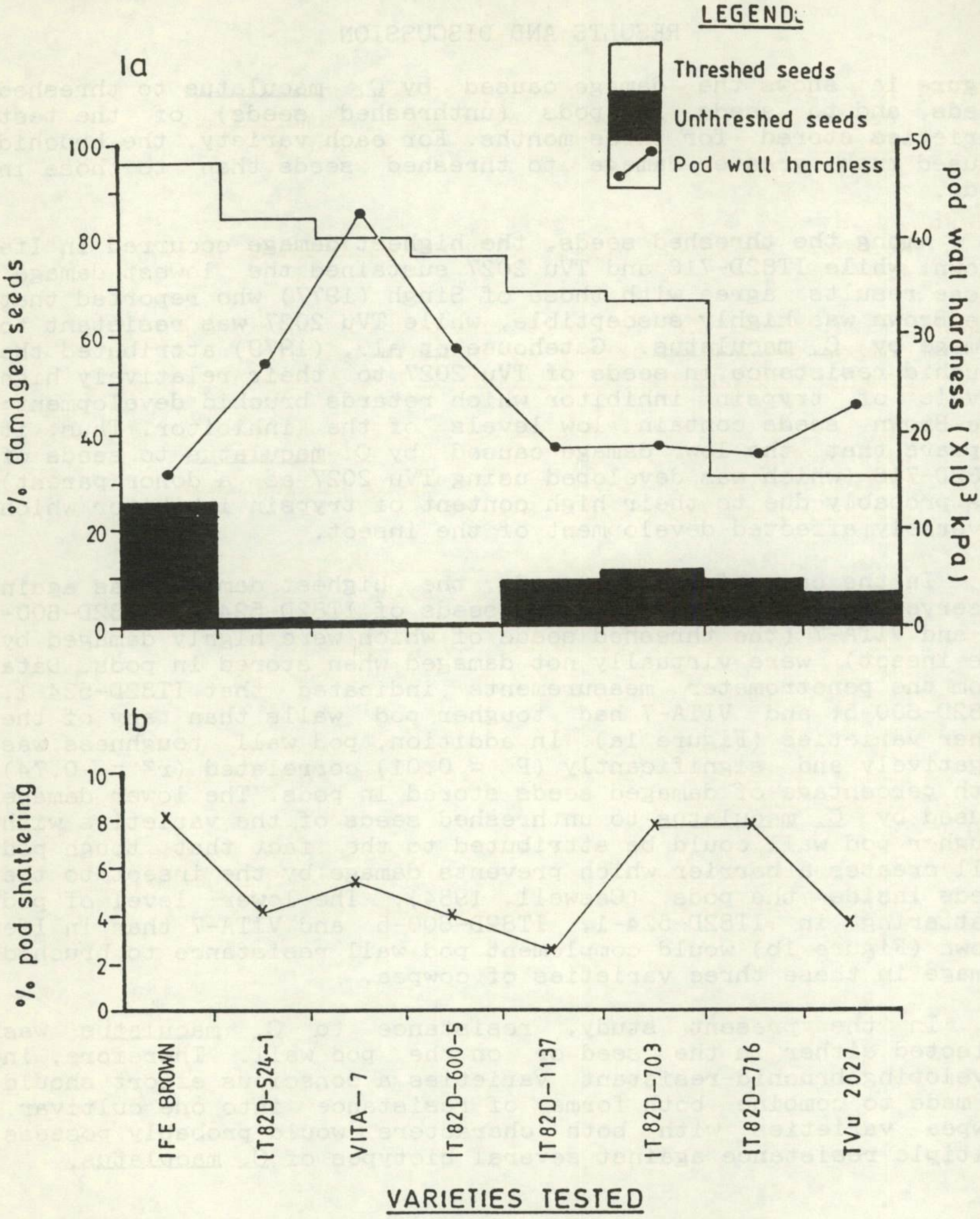

Fig. Ia : Pod wall hardness of cowpea varieties and % damage caused by C. maculatus to threshed and unthreshed seeds stored for 3 months

Fig. Ib : Percent pod shattering of cowpea varieties stored for 3 months

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24. Maize Entomology Research and Insect Resistance Breeding at IITA.

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ABSTRACT

Entomological research by maize scientists at IITA is divided among three major groups of pests, namely maize stem borers (Sesamia calamistis and Eldana saccharina), maize storage pests (principally Stitophilus spp.) and Cicadulina spp. leafhopper vectors of viruses.

Efforts are devoted to: (1) studying the biology, population dynamics and insect pest-host plant interactions, (2) development of mass rearing methods, (3) development of artificial infestation techniques and resistance scoring procedures, and (4) screening and breeding for resistance. Methods to rear stem borers have been improved and it is now possible to produce 50,000 eggs of Sesamia or 300,000 eggs of Eldana per week. Screening methods have been devised and sources of resistance to both stem borers have been identified. Studies on comparative methods to assess for resistance to Sitophilus weevils are underway. Screening of IITA maize varieties has shown genetic diversity for susceptibility/resistance to weevils. Mass rearing of Cicadulina leafhoppers is carried out on a regular basis to screen and breed for resistance to maize streak virus (MSV) and maize mottle/chlorotic stunt virus (MMCSV). Recent work at IITA on the above aspects is summarized and prospects for the development of maize varieties with resistance to insects are discussed.

RESUME

La recherche entomologique menée par les chercheurs de maîs à l´IITA intéresse trois principaux groupes d´insectes nuisibles, notamment les foreuses de la tige (Sesamia calamistis et Eldana saccharina), les insectes nuisibles de stockage (principalement Stitophilus spp.) et Cicadulina spp., cicadelles vecteurs des virus.

Les efforts consacrés : (1) à l´étude de la biologie de la dynamique de population et les interactions insectes nuisibles et plante hôte, (2) à l´élaboration des méthodes d´élevage en masse, (3) à la mise au point de techniques d´infestation artificielle et des procédures d´estimation de la résistance, et (4) au criblage et à la sélection pour la résistance. Les méthodes

d´élevage des foreuses de la tige ont été améliorées et il est possible présentement de produire 50.000 oeufs de Sesamia ou 300.000 oeufs d´Eldana par semaine. Les méthodes de criblage ont été examinées et des sources de résistance aux deux foreuses de la tige ont été identifiées. Des études sur les méthodes comparatives pour évaluer la résistance aux charançons Sitophilus sont en cours. Le criblage des variétés de maïs de l´IITA a montré une diversité génétique pour la sensibilité/résistance aux charançons. L´élevage en masse des cicadelles a été réalisé sur une bonne base en vue de cribler et de sélectionner pour la résistance au virus du streak du maïs (MSV) et le virus tacheté/chlorotique du maïs (MMCSV). Un récent travail mené à l´IITA sur les aspects ci-dessus mentionnés est résumé et des perspectives pour la mise au point de variétés de maïs ayant une résistance aux insectes ont été débattues.

INTRODUCTION

Insect pests are among the most important constraints to maize production in Africa. Losses due to attack by insect pests in Africa vary, both between years and between agro-ecological zones, but they have been conservatively estimated at 15% of total annual grain production. However, it is very likely that with the intensification of maize production, pest problems will increase in importance. Thus, it is necessary to intensify entomological research to facilitate better and more efficient means of insect pest control.

The Maize Research Program of IITA has had an entomological component since early 1970´s when the Program started. At present, priority is given to studies on the biology of insect pests and on breeding for resistance to these pests, especially as host plant resistance is regarded as the key component of an integrated pest management program. However, other methods of control (cultural, biological, and chemical) are also important and national programs could play a role in their development.

Entomological research by maize scientists at IITA is divided among three major pest groups, namely maize stem borers (*Sesamia calamistis* Hmps and *Eldana saccharina* Walker) ; maize storage pests, chiefly *Sitophilus* spp. ; and leafhopper (*Cicadulina* spp.) vectors of viruses. Efforts are devoted to : (1) studying the biology, population dynamics and insect pest-host plant interactions; (2) development of mass rearing methods; (3) development of artificial infestation techniques and resistance scoring procedures; and (4) screening and breeding for resistance.

SUMMARY OF WORK DONE TO DATE

Stem borers

The severity and nature of stem borer damage depends upon the borer species, the plant growth stage, the number of larvae feeding on the plant, and the plant's reaction to borer feeding. Almost all plant parts (leaves, stem, tassel, and ears) are attacked. Crop losses may result from death of the growing point (dead hearts), early leaf senescence, reduced translocation, lodging, and direct damage to the ears. Estimates of yield losses caused by maize borers in Africa range from 10 to 100% (Usua, 1968).

In general, stem borers are far more abundant in second season maize than in that of the first season. Some potential for cultural and biological control of stem borers exists, but resistant varieties have been suggested as the most promising means of control (Bowden, 1976 ; Girling, 1980).

IITA's research on maize borers has largely been confined to S. calamistis and E. saccharina, the predominant species in the forest zone of West Africa. Screening for borer resistance was earlier done under natural infestations, but at present all selections are done under artificial infestations (Bosque-Perez *et al*., 1989).

Mass rearing of borers is required to provide the insects for infestations. Methods to rear stem borers in the laboratory have been improved and at the peak of the production cycle, it is possible to produce 50,000 and 300,000 Sesamia and Eldana, respectively, per week.

Sesamia calamistis infests maize plants at early stages of development. To screen for resistance to this insect, plants are infested 21 days after planting by placing egg masses at the black-head-stage (one day before hatching) between the leaf sheaths at the base of the plant. Plants are infested with 50 to 75 eggs, depending on their degree of inbreeding. Rating of plants is done 14 days after infestation and at tasseling, using a scale based on overall plant damage (Table 1).

Table 1. Rating scale for Sesamia calamistis based on overall plant damage.

Rating	Description
1	No visible leaf injury or small number of pin holes on one or two leaves.
2	Small amount of shot-hole type lesions on two or three leaves.
3	Shot hole injury on four or more leaves and elongated lesions (2.5 cm) on two or three leaves.
4	Four to five leaves with elongated lesions (2.5 cm or more).
5	Broken mid ribs, elongated lesions on six or more leaves, some tassel damage.
6	Severe leaf damage and/or broken tassel and plant slightly stunted.
7	Stunted plant, top portion of the plant dead or drying up, or stalk broken above the ear.
8	Plant broken midway between the ear and the ground, or plant severely stunted and drying.
9	Dead heart or plant killed.

