Forage legume-cereal systems: improvement of soil fertility and agricultural production with special reference to sub-Saharan Africa

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Abstract

Intercropping forage legumes with cereals offers a potential for increasing forage and, consequently, livestock production in sub-Saharan Africa. But in such a system the yield depression of the cereal grain should be minimal, possibly not more than 15%, for it to be acceptable to the farmer.

The time of sowing of cereal and legume is critical for the yield of each crop. Data so far available indicate that undersowing within 10 days of planting a fast-growing cereal such as maize does not depress cereal grain yield significantly, but with slow-growing, long-season crops such as photosensitive sorghum, grain yield is greatly depressed. In the case of sorghum, high grain yield is obtained if the legume is sown 3 - 4 weeks after the cereal.

Intercropping forage legumes and cereals generally results in higher fodder protein yield than cereal alone. However, fairly high yields of legumes are needed to augment the cereal residues in order to produce a feed composition capable of meeting the basal nutritional requirements of ruminants.

The effects of intercropping on soil fertility varies with management practice. It is estimated that legume roots contribute between 5 and 15 kg N/ha to soil N under intercropping.

Introduction

Agricultural output in the 1970s in sub-Saharan Africa (SSA) decreased by 1.3% while population rose by 2.7% (Meerman and Cochrane, 1982). They observed that yields are lower in SSA than elsewhere (Table1). Among causes of declining productivity in SSA are the traditional system of shifting cultivation, very limited use of manures and fertilizers and the expansion of agriculture into marginal lands.

Table 1 Comparative yields of basic food crops in sub-Saharan Africa and other developing countries, 1969-71 and 1977-79.(Reference: 1961-63 yields = 100).

Crop	Sub-Saharan Africa		Developing countries	
	1969-71	1977-79	1969-71	1977-79
Millet	98	94	109	108

Sorghum	92	93	115	151
Rice	108	114	113	129
Maize	114	109	115	126
Roots and Tubers	117	117	129	129

Source: Meerman and Cochrane (1982).

Among the solutions being advocated to reverse the declining productivity are the introduction of cropping systems that conserve moisture and soil fertility and the close integration of livestock and arable farming (Pratt and de Haan, 1979; Bouldin et al, 1980; Oram, 1981). Okigbo (1984) observed that increasing agricultural output in SSA will require improved cropping systems, which will necessitate the integration of traditional and modern technologies as farmers are more likely to adopt modifications to existing farming systems than completely new ones.

Nitrogen deficiency is a major cause of declining soil fertility and poor quality forage. FAO (1983) noted that the major constraint to increased animal production is malnutrition caused either by overstocking or by low protein forage. Nitrogen is required in large quantities by crops and it is also the most expensive nutrient to manufacture since it is tied to escalating energy costs.- Substitution of chemically produced N either wholly or partly could help to alleviate these problems.

This paper examines the potential of forage legume-cereal intercrops in enhancing soil fertility and increasing crop and livestock production in SSA. The socio-economic aspects of the problem are not included in the discussion.

Inter/relay cropping systems

Extent of intercropping in sub-Saharan Africa

Intercropping is defined as the growing of two or more crops simultaneously on the same field (Andrews and Kassam, 1976; Sanchez, 1976). The most common form of cropping pattern in SSA is mixed intercropping, the growing of two or more crops simultaneously with no distinct pattern. Other types of intercropping are row, strip and relay cropping. Edje (1979) reported that a survey in Malawi showed 94% of cultivated land was planted to mixtures. Norman (1967; 1974) found that only 17% of the total cultivated land area in Zaria province of northern Nigeria was under sole cropping. Okigbo and Greenland (1976) examined the characteristics of cropping systems in traditional farming practices in tropical Africa and concluded that the most widespread cropping system consisted of mixed intercropping on compound farms. They also found that relay intercropping was more common than sequential cropping. Most of the legume-cereal intercropping involves grain legumes. The extent of forage legumes in mixtures is not known but is probably very small.

Advantages of forage legume-cereal intercrops

The call for integration of forage legumes with livestock has been accompanied by the suggestion that the key to increased livestock production in SSA lies in intercropping forage legumes and cereals (Gryseels and Anderson 1983). This is because of the heavy reliance of livestock on crop residues during the long dry season. The advantages that have been advanced for such an intercropping system are: (i) the possibility of N accretion from the legume to the cereal, (ii) maintenance of continuity of feed supply during the dry season, (iii) more efficient utilisation of low-quality cereals through the addition of high-protein forages, (iv) return of manure from livestock to the field, (v) increased crop productivity and (vi) greater dependability of return compared sole cropping.