The development of screening methods and the selection of Sesamia-resistant materials have been enhanced by the use of resistant (TZ1 4) and susceptible (TZ1 19) inbred lines as checks ; both lines were developed at IITA. Since 1986, a wide diversity of germplasm has been screened for their reaction to infestation by Sesamia. This includes the BR population of IITA (developed by screening for Sesamia under natural infestation) the CIMMYT MBR (multiple borer resistant) population, a portion of the MIR (maize inbred resistant) lines from Hawaii, and a wide range of germplasm from North and South America resistant to other species of maize stem borers. Sources of Sesamia resistance have been found among all these germplasm groups, as well as within other adapted tropical germplasm. Subsequently, three Sesamia-resistant populations were formed. TZBR-Sesamia-1 was formed in 1987 using six sources of resistance CM 116, INV 575, Cateto Assis Brazil RGS x IV, Cateto Grande Mil, Costeno Mag. 350, and Cubano Cateto Ecuador 339) crossed to TZI 4. It is currently undergoing S1 family selection for tropical adaptation and Sesamia resistance. TZBR-Sesamia-3 was formed in 1988 using 29 lines (mostly from the MBR population) crossed to TZI 4. Another population (TZBR-Sesamia-2) was also formed in 1988 from 7 TZI lines (TZI 4, 6, 8, 9, 10, 17 and 18) which had shown some resistance to Sesamia. Since the source germplasm of TZBR-Sesamia-2 was both tropically adapted and resistant to maize streak virus, it is likely to produce useful varieties for African farmers in a shorter period of time.

In contrast to Sesamia, Eldana begins to infest maize plants around flowering time. Thus, artificial infestations are done within one week after silking. A plant is infested by placing 80-100 black-head-stage eggs behing the leaf sheaths at the node below the ear. At maturity, the infested maize stalks are split open and the percentage of the stalk damage below the ear is estimated. The percentage of the grain damaged by borers is evaluated using a 1-5 rating scale (1=0-5%; 2=6-25%; 3=26-50%; 4=51-75% and 5=76-100% kernel damage). In addition, notes on standard agronomic characters, including stalk breakage, are made. Streak-susceptible germplasm with potential for resistance to Eldana are evaluated as testcrosses to a tropically adapted, streak resistant tester.

In 1985, 102 materials were screened as testcrosses with the hybrid 8338-1 ; of the 50 that were furter tested in 1986/87, 14 were selected, backcrossed to the original introduction, and used to form the TZBR-Eldana-1 population. This population is being improved for adaptation and Eldana resistance by a modified form of S1 family testing. S1 family testing normally has three generations per cycle of selection, namely (1) formation of S1 families, (2) testing and selection of the best families, and (3) recombination of selected families. Large numbers of S1 lines have been planted for screening but, since borer rearing facilities are limited, only two replications are possible, while some of the lines with poor agronomic characters are rejected before artificial infestation. In order to improve the precision of testing, the recombinaison generation (step 3 above) has been modified slightly. Thus, whilst the initially selected S1 lines are being recombined, they are also rescreened for Eldana resistance in a trial with three replicates. Reselection is then conducted among S1 lines pollinated by a mixture of pollen from all the initially selected S1 lines. This selection procedure will continue to be used to improve the TZBR-Eldana-1 population, but future cycles will be conducted using higher selection intensities.

Inbreds lines with tropical adaptation were screened for Eldana resistance in 1987 and the best five (TZI 2, 10, 12, 15, and ICAL 27) were recombined to form a synthetic (TZBR-Eldana-2). Tropically-adapted, late-maturing, open-pollinated populations were also screened for resistance in 1987 and three populations (DMR-LSRW, La Posta and TZSR-W-1) were selected for further testing. Existing S1 lines from La Posta and DMR-LSRW were screened in 1988 and 15 and 33 superior lines, respectively, were selected and recombined to form the TZBR-Eldana-3 population. S1 lines from TZSR-W-1 will be screened in 1989 and included in this population. The availability of sources of resistance to Eldana and the relatively high level of precision achieved in screening trials indicate that rapid progress can be made in selection for Eldana resistance.

Storage pests

Many species of insects infest stored maize in Africa, and severe losses are known to occur as a result of their attack (Dick, 1988). The most important species in West Africa are *Sitophilus zeamais* Motschulsky, *Prostephanus truncatus* (Horn) and Mussidia *nigrivenella* Rag.

At IITA, efforts have been concentrated on Sitophilus weevils, while limited work has been carried out on Mussidia. Prostephanus is present only in Benin and Togo and thus no work on it can be conducted in Nigeria. However, IITA is planning collaborative work on Prostephanus with the Overseas Development Natural Resources Institute (ODNRI) in the U.K.

Work on Sitophilus weevils includes studies on comparative methods to assess resistance ; screening IITA maize varieties, hybrids and inbred lines for their reaction to weevils ; and on-farm storage trials. The latter are conducted in collaboration with IITA's Resource and Crop Management Program.

Collaborative work, on screening methods and the effect of husk cover on weevil infestations, is also underway with scientists from the Republic of Benin. A good husk cover is a key factor in reducing infestations and damage. Pericarp hardness and chemical composition of the endosperm are also known to affect the degree of resistance. Screening of IITA's maize varieties has shown genetic diversity for susceptibility/resistance to weevils (Table 2). Degree of flintiness is negatively correlated with numbers of weevils (Table 3).

Table 2. Number of F1 Sitophilus weevils emerging, index of susceptibility, and grain texture of 10 varieties of maize tested under artificial infestation at Ibadan in 1988.

Variety	Number of F1 weevils	Index of suscepti-y bility+	Grain texture++
IK(1)8149-SR	143	12.3	3.8
Acr.86 TZUT-SR-W	133	12.2	3.2
TZPB-SR	123	11.9	3.7
EV8443-SR	113	11.7	3.7
Acr.85 TZSR-W-1	111	11.4	2.3
EV 8444-SR	103	11.2	3.3
DMR-LSR-Y	90	11.0	1.8
TZ Syn.6	89	11.0	2.2
8321-18	83	10.7	1.5
Pop.25-SR	81	10.6	2.0
F Prob.	0.01	0.03	<0.001
LSD	36.7	1.3	0.99
CV	19.6	6.7	22.3

+: Index of susceptibility = [(logeF)D]100, where
F = number F1 weevils and D = median development period.
++: Scale of 1-5, 1 = flint ; 5 = dent.

Table 3. Correlation matrix of number of F1 weevils, median development period (MDP), index of susceptibility, and grain texture of 24 maize varieties tested under laboratory conditions in Ibadan in 1988.

	No. weevils	MDP	Index
No. weevils		-	-
M D P	-.46*	-	-
Index	.93	-.74**	-
Texture	.49*	-.18	.45*

* : significant ; ** : highly significant.

Screening is done under laboratory conditions using artificial infestations. Sitophilus weevils are reared in the laboratory on a continuous basis. Maize materials for evaluation on a given test are grown together in a field trial, to avoid variability due to growing conditions. Seeds or cobs are frozen for a week to eliminate insects coming from the field. Seeds are infested at moisture content of 12-13%. Samples of grain (50g) of each test material are placed in small glass jars and 50 unsexed weevils added to each jar for a 10-day oviposition period, after which the weevils are removed. Evaluations are also done by placing four cobs in a cloth bag, and infesting with 100 weevils for 10 days. Emerging weevils are counted and removed. All tests are replicated two to four times. The relative level of resistance/susceptibility is assessed using the number of F1 weevils emerging and the median development period (MDP), estimated as the time from the middle of the oviposition period to the emergence of 50% of the F1 generation. An index of susceptibility is then estimated using the formula (LogeF)/D) 100, where F = number of F1 weevils and D = MDP (Dobi 1974). The higher the index the more susceptible the variety. Grain loss is determined using the formula [(UNd) - (DNu)/U(Nd + Nu)]100, where U and Nu are the weight and number of undamaged grains, respectively, and D and Nd the weight and number of damaged grains, respectively.

This work will be expanded to assess larger numbers of materials and segregating generations and it is hoped that progress can be made in this important area of research.

Insect vectors of maize viruses

Cicadulina spp. leafhoppers are the vectors of the two most important viruses of maize in Africa : maize streak (MSV) and maize mottle/chlorotic stunt (MMCS). Severe economic losses have been reported in up to 20 African countries, when epidemics of MSV occurred (Fajemisin, 1984). Several species of Cicadulina are known to be vectors of these two viruses, but their relative importance and distribution vary in different parts of Africa.

Techniques have been developed at IITA to mass rear C. triangula for the MSV resistance screening. These techniques have been perfected over the years and it is possible to rear 200,000 leafhoppers and infest 50,000 plants per week at the peak of the production cycle (Dabrowski, 1985). A complete description of the methods to rear leafhoppers and recommendations on how to modify these for the needs of national programs has been provided by Dabrowski (1989).

To maintain the quality of the colony at IITA, rearing of Cicadulina leafhoppers is done on a regular basis, as are studies on transmission efficiency. At present, emphasis is on the biology and ecology of vectors in relation to virus epidemiology. The grass sources of the viruses and the vectors are being studied, as well as the dry season survival and the origin of new virus infections in maize after the dry season. It is planned to expand work on maize mottle to obtain a better understanding of this virus and to incorporate high levels of tolerance to it in all IITA breeding materials. The development of over 100 varieties of maize with resistance to MSV has been a great success ; this is the right way to address a problem of this nature.

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25. Field Studies of Resistance in Cowpea to Flower Thrips Megalurothrips sjostedti (Trybom).

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ABSTRACT

Field investigations of resistance in some cowpea cultivars to thrips (Megalurothrips sjostedti) were conducted at Kadawa in the Nigerian Sudan savanna in 1986 and 1988. Flower buds, scars of aborted reproductive organs, flowers, pods and thrips were counted. A visual scale was used to assess thrips damage. Short duration cultivars produced more flower buds, flowers and pods earlier in the season than medium and long duration cultivars. The number of flower buds was significantly and positively correlated (r = 0.80) with pooled number of flowers and pods. Thrips did not show consistent preference for any cowpea cultivar, although thrips number was positively, but not significantly, correlated (r = 0.24) with the damage score. There was also a non-significant, positive correlation (r = 0.11) between the number of thrips and the number of aborted reproductive organs. Two medium duration cultivars, Dan-Ilan (a local variety) and TVx 3236 (an improved variety), had relatively low percentage of aborded reproductive organs and were considered to have some level of resistance or tolerance to thrips. Production of a high number of flower buds, early maturity, and adaptability to environment were important characteristics associated with field resistance in cowpea to thrips.

RESUME

Des recherches au champ sur la résistance au niveau de certains cultivars de niébé aux thrips (Megalurothrips sjostedti) ont été menées à Kadawa dans la zone de savane Soudanienne du Nigeria en 1986 et 1988. Les bourgeons des fleurs, les traces d´organes reproductifs abandonnés, les fleurs, les gousses et les thrips ont été comptés. Une échelle visuelle a été utilisée pour évaluer les dégâts causés par les thrips. Les cultivars à cycle court ont produit plus de boutons floraux, des fleurs et des gousses que les cultivars à cycle intermédiaire et long. Une corrélation significative et positive existait entre le nombre des boutons floraux et le nombre total des fleurs et des gousses. Les thrips n´ont pas montré une préférence consistante pour un cultivar quelconque de niébé, quoique la corrélation entre le nombre des thrips et l´ampleur des dégâts soit positive (r = 0,24) mais pas significative. Il existait également une correlation non significative, positive (r = 0,11) entre le nombre de thrips et le nombre d´organes reproductifs avortés. Deux cultivars à cycle intermédiaire, Dan-Ilan (une variété locale) et TVx 3236 (une variété améliorée), avaient relativement un faible pourcentage d´organes reproductifs avortés et avaient quelque degré de résistance ou de tolérance aux thrips. La production d´un nombre élevé de bourgeons de fleurs, à maturité précoce, et l´adaptabilité à l´écologie ont été les caractéristiques importantes associées à la résistance du niébé aux thrips au champ.

INTRODUCTION

Some field investigations on resistance in cowpea to insect pests have been directed towards the detection of quantitative and qualitative characters which would aid in breeding resistant varieties. Perrin (1978) reported that the cultivar, TVu 946, had little attack of Cydia ptychora Meyr. in the field because it had rapid maturity, non-vigorous growth and bore the pods above the foliage. Ezueh and Taylor (1981) demonstrated a positive relationship between damage by C. ptychora and maturity time in selected cowpea cultivars and concluded that cultivars with early maturity, determinate growth and uniform pod ripening would suffer the least damage by the insect in the field. Other characters, such as oviposition preference of C. ptychora, small seededness, and antibiosis in cowpea cultivars were also associated with resistance to the insect (Ezueh, 1981).

Thrips, Megalurothrips spp., are common pests of cowpea wherever it is grown in Nigeria. Of some five species recorded on cowpea, M. sjostedti Trybom is by far the most important (Ta´ama 1983). Okwakpam (1977) reported that flowers and pods were damaged. Singh (1977) observed that both adults and nymphs severely damaged young, developing flower buds which turned brown and aborted. Although some cultivars, such as TVu 1509 and TVx 3236, possess some resistance to thrips (Singh, 1977 ; Ta´ama 1983), there is scanty information on the factors associated with such resistance. This investigation was undertaken to identify some of the characters associated with resistance to thrips in cowpea.

MATERIALS AND METHODS

The experiments were conducted on the Institute´s irrigation Research Station farm at Kadawa (11° 80´ N, 80 15´ E) Kano State, in the rainy seasons of 1986 and 1988. In 1986 ten (five short duration, three medium duration and two long duration, cowpea cultivars (Table I) were grown on five-row plots in four replicates arranged in a randomized complete plot design. Each plot measured 4 m x 3.75 m and plots were separated from each other by buffer zones (2 x 1.5 m). On 23 July, two seeds of each cultivar were handsown per hole at a spacing of 20 cm (intra-row) and 75 cm (inter-row); later seedling were thinned to one/hill. A pre-emergence herbicide, metolachlor + metobromuron (Galex), was applied at 2 kg a.i./ha ; the plot subsequently received one supplementary hoe weeding. Two cultivars (Dan-Ilan and TVx 3236) with some level of resistance to thrips (S.A. Shoyinka, personal communication) were used as checks. No insecticide was used.

In 1988, ten (four short duration, four medium duration and two long duration) cultivars (Table 7) were also planted on 1 August on five row plots in three replicates. Other experimental procedures were similar to those of 1986.

The parameters assessed included total number of each of the following : flower buds, aborted flower buds, flowers, damaged flowers, thrips, pods, and flowers damaged by _Maruca testulalis_. To assess the number of reproductive organs, one stand of each cultivar was gently pulled out from each plot at weekly intervals, beginning from 2 September, i.e. 41 days after planting (DAP) to 29 September (69 DAP) in 1986. In 1988, sampling was from 21 September (50 DAP) to 28 September. Each cowpea plant was put immediately in a labelled polythene bag and taken to the laboratory. The flower buds, scars of aborted reproductive organs, flowers, and pods were counted separately. The percentage of flowers damaged by _M. testulalis_ was estimated and was used to work out the number of flower buds destroyed by this insect.

In 1986, the number of thrips was estimated in six flowers randomly picked from each plot at weekly interval from 41 to 62 DAP. Immediately after picking, the flowers were put in labelled vials containing 30% alcohol, taken to laboratory, dissected in the alcohol and the thrips counted. Similar method was used in 1988 to estimate the number of thrips, except that six racemes per plot were sampled. Damage to racemes by thrips was visually rated using the method of Salifu (1984). Six racemes were collected per plot and rated on a scale of 0-4, in which 0 = no damage, and 4 = very severe damage. The score was subjected directly to analysis of variance to evaluate differences among cultivars.

RESULTS

The number of flower bud, flowers, and pod per cowpea plant varied widely among the cultivars. AT 41 DAP in 1986, three short duration cultivars (IT82E-60, IT84E-124 and IT82D-74) had significantly ($P = 0.05$) higher number of flower buds than cultivars with longer maturity periods (Table 1). IT82E-60 and IT84-124 significantly ($P = 0.05$) aborted more flower buds, although they produced more flowers, than the rest of the cultivars. More thrips occurred on the short duration cultivars than on each of the other cultivars, although not all the differences were significant. Dan-Ilan and TVx 3236 had the lowest percentage of aborted flower buds, indicating that they possess some level of resistance or tolerance to thrips attack. The long duration cultivars were just beginning to form flower buds at 41 DAP ; at this stage, IT83S-818 and IT82D-699 appeared to be the most susceptible short and long duration cultivars, respectively.

Table 1. Mean number of flower buds, thrips, flowers and pods on cowpea cultivars at Kadawa 41 days after planting in 1986.

Cultivars*	Total flower buds/plant	Abordted flowers buds/plant	Thrips/ 6 flowers	Flowers/ plant	Pods/ plant
IT84E-60(s)	127.75±2,66	13.75±0.58	9.75±1.53	2.50	0.50
IT84E-124(s)	138.25±6.51	17.75±0.58	10.50±4.04	3.50	0.0
IT83s-818(s)	69.75±2.43	12.00±6.56	11.75±4.51	0.50	0.0
IT82D-714(s)	80.75±4.75	8.50±5.00	8.50±1.15	0.50	0.0
Dan-Ilan(m)	61.5±8.46	5.00±3.00	4.50±2.51	0.50	0.0
K-59(s)	56.0±6.23	5.57±1.53	7.75±1.53	0.50	0.0
IT82D-699(m)	46.75±7.25	7.75±4.51	4.50±0.58	0.0	0.0
TVx 3236(m)	60.25±3.12	2.50±0.58	2.75±1.53	0.75	0.0
IAR 72(l)	12.5±3.38	0.0±0	2.50±0.58	0.0	0.0
IAR 180-4(l)	15.0±6.15	-	3.50±1.06	0.0	0.0
LSD (P = 0.05)	15.31	5.72	4.34		

*(s) Short duration (maturity time, 65-75 days)
(m) Medium duration (maturity time, 80-95 days)
(l) Long duration (maturity time, 100-125 days).

The data obtained at 48 DAP (Table 2) showed that the three short duration cultivars produced significantly (P = 0.05) more flower buds than medium and long duration cultivars. The medium duration cultivar, IT82D-699, had the highest percentage of aborted flower buds. The results showed that the varieties with higher number of flower buds tended to produce more flowers and pods (Tables 1 and 2); the positive correlation coefficient between number of flower buds and pooled number of flowers and pods being 0.80. The variation in number of thrips was not associated with differences in maturity period of cultivars. The number of thrips was positively, but non-significantly, correlated (r = 0.11) with the number of aborted flower buds. This indicates that the level of flower bud abortion may not entirely depend on the number of thrips. For example, Dan-Ilan (Table 2) had the highest number of thrips but comparatively low percentage of aborted flower buds ; this suggests some inherent ability of this cultivar to resist or tolerate thrips damage.

Table 2. Mean number of flower buds, thrips, flowers and pods on cowpea cultivars at Kadawa 48 days after planting in 1986.

Cultivars*	Total flower buds/ plant	Aborted flower buds/ plant	Thrips 6 flowers	Flowers/ plant	Pods/ plant	Flowers + Pods
IT82E-60(s)	201.25±21.88	34.00±7.00	13.00±6.24	11.00±5.57	0.75±0.58	11.75
IT84E-124(s)	183.0±20.87	33.75±1.53	13.50±5.03	9.75±1.15	4.50±1.53	14.25
IT83S-818(s)	161.50±19.43	33.00±12.12	19.75±18.23	12.50±2.52	3.50±2.52	16.0
IT82D 714(s)	197.50±28.52	21.75±7.09	7.50±2.08	10.75±7.02	3.50±2.52	14.25
Dan-Ilan (m)	128.75±8.38	18.75±8.50	23.00±11.00	7.75±1.53	1.50±0.58	9.25
K-59(s)	131.25±3.57	32.00±9.54	14.00±4.58	11.00±2.00	3.75±0.58	14.75
IT82D-699(m)	87.75±1.38	24.75±2.08	12.50±2.08	2.50±2.08	0.50±0.58	3.0
TVx 3236(m)	135.25±22.73	24.75±7.51	19.75±0.0	3.0±2.65	1.50±2.04	4.50
IAR 72 (l)	13.50±4.25	2.75±2.31	5.50±0.0	0.0±0.0	0.0±0.0	0.0
IAR 180-4(l)	44.75±4.50	4.50±1.15	14.50±7.37	0.0±0.0	0.0±0.0	0.0
LSD (P = 0.05)	45.25	11.45	10.42	5.81	2.89	

* (s) Short duration (maturity time, 65-75 days)
(m) Medium duration (maturity time, 80-95 days)
(l) Long duration (maturity time, 100-125 days)

AT 55 DAP, two medium duration cultivars (Dan-Ilan and TVx 3236) produced about the same number of flower buds, flowers, and pods as most of the short duration cultivars (Table 3).

Table 3. Mean number of flower buds, thrips, flowers and pods on cowpea cultivars 55 days after planting at Kadawa in 1986.