Forage legumes in cereal systems

Improvement of companion crop

Transfer of nitrogen: In a situation in which the farmer uses little or no fertilizer and the soil is very low in organic matter, the issue of transfer of N from legume to cereal assumes great importance. Two types of beneficial effects have generally been reported: higher N content and/or higher grain yield of the intercropped cereal in comparison with the cereal alone without any added N. While several investigators (Henzell and Vallis 1977; Whitney, 1977; Haystead and Lowe 1977) have found no evidence that the presence of a cereal or grass has a specific effect on the release of N from actively growing roots, other workers (Simpson 1976; Skerman, 1977; Eaglesham, 1980; Reynolds, 1982) have reported higher N contents and uptake in mixtures compared with sole-crop systems.

Most of the experiments involving exudation of N from legume roots have been conducted in pots. Under reduced light in the greenhouse, evidence has been obtained for considerable exudation (Black, 1968; Willey, 1979). However, shading may have a completely different effect in the field. Where legumes are continously shaded their overall capacity to fix N is likely to be impaired since growth and photosynthesis will be limited.

Field estimates of N accretion could be indirectly deduced if it could be shown that a cereal crop contains more N where it is associated with a legume than when it is grown alone without N fertilization. It appears that tropical forage legumes differ markedly in their ability to benefit associated cereals that have approximately the same growing period. In a comparative study with various legumes, Agboola and Faysmi (1972) reported an increase in maize grain yield over the control when *Phaseolus aureaus* (mungbean) was interplanted with the maize. The transfer of N from the legume to the maize was equivalent to 45 kg N/ha. Calopo and cowpea did not have similar effect. In an experiment at Debre Zeit, Ethiopia, Nnadi and Haque (1986) found higher N content in grain from maize that was intercropped with vetch whereas lablab and clover showed no such effect.

Competition for soil nitrogen: Pasture legumes are weak competitors for soil N if grown with grasses (Walker et al, 1956; Henzell and Vallis, 1977). If this finding can be extrapolated to cereals, then it follows that in a soil which is deficient in N the cereal crop will absorb most of the mineral N. This will compel the legume to fix more N than in a situation in which it is growing alone, provided other factors, such as light and water, are not limiting.

Fertilizer response

A large portion of SSA is situated in belts of uncertain rainfall in which there is uncertain response to N fertilizer. The primary aim here should be to maximise biological N fixation by utilising suitable legumes. However, since legume growth and consequently the amount of N fixed is affected by other nutrients there is also the need to examine the response of intercrops especially to P which has been reported to be widely deficient in SSA (Jones and Wild, 1975; Le Mare, 1984; Haque et al, 1985). Unfortunately only a few experiments have analytical data on nutrient composition and uptake.

Nutrient composition: Gardner and Boundy (1983) observed that N, P and Mn contents of wheat intercropped with lupine were significantly higher than those of wheat grown alone. The P and N contents of lupins were unaffected by intercropping (Table 2). Shelton and Humphreys (1975c) reported that intercropping upland rice (*Oryza sativa*) with stylo (*S. guianensis*) had no effect on the N content of the rice but significantly reduced its P content.

Table 2. Effect of intercropping on the N, P and Mn contents of wheat and lupins.

Cropping system	N	P	Mn
	%	%	ppm
Wheat alone	0.79	0.13	90
Wheat intercropped	0.86	0.15	150
Significance (F Test)	0.01	0.04	0.001
Lupin alone	2.35	0.14	7370
Lupin intercropped	2.35	0.14	6070
Significance (F Test)	NS	NS	0.001

Source: Gardner and Boundy (1983).

Haque (1984) found that the N content of lablab in intercrops with sorghum or maize was lower than in the legume crop grown alone. There was not much difference between the N values of pure and intercropped cereals.

Grain and stover yield: The general experience in intercropping experiments is that the grain and stover yields of a given crop in the mixture are less than the yields of the same crop grown alone, but that the total productivity per unit of land is usually greater for mixtures than for sole crops. Shelton and Humphreys (1975c) reported that yield of upland rice was 12% less when intercropped with *S. guianensis* than when grain alone. Gardner and Boundy (1983) also observed yield depression of cereal by lupins. Similar trends have been observed in the intercrops of *Dolichos lablab* with maize and sorghum at Debre Zeit, Ethiopia (Haque, 1984). The combined yield of the intercrops gave varying Land Equivalent Ratios (LER) ranging from 0.81 to 1.07 for sorghum and 0.86 to 1.07 for maize, depending upon the planting geometry (Table 3). Chetty (1983), in a review of work done over a 10-year period in India, noted little depression of the yield of finger millet by fodder legumes, field beans, *Dolichos lablab* and lucerne (Table 4).