Cultivars*	Total flower buds/ plant	Abordted flower buds/ plant	Thrips/ 6 flowers	Flowers plant	Pods/ plant	Flowers + Pods/ plant
IT82E-60(s)	277.0±37.66	63.0±21.40	33.75±5.57	20.5±13.87	7.5±6.95	28.0
IT84E-124(s)	186.04±35.74	75.25±6.70	45.50±5.69	10.5±1.29	19.25±1.26	29.75
IT83S-818(s)	307.5±9.13	71.75±3.30	31.0±6.07	24.00±8.68	14.0±4.08	38.0
IT82D 714(s)	187.59±9.43	69.75±21.98	33.25±7.82	13.0±1.83	20.5±1.29	33.5
Dan-Ilan(m)	223.25±21.03	40.5±2.38	43.25±8.87	23.5±1.29	10.75±2.63	34.25
K-59(m)	163.25±19.04	74.74±24.64	35.0±8.89	8.0±6.38	13.75±6.70	21.75
IT82D-699(m)	160.25±19.36	72.50±29.47	32.50±7.27	7.5±3.51	7.5±5.80	15.0
TVx 3236(m)	220.50±34.58	41.50±11.62	66.75±15.6	16.75±4.99	13.25±4.99	30.0
IAR 72(l)	91.0±2.20	52.75±14.17	47.25±9.87	1.75±2.06	0.0±0	1.75
IAR 180-4(l)	58.0±4.42	32.00±1.63	28.50±6.18	0.0±0	0.0	
LSD (P =0.05)	68.88	25.10	25.77	9.12	6.8	

* (s) Short duration (maturity time, 65-75 days)
(m) Medium duration (maturity time, 80-95 days)
(l) Long duration (maturity time. 100-125 days)

The percentage of flower bud abortion was, however, lowest in Dan-Ilan and TVx 3236, despite their infestation by comparatively high number of thrips.

At 62 DAP, some of the short duration cultivars had become senescent. The long duration cultivars still had significantly (P = 0.05) lower numbers of flower buds and aborted flowers than other cultivars (Table 4). Dan-Ilan had significantly the highest number of thrips. There was a decline in the number of flowers carried by the short and medium duration cultivars.

Table 4. Mean number of flowers buds, thrips, flowers and pods on cowpea cultivars at 62 days after planting at Kadawa in 1986.

Cultivars*	Total flower buds/plant	Aborted flower buds/plant	Thrips/ 6 flowers	Flowers/ plant	Pods/ plants
IT82E-60 (s)	339.75±30.56	280.25±39.06	53.75±4.37	2.65±1.58	7.25±4.92
IT82E-124(s)	224.0±23.24	120.5±27.77	54.75±7.77	2.25±2.67	20.75±10.83
IT83S-818(s)	278.50±14.05	234.5±13.40	31.75±4.73	0.0±0	10.5±4.65
IT82D-714(s)	340.75±28.51	223.0±49.08	45.0±8.48	3.5±1.73	4.75±0.92
Dan-Ilan(m)	330.0±30.23	265.0±28.96	74.75±1.80	1.5±1.73	23.75±12.42
K-59(s)	332.0±7.14	239.5±12.18	38.75±6.24	1.75±2.06	7.50±6.35
IT82D-699(m)	308.25±9.04	289.5±9.88	43.25±2.56	1.25±0.5	5.75±5.76
TVx 3236(m)	376.50±47.41	217.25±20.56	42.0±9.43	2.25±2.80	12.75±10.11
IAR 72 (l)	150.25±19.25	100.±27.77	45.75±10.43	1.25±1.84	0.5±0.58
IAR 180-4(l)	131.0±4.97	84.0±15.06	41.50±9.82	0.0±0	1.0±1.63
LSD (P=0.05)	72.70	58.16	21.42	2.34	12.24

* (s) Short duration (maturity time, 65-75 days)
(m) Medium duration (maturity time, 80-95 days)
(l) Long duration (maturity time, 100-125 days).

At 69 DAP, Dan-Ilan had significantly (P = 0.05) more flower buds than any of the other cultivars (Table 5). Most of the short duration cultivars had become so senescent that it was no longer possible to count he scars of aborted flower buds. The long duration cultivars had significantly (P=0.05) lower number of pods than shorter duration cultivars. The number of thrips declined on the short and medium duration cultivars except in IAR 180-4, probably because it bore some fresh flowers.

Table 5. Mean number of flower buds, thrips, flowers and pods on cowpea cultivars 69 days after planting at Kadawa in 1986.

Cultivars	Total flower buds/plant	Thrips/ 6 flowers	Flowers/ plant	Pods plant
IT82E-60(s)	33.0±19.22	35.50±3.88	0.0	15.0±4.16
IT84E-124(s)	228.25±6.97	19.0±1.78	0.0	14.75±1.11
IT83S-818(s)	342.75±7.49	25.25±4.87	0.0	10.75±2.02
IT82D-714(s)	378.0±15.41	26.5±1.55	0.0	23.25±4.87
Dan-Ilan(m)	546.75±53.46	41.75±10.70	6.50	32.75±4.87
K-59(s)	308.50±25.33	13.75±4.33	0.50	15.0±2.16
IT82D-699(m)	385.50±12.45	13.25±3.84	1.0	12.0±2.27
TVx 3236(m)	405.25±30.91	17.25±4.13	4.00	29.50±3.01
IAR 72(l)	153.75±13.03	37.75±4.53	1.00	1.50±0.65
IAR 180-4(l)	157.0±17.77	83.75±23.22	3.0	1.0±0.41

* (s) Short duration (maturity time, 65-75 days)
(m) Medium duration (maturity time, 80-95 days)
(l) Long duration (maturity time, 100-125 days).

In 1988, the rainfall was unusually heavy, resulting in excessive moisture and retarded plant growth so that the first sampling was taken 50 days after planting. Dan-Ilan had significantly (P=0.05) the highest number of flower buds, flowers, and pods (Table 6).

Table 6. Mean number of flower bus, thrips, flowers and pods on cowpea cultivars 50 days after planting at Kadawa in 1988.

Cultivars*	Total flower buds/ plant	Aborted flower buds/ plant	Flowers + Pods/ plant	Flowers/ plant	Pods/ plant
KN-1	52.67±39.55	10.33±0.58	8.33±3.06	2.33±1.15	6.00±2.00
IT82E-32(s)	52.57±6.66	10.33±3.5	5.00±0.0	2.67±0.58	2.33±0.58
IT84E-124(s)	42.00±26.91	7.33±2.89	6.67±4.04	1.67±0.58	5.00±3.00
IT84S-2246-4(s)	31.33±5.03	8.33±2.52	5.57±0.58	3.67±0.58	2.00±1.00
Dan-Ilan(m)	94.67±54.00	11.00±6.89	13.67±3.55.	9.00±3.61	4.67±0.58
TVx 3236(m)	26.67±5.03	2.33±2.52	3.00±1.73	1.33±0.58	1.67±1.15
Sampea 7(m)	28.33±21.50	6.67±3.06	1.67±1.15	1.00±1.00	0.67±0.58
IT82D-699(m)	18.33+5.46	5.33+0.58	2.00+1.00	0.67+0.58	1.33+0.58
IAR 72(l)	4.67±1.15	0.0±0.0	0.0±0	0.±0	0 ± 0
IAR 180-4 (l)	3.33±2.31	0.0±0.0	0.0±0	0 ±0	0 ± 0
LSD (P= 0.05)	38.84	5.89	3.52	2.27	2.19

* (s) Short duration (maturity time, 65-75 days)
(m) Medium duration (maturity time, 80-95 days)
(l) Long duration (maturity time, 100-125 days)

The unusually high rainfall, and consequent waterlogging of the soil, may have accounted for the lower flower and pod production in other cultivars. The local-cultivar, Dan-Ilan, apparently performed better than the other cultivars because of its better adaptation to the environment. Like in 1986, Dan-Ilan and TVx 3236 had low percentage of flower bud abortion (Table 6). The flower buds and flowers were too few to permit assessment of damage by thrips.

At 57 DAP, all short duration cultivars (KN-1, IT84E-32, Dan-Ilan, and TVx 3236) had significantly ($P = 0.05$) more flower buds than the long duration cultivars and two medium duration cultivars, Sampea 7 and IT82D-699 (Table 7). The lowest percentage of flower bud abortion was recorded from Dan-Ilan, IT84E-124, and TVx 3236, in that order. Dan-Ilan also significantly ($P = 0.05$) produced the highest number of pods. Although more thrips occurred on IT84S-2246-4 and IAR 72, the two cultivars did not have the highest thrips damage score. Indeed, there was a non-significant positive correlation ($r = 0.24$) between thrips number and damage score.

Table 7. Mean number of flower buds, thrips, flowers, pods and thrips damage score on cowpea cultivars at Kadawo 57 days after planting in 1988.

Cultivars	Total flower buds/ plant	Aborded flower buds/ plant	Thrips/ 6 racemes +6 flowers	Flowers/ plant	Pods/ plant	Thrips damage score
KN-1(s)	92.67±46.06	44.67±12.5	6.67±6.66	0 ± 0	4.00±2.65	1.67±1.15
IT82E-32(s)	82.00±15.09	34.00±4.00	12.07±6.11	1.00±1.00	3.00±1.00	3.33±0.58
IT84E-124(s)	49.67±32.08	11.33±4.50	10.00±4.00	0.33±0	1.67±0.58	1.67±0.58
IT84S-2246-4(s)	53.67±17.95	24.00±7.00	27.33±12.06	0 ± 0	0 ± 0	2.33±0.58
Dan-Ilan(m)	86.33±28.01	14.00±6.00	11.33±3.51	0.33±0	7.00±1.0	2.00±1.00
TVx 3236(m)	82.33±10.26	28.00±10.54	12.67±9.50	3.00±1.00	1.0±1.0	1.17±0.76
Sampea 7(m)	26.67±11.04	13.67±3.51	10.00±2.00	0.00±0.00	0.00±0.00	2.67±1.04
IT82D-699(m)	25.67±7.24	19.33±3.79	5.33±3.51	1.00±1.00	1.67±1.53	3.33±0.58
IAR 72(l)	9.00±1.00	6.67±5.51	27.00±1758	0.00±0	0±0	2.50±1.32
IAR 180-4(l)	6.67±1.53	4.00±1.00	9.00±4.00	0.0±0	0±0	1.83±1.20
LSD (P = 0.05)	34.55	22.38	14.89	1.19	2.02	1.65

* (s) Short duration (maturity time, 65-75 days)
(m) Medium duration (maturity time, 80-95 days)
(l) Long duration (maturity time, 100-125 days).

DISCUSSION

The short duration cultivars produced more flower buds than the medium duration and long duration cultivars at the beginning of the season when the population of thrips was low. It is likely that due to low population of the thrips, some of the flower buds merely escaped thrips damage and therefore bloomed. Salifu (1984) found a positive correlation between thrips number and damage. Similar positive, but non-significant, correlation was observed in the present study. It may be inferred that thrips damage could be reduced by timely planting of short duration cultivars which then produce flower buds before the build-up of thrips population. Ezueh (1981) showed that quick maturing varieties escaped the greater part of cowpea moth (Cydia ptychora) attack, paritularly if they are sown early. It seems that the reduced susceptibility in the short duration cultivars was an escape from infestation (phenological resistance), a phenomenon which exploits the lack of synchronization of growth patters of insects and their host plants (Thorsteinson, 1960).