In general, applying fertilizer N to fodder legume-cereal intercrops has been found to decrease the yields of the legume and to increase the yield of the cereal (Humphreys, 1978; Venkateswarlu, 1984).

Protein yield: Protein yield per hectare is increased by intercropping cereals and forage legumes. Waghmare and Singh (1984a) reported that the protein yield of sorghum was higher when intercropped with fodder cowpea than with grain legumes grown to maturity (Table 5). Intercropping stylo with sorghum has also given higher quality fodder (Mohamed-Saleem, 1984a). Haque (1984) showed that very high crude protein yields can be obtained from intercropping sorghum or maize with lablab. Highest crude protein yields were obtained from treatments in which two rows of sorghum and one row of lablab were planted, but with maize the highest protein yields occurred where cereal and legume were mixed and then broadcast (Figures 1 and 2). It is interesting to note that at maturity the crude protein yield of maize stover was higher than those of the intercrops. Generally the amount of crude protein in the system decreases with increasing time lag between the sowing of cereal and legume (Kanyama and Edje, 1976; Mohamed-Saleem, 1984b). Table 6 shows that the decrease in crude protein yield with time is attributable to low legume yield.

Table 3. Effect of intercropping lablab on grain yield (kg/ha) of sorghum and maize at Debre Zeit, Ethiopia, 1984.

Cropping systems	Sorghum	Maize
S_1 Cereal (pure)	1891	2032
S_2 Cereal/lablab (1:1)	-	-
Cereal	1031	1563
lablab	362	400
Total	1393	1963
S_3 Cereal/lablab (2:1)		
Cereal	1191	1448
Lablab	327	446
Total	1518	1894
S_4 Cereal/Lablab (between normal rows)	-	-
Cereal	1340	1408
Lablab	247	378
Total	1587	1786
S_5 Cereal/Lablab (broadcast)		
Cereal	1193	1556
Lablab	266	400
Total	1459	1956
Lablab (pure)	737	516

Source: Haque (1984)

Table 4. Effect of intercropping finger millet with fodder crops on finger millet yield, Bangalore, India. (Row ratio 7:1).

Cropping system	Year	Rainfall (mm)	Yield (t/ha)	
			Millet	Intercrop
Finger millet + field bean 1978	565	2.69	-	
			2.01	2.62
Finger millet + dolichos	1978	627	2.69	-
			2.54	2.69
	1979	850	1.22	-
			1.15	1.24
	1980	270	1.75	-
			1.70	1.60
Finger millet + lucerne	1978	426	2.69	-
			2.49	7.10
	1980	270	1.57	1.10

Source: Chetty (1983)

Table 5. Effect of intercropping on grain and stover yields (t/ha) and N uptake (kg/ha) of sorghum.

Intercropping	Grain yield (t/ha)		Stover yield (t/ha)		N uptake (kg/ha)	
system	1978	1979	1978	1979	1978	1979
Sorghum	3.09	3.44	6.50	6.95	52.6	53.1
Sorghum + greengram	3.32	3.71	6.80	7.84	76.6	90.1
Sorghum + groundnut	3.29	3.25	6.60	7.12	82.5	94.6
Sorghum + grain cowpea	3.25	3.73	6.95	7.69	86.9	89.6
Sorghum + forage cowpea	3.79	4.09	7.62	7.94	136.0	123.6
Sorghum + soyabean	3.15	3.55	6.70	7.24	77.2	78.3
SED	0.11	0.12	0.50	0.27		

Source: Waghmare and Singh (1984a)

Figure 1. ***Fodder crude protein yields of sorghum/lablab intercrops at various growth stages.***