At 69 DAP in 1986, medium duration cultivars (TVx 3236 and Dan-Ilan) produced the highest numbers of flower buds, even though short duration cultivars initially produced more flower buds. The positive correlation between the number of flower buds, on the one hand and numbers of flowers and pods, on the other, suggests that production of high numbers of flower buds could confer some level of resistance or tolerance to thrips attack. Thus, a combination of early maturity and production of high number of flower buds could be exploited in breeding for resistance to thrips in cowpea.

In the two years of experimentation, Dan-Ilan, a local cultivar, produced higher numbers of flowers and pods than the improved cultivars ; it also had low percentage of flower bud abortion, despite heavy infestation by thrips. These observations emphasize the importance of careful study of locally adapted cultivars early in a breeding programme.

The long duration cultivars appeared to be very susceptible to thrips attack, probably because they produced their flower buds when thrips population was high. Taylor (1964) pointed out that indeterminate cowpea varieties favoured the development of several generations of Laspeyresia ptechora that subsequently caused severe damage to the crop.

Thrips did not show any consistent preference or non-preference for any cultivar in this study. The low nomber of thrips reported on TVx 3236 by earlier workers (Ta´ama, 1983; Salifu, 1984) agrees only with data of the first sample taken 42 days after sowing in 1986. The difference may be because the present study was conducted in the field where environmental factors could not be controlled.

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26. Farmers Practices´ and the Incidence of Striga in Northern Ghana.

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ABSTRACT

A study was conducted in the Bawku and Tumu districts of Northern Ghana in August, 1988 to characterize the cropping systems, assess the incidence of Striga on crops, and identify control measures used by farmers to control Striga. A questionnaire, designed with the help of a previous informal survey, was administered to 100 farmers, chosen at random from the two districts. All the farmers were aware that cereals are susceptible to Striga. Thus, 68% of the farmers fallow their fields every 2 to 4 years to control Striga, while 90% controlled Striga by handpulling. Continuous cropping and poor soil fertility were recognized by 60% of the farmers as favouring Striga attack. About 58% of the farmers, who had observed Striga parasitising weeds, identified Digitaria as one of the weed hosts. Striga hermonthica was the prevalent species.

RESUME

Une étude a été conduite dans les districts de Bawku et de Tumu au Nord du Ghana en Août 1988 afin de déterminer les systèmes de production, d´évaluer l´incidence du Striga sur les cultures, et d´identifier les méthodes de lutte utilisées par les agriculteurs contre le Striga. Un questionnaire conçu à l´aide d´une étude informelle antérieure, a été distribué à 100 agriculteurs, sélectionnés au hasard au niveau des deux districts. Tous les agriculteurs avaient conscience de la sensibilité des céréales au Striga. Ainsi, 68 % des agriculteurs laissent leurs champs en jachère tous les 2 à 4 ans afin de lutter contre le Striga, alors que 90 % d´entre eux luttent contre le Striga par le système d´arrachage manuel. La culture continue et la pauvre fertilité du sol ont été reconnues par 60 % des agriculteurs comme des facteurs favorables à l´attaque du Striga. Environ 58 % des agriculteurs, qui avaient observé des mauvaises herbes hôtes de Striga, ont identifié Digitaria comme l´une des mauvaises herbes hôtes. Striga hermonthica constituait l´espèce dominante.

INTRODUCTION

Striga spp. (witchweed) is a serious problem in the northen parts of Ghana, i.e., areas north of latitude 8°N, especially the Upper East and Upper West regions. In the Northern region severe damage occurs in the agricultural districts of Tamale, Damongo, Bimbila and Salaga. In these regions, Striga causes serious economic losses to a range of host plants, particularly sorghum, millet, and maize ; on these three crops yield losses of up to 78 to 100% have been reported (Ampong-Nyarko, 1986). Apart from the direct yield reduction, there are socio-economic losses. For example, the farms are being located at increasingly longer distances from settlements, with the hope of locating Striga-free fields.

In the past, farmland was relatively abundant in northern Ghana, thereby permitting traditional practices involving 3-4 years of cropping followed by 6-10 years of fallow. The severity of Striga attack probably contributed to this pattern of land use (Ampong-Nyarko 1986). Recently, however, population pressure on the land use has necessitated more permanent and intensive farming practices. It appears that farmers recognize Striga as an important production constraint ; thus, Striga has been given local names such as "Bochoa" (i.e., caustic soda, in recognition of its scorching effect) and "Saga" (i.e., dangerous). However, the extent of the problem has so far not been fully appreciated by research and extension agencies in Ghana. There is therefore, the need to create awareness of the magnitude of yield losses caused by Striga.

The general objectives of the present study included : (i) to determine the incidence of Striga damage on crops, (ii) to characterize the cropping systems in the affected districts and to establish any relationships between cropping systems and Striga incidence, and (iii) to identify local control methods.

METHODOLOGY

An informal surveys of farmers' cropping systems and the incidence of Striga was conducted in the Northern sector of Ghana in early July, 1988. The results were used to design a questionnaire for the Bawku and Tumu districts which were considered important areas for the Striga study. Using the cluster sampling procedure, 100 farmers, 10 each from 10 villages, were selected from the two districts. In August, after pretesting, the questionnaire was administed by trained personnel from the project. The Bawku and Tumu districts are in the Guinea savannah zone with maximum and minimum daily temperatures of 31 and 22°C, respectively, and a relative humidity of 81%. The mean rainfall during the cropping season for Bawku and Tumu districts are 902 and 815 mm, respectively.

RESULTS AND DISCUSSION

The most important crops grown in the study area include maize, millet, sorghum, rice, cotton, and cowpea. However, in the Tumu district, maize is more important than in the Bawku district. In the Bawku district, maize is commonly intercropped with millet and/or sorghum, while cowpea is often intercropped with sorghum or millet. In the Tumu district, by contrast, maize and cowpea are commonly monocropped. Millet/sorghum intercropping systems are practised in both districts.

About 65% of the farmers use both compound and ammonium sulphate fertilizers, while 4% apply only compound fertilizer ; 26% and 60% of the farmers apply compound fertilizer in the second and the third to the fourth weeks after planting, respectively, while ammonium sulphate is usually applied at the tasselling stage. Maize is weeded twice by 70% of the farmers at between 2-3 and 4-6 weeks after planting.

The study showed that cereals are the most common crops attacked by <u>Striga hermonthica</u>. The incidence of <u>S. gesnerioides</u> attack on cowpea was relatively low. Crops in 66% of the fields were affected by <u>Striga</u>. All the farmers were aware that cereals are susceptible to <u>Striga</u> attack, but only 44% knew that cowpea can be affected by <u>Striga</u>.

Land prepared with animal-powered impliments comprised about 53% and had the highest incidence of <u>Striga</u> (Table 1). Cereals (monocrops or mixtures) were grown in 77% of the fields, 83% of which were infested with <u>Striga</u>. <u>Striga</u> occurred in 6% of the remainning fields (Table 2). Cereals grown in 88% of the fields tilled by animals were attacked by <u>Striga</u> (Table 3). About 13% of the area under cereals was monocropped to maize ; of these, 79% has <u>Striga</u>, the incidence of which was up to 98% (86 <u>Striga</u> plants/m^2) at Boti, Tumu district (Tables 4 and 5).

Table 1. Incidence of <u>Striga</u> in fields with various crops in relation to land preparation method.

Method of land preparation	Fields with <u>Striga</u> (%)	Fields without <u>Striga</u> (%)
Tractor	31.5	68.5
Manual	60.6	39.4
Animal	71.1	28.9
Tractor + animal	50.0	50.0
Manual + animal	81.8	18.2

Table 2. Incidence of Striga in cereal and non-cereal fields.

Crops grown in field	Fields with Striga (%)	Fields without Striga (%)
Cereals (monocrop or mixture)	83.3	16.6
Non-cereals	6.0	94

Table 3. Incidence of Striga in cereal fields in relation to land preparation method.

Method of land preparation	Fields with Striga (%)	Fields without Striga (%)
Tractor	54.5	45.5
Manual	81.6	18.4
Animal	88.1	11.9
Tractor + animal	50.0	50.0
Manual + animal	89	10.3

Table 4. Incidence of Striga spp. in Bawku and Tumu districts of Ghana.

	Incidence of Striga (%	
District/village	S. hermonthica	S. gesnerioides
Bawku	117	3
Kokote	100	0
Winnaba	100	0
Manga	93	7
Tilli	100	0
Narogo	93	7
Tumu	79	21
Boti	98	2
Torsaw	42	58
Sorbelle	97	3

Table 5. Striga counts (number/m^2) in Bawku and Tumu districts of Ghana.

	Number of Striga plant/m^2	
District/village	S. hermonthica	S. gesnerioides
Bawku district	16.0	1.5
Kokote	13.0	
Winnaba	20.0	
Manga	13.0	1.0
Tilli	9.0	
Narogo	25.0	2.0
Tumu district	52.0	6.0
Boti	86.0	2.0
Torsaw	10.0	14.0
Sorbelle	29.0	1.0

The study revealed that 38% of the farmers, mostly in Bawku district, do not fallow their land, while 48% fallow their land for 2-4 years ; about 68% of the latter practise land fallowing as a control measure against *Striga*. Continuous cropping and low soil fertility were identified by 66% of the farmers as favouring *Striga* attack. *Striga* spp. had been observed in fields under fallow by about 60% of the farmers.

Thirthy-one percent of the farmers had observed *Striga* attacking weeds ; 58 % of these identified *Digitaria* sp. as being susceptible to *Striga*. other grass hosts of *S. hermonthica* identified by farmerss includes *Andropogon* sp. and *Paspalum* sp. ; also *Indigofera hirsuta* was identified as host of *S. gesnerioides*.

Farmers used various methods to control *Striga*. For example, 61% of the farmers used crops they regarded as non-host (e.g., groundnut, bamraranuts, soyabean, and cotton) in various ways to control *Striga* attack in cereals and cowpea. Other methods used singly or in combinations by varying proportion of the farmers included fertilization with ammonia (50% of farmers), hand polling (90% of farmers), fallowing (50% of farmers), and crop rotation (20% of farmers). The study revealed that where field infestation was heavy, the farmers adopted a fatalistic attitude of not caring.

CONCLUSION

The study has shown that *S. hermonthica* is the dominant species of *Striga* in Northern Ghana with *Striga gesnerioides* occurring only in few areas. Continuous cropping and poor soil fertility were associated with high *Striga* populations. *Digitaria* sp. and *Indigofera hirsuta* were identified as hosts of *S. hermonthica* and *S. gesnerioides*, respectively. Control measures used by farmers included handpulling, fertilization with ammonia, and rotation with non-host crops.