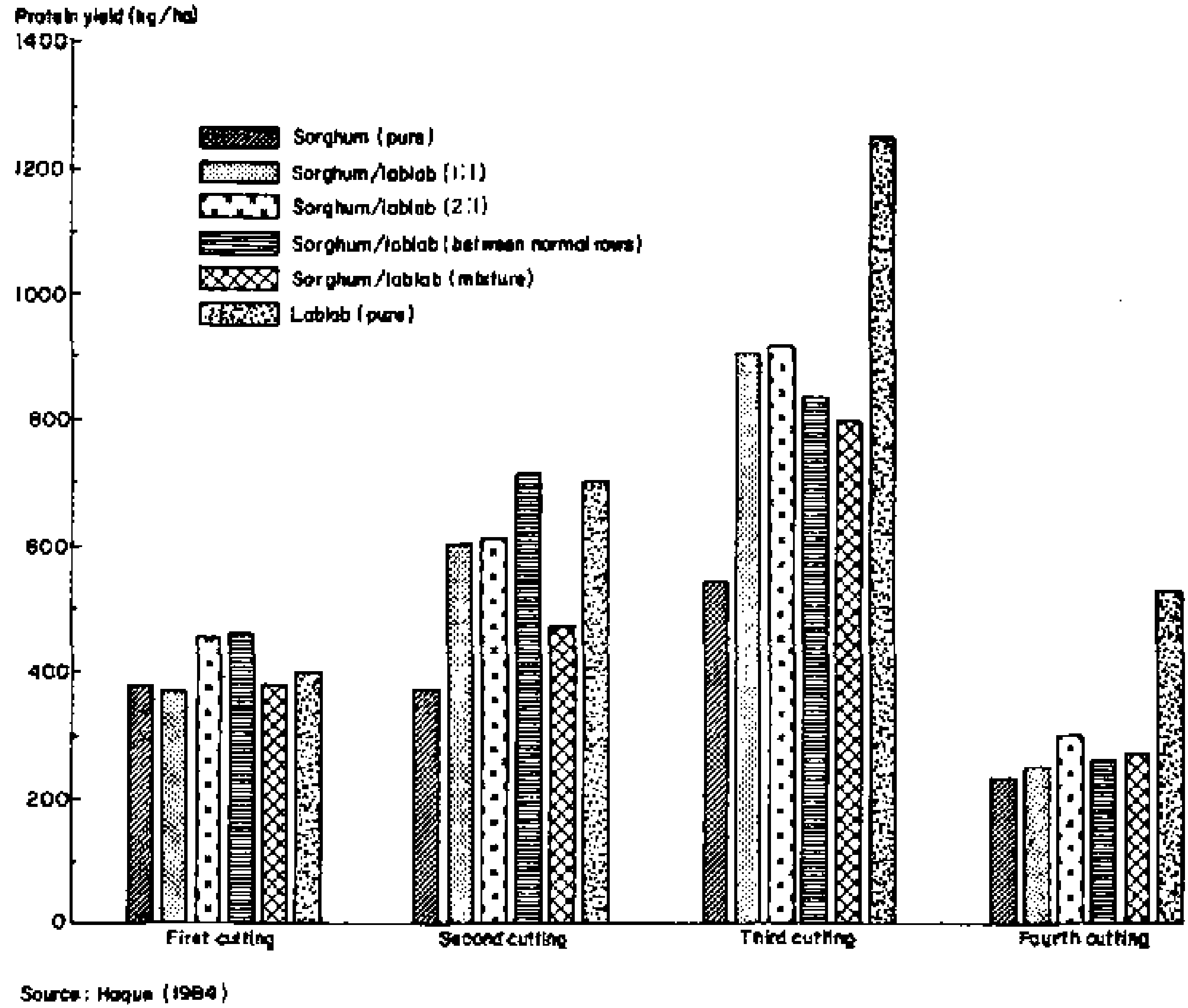


Figure 2. ***Fodder crude protein yields of maize/lablab intercrops at various growth stages***