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27. Incidence des Doses d´Azote sur l´Emergence du *Striga asiatica* en Culture du Maïs au Togo.

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RESUME

Au Sud-est du Togo, sur Terres de Barre Dégradées, un essai de différentes doses d´azote (urée) visant à résuidr l´attaque due au *Striga asiatica* a été conduit. De cette étude, il ressort que l´application de 120 N/ha réduit significativement le nombre de plants de *Striga asiatica* (d´environ 53 %) par rapport au témoin NO et de ce fait augmente le rendement du maïs de 132 %.

ABSTRACT

A trial was conducted in south east of Togo on "Terres de Barre Dégradées" by using different levels of nitrogen (0, 60, 120, and 240 kg N/ha) in form of urea on *Striga asiatica* attack. The results showed that application of 120 kg N/ha reduced the incidence of *S. asiatica* attack to 53%, compared to the check (N=0). Also that the yield of maize was increased to 132 %.

INTRODUCTION

Striga asiatica est un des facteurs limitant l´expression des potentialités du maïs dans le sud-est du Togo. Les pertes de rendement liées à ce parasite sont focntion de la variété cultivée et se situent entre 15 et 60 % (Agbobli et Huguenin, 1987). A ce jour, on ne dispose d´aucune méthode de lutte efficace et économiquement rentable pour le petit paysannat contre ce parasite.

Cependant de nombreux travaux ont montré que le fumure azotée inhibe l´émergence et le développement du *S. asiatica* (Mathur et Mathur, 1967 ; Yaduraju *et al*., 1979).

Ce phénomène a également été signilé pour le *S. hermonthica* (Last, 1960 ; Faiz *et al*., 1983).

L´utilisation de fortes doses d´azote assure une éradication complète de l´infestation de *Striga* et favorise l´obtention de bons rendements (Ramaiah, 1983). Des études sont actuellement conduites pour déterminer les doses à appliquer dans le cadre d´une lutte efficace contre le *Striga*.

Il apparaît donc évident qu´une augmentation du niveau d´azote pourrait avoir un effet bénéfique dans la lutte contre le Striga.

L´objectif de cette présente étude est d´identifier la dose d´azote pouvant réduire le taux d´émergence de S. asiatica tout en assurant un bon rendement de la culture du maïs.

MATERIELS ET METHODES

Cette expérimentation a été menée sur le point d´essai IRAT (Institut de Recherches Agronomiques et des cultures vivrières) d´Agbomedji, situé au sud-est du Togo sur "Terres de Barre Dégradées" (sols ferrallitiques). Le dispositif expérimental consistait en blocs de Fisher randomisés, d´une superficie totale de 924 m². L´essai comportait six traitements à quatre répétitions : un témoin absolu (NO PO KO) et 5 doses d´azote avec une fertilisation équilibrée de phosphore et potasse : (soit 30 P et 60 K) : NO PK, N1 (60) PK, N2 (120) PK, N3 (180) PK, N4 (240) PK. L´azote a été apporté sous forme d´urée. Sur chaque traitement, un choix aléatoire de winq carrés de 1 m² a été fait. Sur ces carrés, les comptages de plants de Striga émergés ont été effectués.

Le mode de culture retenu correspond aux pratiques traditionnelles améliorées, préconosées dans la région (semis en ligne, densité de 42000 plants/ha...). Tous les travaux culturaux ont été semés par le paysan, sous le contrôle d´un encadreur du développement rural.

La variété testée dans l´essai est une population ZL2ND (Zea local blanc denté, obtention DRA/Togo à partir de cultivars locaux), choisie pour sa sensibilité" au S. asiatica.

Les paramètres observés dans cet essai ont porté sur :

. le nombre de plants de Striga émergés par m² ;
. la mesure, en fin de cycle cultural du rendement.

RESULTATS

Les résultats des comptages au champs de plants de Striga émergés durant le cycle végétatif montrent que N240 PK réduit considérablement le nombre de plants de Striga émergés (Tableau 1).

Tableau 1. Incidence des doses d'azote sur l'émergence du *Striga asiatica* en culture du maïs.

Traitements	Moyenne plants *Striga* émergés sur 4 m^2	Ecart type
N0 P0 K0	88 a*	± 4,50
N0 P39 K60	59 b	± 6,02
N60 P30 K60	48 b	± 3,30
N120 P30 K60	28 c	± 4,16
N180 P30 K60	20 cd	± 1,41
N240 P30 K60	8 d	± 0,95
Moyenne	42	-
CV (%)	6,7	-
Signification	S (5 %)	-

(* Test de Duncan : les traitements indiqués par les mêmes lettres ne sont pas significativement différents au seuil de 5 %).

L'analyse statistique des résultats montre qu'il existe une différence significative (au seuil de 5 %) entre le témoin absolu (N0 P0 K0) et l'ensemble des autres traitements. Par contre, il n'existe pas de différence significative entre les traitement suivants : N0 PK et N60 PK ; N120 PK et N180 PK ; N180 PK et N240 PK.

On constate que le pourcentage de réduction du nombre de plants de *Striga* par rapport au témoin N0 P30 K60 varie considérablement en fonction de la dose d'azote apportée (Tableau 1). Il est de 53% pour N120 et de 86 % pour N240.

Une parfaite correlation est notée (r = -0,99, n = 5, 5 = 0,001) entre le nombre de plants de *Striga* émergés et l'augmentation des doses d'azote (Figure 1).

Si l'augmentation de la dose d'azote diminue considérablement le nombre de plants de *Striga* émergé, on constate par contre que le rendement diminue au-delà de 120 N/ha (effet dépressif de l'azote aux fortes doses). L'augmentation est de 130 % (28 contre 12 q/ha) pour N120, alors qu'elle n'est que de 80 % pour N240 (22 contre 12 q/ha).

L'analyse statistique des données des rendements révèle qu'il existe une différence significative (au seuil de 5 %) entre le traitement N120 et toutes les autres doses d'azote apportées.

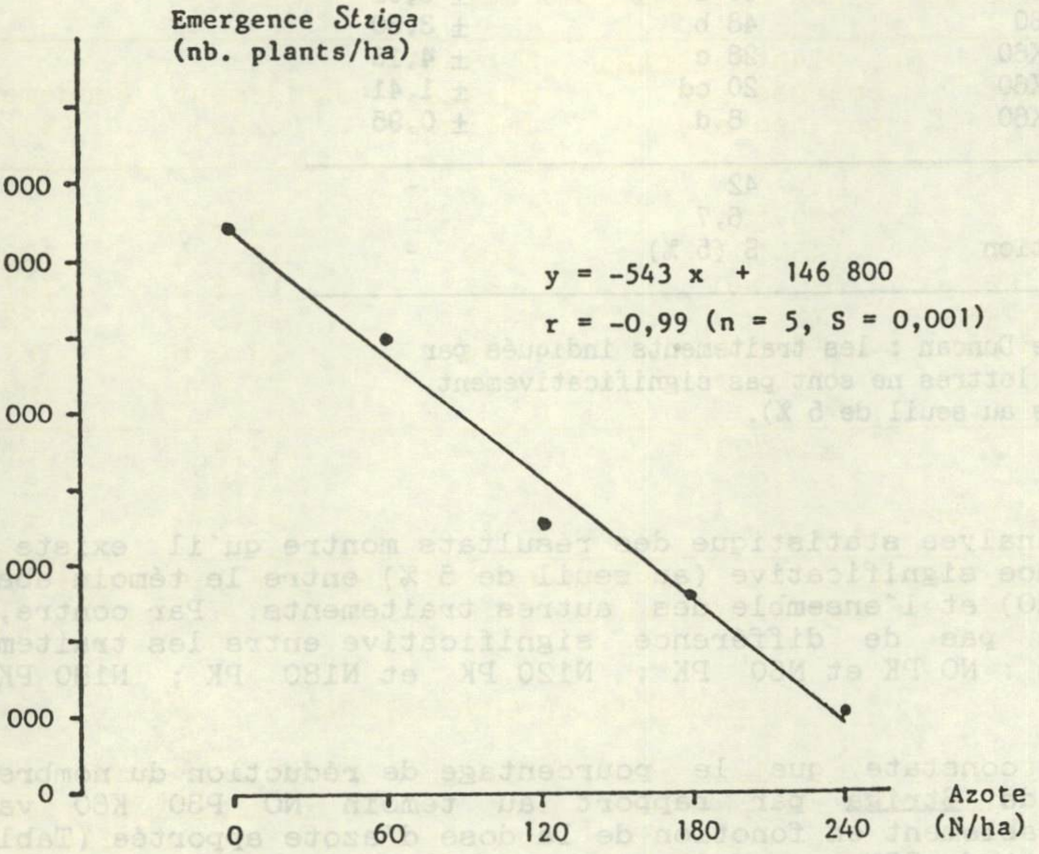

Figure 1 : Relation entre l'émergence du *Striga* et la dose d'azote.

La comparaison des doses d´azote en fonction des rendements enregistrés par le test de Duncan (Tableau 2) permet de remarquer que l´apport d´une forte dose d´azote n´implique pas nécessairement une augmentation du rendement. Dans les conditions de cette expérimentation la dose N120 à l´hectare assure une meilleure productivité de la variété ZL2BD.

Tableau 2. Incidence des doses d´azote sur le nombre de Striga émergé et ses conséquences sur le rendement.

Traitement	Nb. plants Striga émergés par par hectare	% plants Striga émergés	Rendement (q/ha)	Rendement (%)
NO PO KO	220 000	-	8,4 a*	-
NO P30 K60	148 000	100	12,0 a	100
N60 P30 K60	120 000	81	17,6 b	147
N120 P30 K60	70 000	47	27,8 c	232
N180 P30 K60	50 000	34	20,0 b	167
N240 P30 K60	20 000	14	21,6 b	180
Moyenne	105 000	-	17,9	-
CV (%)	-	-	15,9	-
Signification	-	-	S (5%)	-

(* test de Duncan : les traitements indiqués par les mêmes lettres ne sont pas significativement différents au seuil de 5 %).

DISCUSSION ET CONCLUSIONS

Les résultats de cette présente étude ne sont qu´une première approche du problème posé par le S. asiatica, parasite du maïs au Togo. Il convient, en effet de les confirmer sur plusieurs saisons culturales, en utilisant également d´autres variétés de maïs.

Quoi qu´il en soit, ces premiers résultats nous ont d´ores et déjà permis de mettre en évidence, chez le coupe maïs-Striga, que :

- la fertilisation azotée limite l´émergence du Striga ;
- l´effet bénéfique de la réduction du Striga en fonction de la dose d´azote n´implique pas nécessairement une augmentation du rendement concomitante ;
- un apport de 120 kg d´azote à l´hectare avec la variété ZL2BD entraîne une réduction de 53 % des plants de Striga émergés et une augmentation de 132 % du rendement, alors que un apport de 240 kg d´azote à l´hectare entraîne une réduction de 86 % de plants de Striga émergés et seulement une augmentation de 80 % du rendement.

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28. Nitrogen Fertilizer Effects on *Striga* Attack of Cowpea in Northern Nigeria.

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ABSTRACT

Field trials were conducted in 1985 and 1986 at two sites in Nigerian Sudan savanna to evaluate the effect of nitrogen fertilizer and cowpea cultivar on incidence of cowpea infection by *Striga gesnerioides*. The effectiveness of N fertilizer in significantly reducing cowpea attack by *Striga* was evident only in 1986. At Yana (Bauchi State), the greatest reduction in incidence of infection was obtained with 30 kg N ha-1, while at Tomas (Kano State), significant reductions were obtained only at higher levels (60-120 kg/ha) of N. Reduction in *Striga* incidence was not accompanied by significant increase in grain yield. For suppression of attack, SUVITA-2, the most resistant of the cultivars, required lower levels of N while SAMPEA-7, the most susceptible, required higher levels of N.

The resistance of SUVITA-2 tended to be site-specific ; it was highly resistant at Yana but moderately susceptible at Tomas, suggesting the existence of more than one pathogenic strain of *S. gesnerioides* in northern Nigeria.

RESUME

Des essais au champ ont été conduits en 1985 et 1986 dans deux sites de la zone de savane Soudanienne du Nigéria afin d'évaluer l'effet de l'engrais azoté et du cultivar de niébé sur l'incidence de l'infestation du niébé par *Striga gesnerioides*. L'efficacité de l'engrais azoté à réduire de façon significative l'attaque du niébé sur le *Striga* était évident seulement en 1986. A Yana (Etat de Bauchi), la plus grande réduction de l'incidence de l'infestation a été obtenue avec 30 kg N/ha^{-1}, alors qu'à Tomas (Etat de Kano), des réductions importantes ont été enregistrées en utilisant des doses d'azote plus fortes (60-120 kg/ha). La réduction de l'incidence du *Striga* n'a pas entrainé une augmentation importante du rendement en grains. Pour la suppression de l'attaque, SUVITA-2, le plus résistant parmi les cultivars, a eu besoin de doses d'azote plus faibles alors que SAMPEA-7, le cultivar le plus sensible, a exigé des doses d'azote plus fortes.

La résistance de SUVITA-2 tendait à dépendre de la spécificité du site ; il était fortement résistant à Yana mais modérément sensible à Tomas, indiquant l'existence de plus d'une source pathogène de *S. gesnerioides* au Nord du Nigéria.

INTRODUCTION

Cowpea constitutes a natural protein supplement to staple diets in Africa. The need for increased production of the crop cannot, therefore, be over-emphasized. In the semi-arid regions of Nigeria cowpea fodder (dried shoot and leaves) also provide a valuable animal feed during the dry season (Emechebe *et al*., 1988).

Nigeria produced about 77.7% of the World´s total cowpea production in 1973 (FAO, 1973) but by 1981, Nigeria´s contribution to the World´s cowpea output had dropped to 37.4%, despite increased land area devoted to the crop (Rachie, 1985). Reliable estimate of current production in Nigeria is not known, but estimated cowpea hectarage has been put as between 1.5 million (Leleji, 1987) to 4 million (Raheja, 1986).

About 80% of Nigeria´s cowpea is grown in the savannas, especially the northern Guinea and the Sudan ecological zones (Emechebe *et al*., 1988). With optimum level of management, cowpea yields would be high but yields at the farmer´s level are low ; the average yield of 240 kg/ha constitutes about 9 % of the potential yield (Anon. 1986).

The major factors responsible for low yields include erratic rainfall, low soil fertility, insect pests, diseases, poor management practices, and attack by parasitic weeds, namely *Striga gesnerioides* (Willd.) Vatke and *Alectra vogelii* Benth. According to Emechebe *et al*. (1988) *Striga* is currently considered to be much more important and widely distributed than *Alectra*. Yield losses due to *S. gesnerioides* of about 26-56 % have been reported (Aggarwal, unpublished) but can be as high as 100% (Emechebe, 1981).

Enven though considerable work has been done on various control methods for *Striga* in cereals, control of cowpea *Striga* has received relatively little attention (Aggarwal, 1986). Emphasis on control of *Striga* in cowpea has been placed mainly on host plant resistance (Aggarwal, 1985, 1986 ; Emechebe *et al*., 1988 ; Atokple, 1989). However, complete reliance on host plant resistance is not advisable ; rather a strategy that combines *Striga*-resistant cultivars with appropriate complementary agronomic practices has been advocated (Ramaiah, 1984).

Nitrogen fertilizer has been used as a means of controlling *Striga* in cereals (Last, 1960, 1961 ; Ogborn, 1970 ; Bebawi, 1981, Babawi and Farah, 1981 ; Ogunlela, 1983 ; Ramaiah, 1984) though in some cases it has been combined with phosphorus fertilizer and the effect of N could not be separated from that of P (Last, 1961 ; Ogunlela, 1983). For obvious reasons, the use of N fertilizer in controlling cowpea *Striga* has not been investigated. Cowpea, being a legume, fixes its nitrogen in association with *Rhizobium*. High levels of nitrogen suppress nodulation, thereby reducing yields (Dart and Mercer, 1965). Preliminary studies in sand culture, however, showed that 140 ppm N, supplied as sodium nitrate solution, drastically reduced the incidence of S. gesnerioides infection in potted cowpea (Emechebe et al., 1988). There was however a corresponding decrease in nodule numbers.

Striga is favoured by low soil fertility and unreliable, low rainfall. Despite the effect of nitrogen on nodulation, there seems to be a need for a concerted research effort on the use of fertilizers, in general, to control Striga in cowpea, given the devastating effect of this obnoxious parasitic weed on cowpea grain yield on marginal soils of Africa.

The work reported here forms part of an integrated study of soil nutritional effects on Striga attack of cowpea in the Nigerian Sudan savanna.

MATERIALS AND METHODS

The experiment was carried out in 1985 and 1986 wet seasons at Yana (11°22′N, 10°03′E) and Tomas (12°9′N, 8°31′E) in Bauchi and Kano States of Nigeria, respectively. Both sites are located in the Sudan savanna ecological zone of Nigeria. The soil texture varied from loamy sand at Yana to sand at Tomas with low organic carbon and total nitrogen. Detailed physico-chemical properties and rainfall data for the experimental sites are shown in Table 1.

Trials at each location consisted of four levels of nitrogen (0, 30, 60, and 120 kg N/ha) applied as calcium ammonium nitrate (CAN) at Yana and as urea at Tomas. Three cultivars of cowpea (SAMPEA-7, SUVITA-2 and a local check) were used. SAMPEA-7 is a semi-erect, medium maturing cultivar which is highly susceptible to Striga gesnerioides. SUVITA-2 is also medium maturing cultivar which has been found resistant to Striga in Burkina Faso (Aggarwal et al., 1984) but was found to be susceptible when tested in Mali, Niger and Nigeria (IITA-SAFGRAD, 1983). The "Local check" used at Yana were IT82E-60 and Kananado in 1985 and 1986, respectively, while Dan-Ilan was used in Tomas. The twelve treatment combinations of N and cultivar were arranged in a randomized complete block design in three replicates, each plot being 4 m x 5, 75-cm ridges.

Nitrogen fertilizers in full doses were applied as side dressing in a small furrow at one side, 5 cm away from the centre of the ridges. All plots received a basal application of about 24 kg P/ha, as single superphosphate, and 20 kg K_2O/ha, as muriate of potash (60% K_2O).

Table 1. Some physical and chemical properties of soils and rainfall data of experimental sites (Yana and Tomas).

Soil properties	Yana	Tomas
Clay (%)	4.8	4
Silt (%)	11.5	4
Sand (%)	83.7	92
pH (CaCl2)	5.7	4.9
Org. C (%)	0.41	0.18
Total N (%)	0.038	0.025
Available P (ppm)	6.95	3.15
Exchangeable cations (meg/100)		
Ca	2.47	0.75
Mg	0.48	0.31
K	0.20	0.12
CEC (meg/100g)	3.26	1.25

Rainfall data (mm)

	Yana		Tomas	
	1985	1986	1985	1986
January	-	9.6	-	-
February	-	-	-	-
March	3.3	20.7	22.6	-
April	-	5.1	0.4	2.0
May	42.6	42.2	49.3	10.7
June	135.9	74.8	155.2	99.5
July	204.7	199.9	193.6	156.4
August	225.2	69.2	197.2	203.9
September	191.4	101.4	176.0	129.4
October	-	-	-	4.0
November	-	-	-	-
December	-	-	-	-
Total	803.1	523.1	794.3	605.9
Long term mean	1061		821	

Planting was done at Yana on 10 July and 7 July and harvested on 30 and 6 October in 1985 and 1986, respectively. The corresponding dates for similar operations at Tomas were 8 and 22 July and 6 and 17 October in 1985 and 1986, respectively. Two seeds of cowpea were planted per hole at 20 cm inter-plant spacing and thinned to one plant per stand (approximately 66,666 plants/ha) at 10 days after sowing.

Normal weeding was done as found necessary but without removal of emerged Striga plants. Plants were sprayed three times in a season with a mixture of 100 ml of cymbush 10EC (50 g a.i./ha) and dimethoate (500 g a.i./ha).

Yield data and Striga counts were taken from the central 3 m of the 3 inner rows (6.75 m^2).

Analysis of data

Data collected were subjected to two-way analysis of variance to test treatment differences and to compare treatment means, using the test of least significant difference at $P<0.01$ or 0.05 (Steel and Torrie, 1960) ; the incidence of infection percentages were transformed to arcsine values before analysis of variance. Simple correlation coefficients were calculated to evaluate the relationships between Striga numbers and incidence of infection, on the one hand, and cowpea grain and fodder yields, on the other.

RESULTS

Data on various parameters assessed during the studies are presentes separately for the two sites for each of the two years. They were not pooled because different local checks were used between locations.

Results of the effects of nitrogen and cowpea cultivar on Striga emergence, incidence of infection, grain and haulm yields at Yana and Tomas are shown in Tables 2, 3 and 4.

Incidence of Striga infection

Nitrogen fertilizer had no significant effect on Striga emergence, incidence of infection (% of cowpea plants with emerged Striga) or number of Striga plants per attacked cowpea plant at both sites in 1985 (Tables 2 and 3).

Table 2. Effects of nitrogen and cultivar on incidence of infection of cowpea by *Striga gesnerioides*, and on grain and haulm yield at Yana, Nigeria, 1985 and 1986.

	1985				1986				
Treatment	No. of *Striga*/ plot	Cowpea plants attacked (%)	*Striga* attached/ cowpea	Grain yield (kg/ha)	No. of *Striga*/ plot	Cowpea plants attacked (%)	*Striga* attacked/ cowpea	Grain yield (kg/ha)	Haulm yield (kg/ha)
N rates** (kg/ha)									
0	54.4	31.6	3.2	296	69.6	25.5	3.7	1002	4518
30	50	36.3)	3.1	446	49.7	16.1	3.8	913	5141
60	72.3	34.2	3.4	194	50.0	19.1	4.1	931	4436
120	56.2	31.2	2.7	314	42.9	18.1	4.7	837	6555
LSD (0.05)	ns	ns	ns	ns	ns		ns	ns	ns
S.E. ±	13.4		0.7	81.8	10.04		1.26	111.7	732
Cultivar									
SAMPEA-7	84.5	51.4)	3.8	384	131	44.4	3.7	475	3478
SUVITA-2	3.8	2.3	1.5	227	7.9	4.3	3.4	1367	1506
Local check	56.5	46.7	4.0	327	19.9	10.5	5.0	n.a	10505
LSD (0.05)			1.78	n.s			n.s		1864.7
0.01	46.4	15.60			34.8	10.9		332.5	
S.E. ±				70.8			1.09		

**N applied as calcium ammonium nitrate; n.s: not significant ; n.a: not available.

Table 3. Effects of nitrogen and cultivar on incidence of infection of cowpea by *Striga gesnerioides*, and on grain and haulm yields at Tomas, Nigeria, 1985 and 1986.

	1985					1986			
Treatments	No. of *Striga* plot	Cowpea plants attacked (%)*	*Striga* attacked/ cowpea	Grain yield (kg/ha)	Haulm yield (kg/ha)	No.of *Striga* plot	*Striga* attacked cowpea plant	Grain yield (kg/ha)	Haulm yield (kg/ha)
N rates** (kg/ha)									
0	20.2	35.5	1.1	757	4362	45.0	1.6	988	1695
30	17.2	37.3	1.2	1111	3811	34.8	1.6	1045	2765
60	12.1	27.7	0.8	876	5132	17.9	1.6	1095	2293
120	20.2	24.7	1.5	1133	5180	12.6	1.2	1070	2667
LSD 0.05	ns	ns	ns	ns	ns	13.9	ns	ns	519.8
S.E. ±	3.0		0.2	170	546		0.15	47	
<u>Cultivar</u>									
SAMPEA-7	21.6	44.8	0.9	1020	2728	44.9	1.8	1066	2469
SUVITA-2	13.3	16.4	1.4	1222	3833	25.6	1.5	1321	2790
Local check	17.6	32.8	1.2	665	7391	12.2	1.3	762	1806
LSD 0.05	ns		ns	433.5	1391	13.2	ns	120	543.7
0.01					1893	18.1		163.3	740.0
S.E. ±	2.6		0.18				0.33		

ns : not significant ; **: N applied as urea.

Even though there was no significant nitrogen x cowpea cultivar interaction, the cultivars tended to respond differently to N. Thus, SUVITA-2 required lower levels of N than the other two cultivars to withstand the Striga infection, especially at Yana where 60 kg N/ha virtually suppressed Striga emergence. The differences among cultivars in respect of Striga emergence counts, incidence of infection, or number of Striga plants per attached cowpea plant were significant ($P<0.05$) at Yana ; in every respect, SUVITA-2 was the least susceptible. At Tomas only, the incidence of infection in SUVITA-2 was significantly lower than that in any of the other cultivars.

In 1986, the incidence of Striga infection at Yana was significantly ($P<0.05$) lower in plots that received N fertilizer than in those that did not receive N fertilizer ; the effect of N on the other infection indices were not significant. At Tomas, applied N at 60 or 120 kg/ha significantly reduced Striga emergence (Table 3) and incidence of infection (Table 4) compared to both unfertilized plots and plots that received 30 kg N/ha. Cultivars again exhibited different levels of resistance to Striga in 1986, but the trend was inconsistent. Thus, SUVITA-2 was the least susceptible at Yana while at Tomas the Local Check was the most resistant. At Tomas, there was a significant cowpea cultivar x N interaction ; the incidence of infection in SAMPEA-7 was higher at 30 kg N/ha than at 0 kg N/ha, while it was lower in the other two cultivars at 30 kg N/ha than at 0 kg N/ha.

Table 4. Interactive effects of nitrogen rate and cultivar on infection of cowpea by Striga gesnerioides at Tomas, 1986.

N - rate (kg/ha)	Cowpea plants attacked (%)			N Mean
	SAMPEA-7	SUVITA-2	LOCAL CHECK	
0	29.2	43.6	26.0	32.9
30	35.2	15.6	18.0	22.9
60	23.7	8.9	10.0	14.2
120	17.0	3.6	2.9	7.2
Cultivar Mean	26.3	17.9	14.2	

LSD 0.05 for N = (0.0896) * Arcsine transformation in brackets
V = (0.0778)
NxV = (0.1554)

Grain and haulm yields

Grain yields were not significantly influenced by nitrogen treatments at either site in both years. However, at both Yana and Tomas, grain yields of plots given 30 kg N ha-1 tended to be higher than those that did not receive N fertilizer in 1985 (Tables 2 and 3). However, in 1986, all levels of applied N tended to decrease grain yields at Yana; by contrast they marginally increased yields at Tomas.

At Yana differences in grain yield among cultivars were significant ($P<0.01$) only in 1986, with SUVITA-2 outyielding SAMPEA-7. On the other, the grain yields of cultivars differed significantly ($P<0.01$) from one another in both years at Tomas. Thus, both SUVITA-2 and SAMPEA-7 outyielded the local check in 1986.

At Tomas in 1985, nitrogen fertilizer had no significant effect on haulm yield, but the haulm yield of the local check was significantly ($P<0.01$) higher than that of SAMPEA-7 or SUVITA-2. Similarly, haulm yield did not respond to N at Yana in 1986 but there was significant ($P<0.05$) response to 30 kg N/ha at Tomas. Differences between cultivars were significant at both sites. At Yana, the local check significantly outyielded both SAMPEA-7 and SUVITA-2, while SAMPEA-7 yielded significantly higher ($P < 0.05$) than SUVITA-2. In contrast, at Tomas the local check yielded significantly lower than SAMPEA-7 or SUVITA-2.

Correlations

Simple correlation coefficients (r) between *Striga* counts and incidence of infection on the one hand and, on the other, grain and haulm yields are shown in Table 5. No significant correlation was found between either *Striga* counts or incidence of infection and grain yield at both sites in 1985. However, in 1986, both *Striga* emergence and incidence of infection were significantly ($P <0.01$) and negatively correlated with grain yield at Yana. There was also no significant correlation between the two *Striga* infection indices and haulm or grain yield at Tomas.

Table 5. Correlation coefficients between *Striga* numbers and cowpea plants attacked (%) and grain and haulm yields of cowpea at Yana and Tomas, 1985 and 1986.

YANA

Variable	Grain Yield (kg/ha) 1985	Grain Yield (kg/ha) 1986
Number of *Striga*/plot	0.201	-0.737**
Striga attacked/cowpea plant	0.401	0.038
Cowpea plants attacked (%)	0.339	-0.808**

TOMAS

Variable	Grain Yield (kg/ha) 1985	Grain Yield (kg/ha) 1986	Haulm Yield (kg/ha) 1985	Haulm Yield (kg/ha) 1986
Number of *Striga*/plot	0.106	0.176	-0.109	-0.166
Striga attacked/cowpea plant	0.008	0.103	-0.035	-0.246
Cowpea plants attacked (%)	0.183	0.099	-0.276	-0.21

**Significant at the 1% level of probability.

DISCUSSIONS

The evidence from the present studies suggests that nitrogen could be effective in reducing the severity of *Striga* attack in cowpea in some areas of northern Nigeria, especially if the cultivars has some degree of resistance to the parasite. This confirms the report on preliminary studies in sand culture (Emechebe *et al.*, 1988). The results also indicated that, generally, nitrogen fertilizers had adverse effect on *Striga*, an observation that agrees with previous studies on *S. asiatica* in maize (Shaw *et al.*, 1962) and on *S. hermonthica* in sorghum (Last, 1960 ; Ogborn, 1970 ; Bebawi, 1981 ; Ramaiah, 1985).

The different levels of resistance exhibited by SUVITA-2 at Yana and Tomas suggests the existence of different pathogenic strains of *S. gesnerioides* in northern Nigeria. The report that SUVITA-2 was resistant in Burkina Faso (Aggarwal *et al.*, 1984) but susceptible in Mali, Niger and Nigeria (IITA-SAFGRAD, 1983) may not, therefore, be applicable to the whole of Nigeria. The higher number of emerged *Striga* at Yana (as compared to Tomas) on the susceptible cultivars was probably due to higher Striga seed density in the soil at Yana. However, the greater effectiveness of N fertilizer in reducing Striga emergence at Tomas is probably attributable to two factors. The more sandy soils at Tomas (compared to heavier soils at Yana) might have exposed the young seedlings of the Striga to higher concentrations of the N fertilizer which could retard Striga growth and subsequent emergence above the soil surface. On the other hand, the use of urea at Tomas and of CAN at Yana might account for the differences. There is *in vitro* evidence that soil applied urea may directly inhibit germination of Striga spp. (Pesch and Pieterse, 1982). Recent studies have also indicated that urea tended to be slightly better than CAN in suppressing Striga emergence (Adu, 1988).

Lack of corresponding increases in grain yield with decreases in Striga infection associated with N fertilizer was probably due to the opposing effect of nitrogen fertilizer on the physiological activities of the crop. The presence of the nitrogen probably helped the plant to suppress Striga infection by systematically increasing host´s root tissue nitrogen to a level at which Striga parasitism was inhibited (McNally and Stewart, 1982 ; Stewart *et al.*, 1985). On the other hand, the high doses of N might have adversely affected nodule production (Dart and Mercer, 1965), thereby reducing nitrogen fixation. Unfortunately, it has been shown that fixed nitrogen lost due to poor nodulation is not adequately compensated for by application of combined N (Dart *et al.*, 1977), especially as cowpea depends mainly on its fixed N for seed formation (Summerfield *et al.*, 1977). Small amounts of applied N at sowing (about 30 kg N/ha) benefits symbiotic fixation (Dart and Mercer, 1965) ; this probably accounts for the relatively higher grain yields at 30 kg N/ha. Inorganic N, while not increasing grain yield, increases vegetative development as shown in this study by the higher haulm yields of plots that received fertilizer N.

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