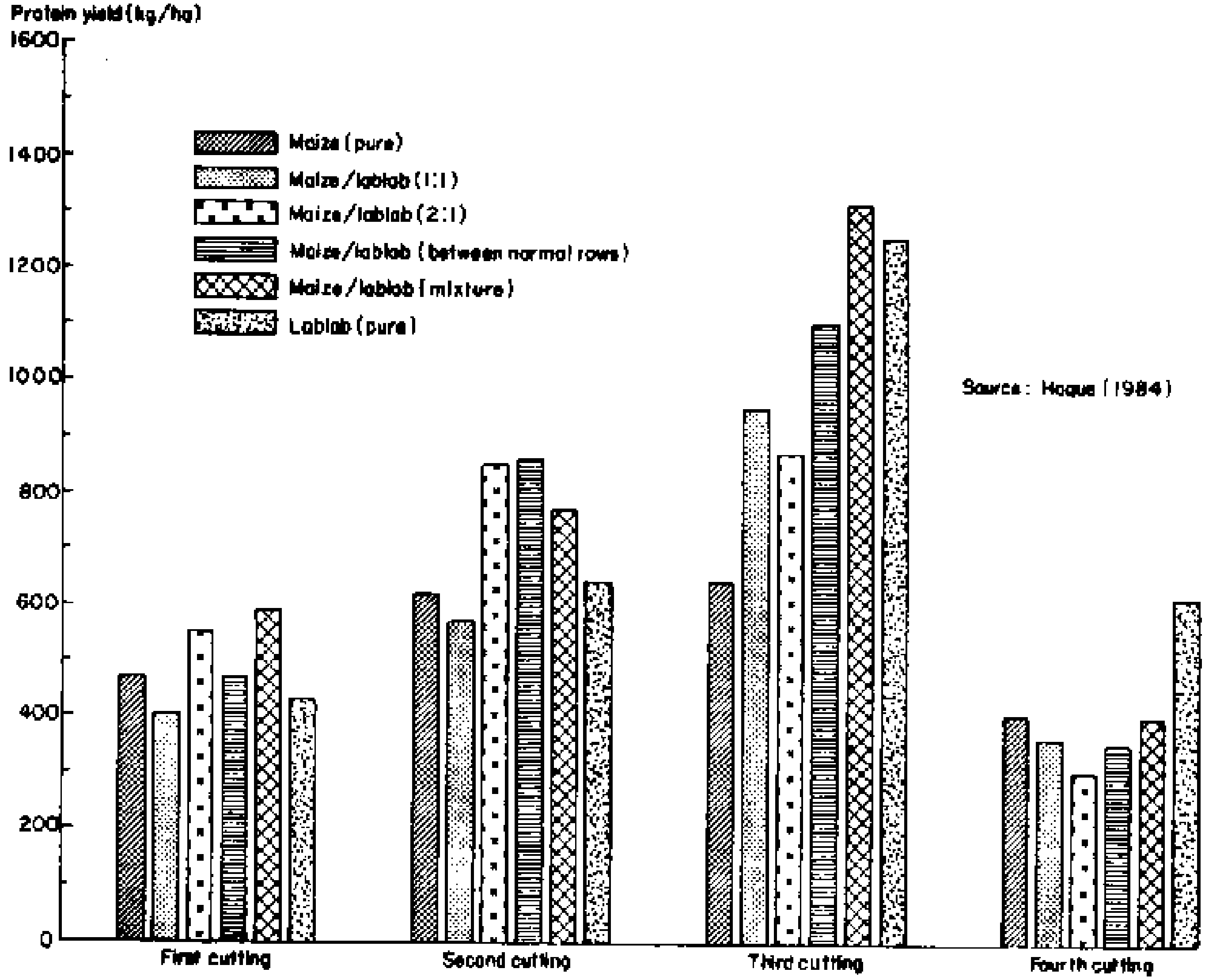


Table 6. Effects of sowing date of stylo on grain, stover and crudeprotein yields of maize and on dry-matter and crude-protein yield of stylo.

Treatment	Grain yield	Stover yield	Crude protein
	Maize (t/ha)		
Pure maize	10.02	14.66	0.44
Undersown with stylo at 5 DAP	9.65	13.19	0.49
Undersown with stylo at 4 WAP	10.24	14.07	0.41
Undersown with stylo at 8 WAP	10.15	14.37	0.42
SE	NS	NS	NS
	Stylo (kg/ha)		
Pure stylo		2380	255
Undersown at 5 DAP		154	16
Undersown at 4 WAP		20	1.1
SE		1.5	0.2

DAP = days after planting; WAP = weeks after planting. Source: Kanyama and Edje (1976).

Improvement of feed quality

Qualitative improvement of cereal residue

If a cereal-forage legume intercrop is to increase livestock production the yield of legumes should be high. Ruminant animals can synthesise most amino acids if the N supply is adequate. Therefore, protein quality is not of major importance to animals grazing pasture or feeding on crop residue. The most important factor is crude protein content. For maintenance, the N content of the feed ingested should be at least 1.1% (Humphreys, 1978). To meet even this minimum level requires that the yield of legume be quite high.

Suppose a sorghum crop yields 5 tonnes of stover per hectare and contains 0.35% N, while the stylo intercrop contains 2.5% N. The amount of stylo needed to attain the minimum N for basal metabolism (1.1%) may be calculated as follows: Let the amount of stylo in kg/ha be Y, then

$(5000 \times 0.35\%) + (Y \times 2.5\%) = (5000 + Y)(1.1\%)$

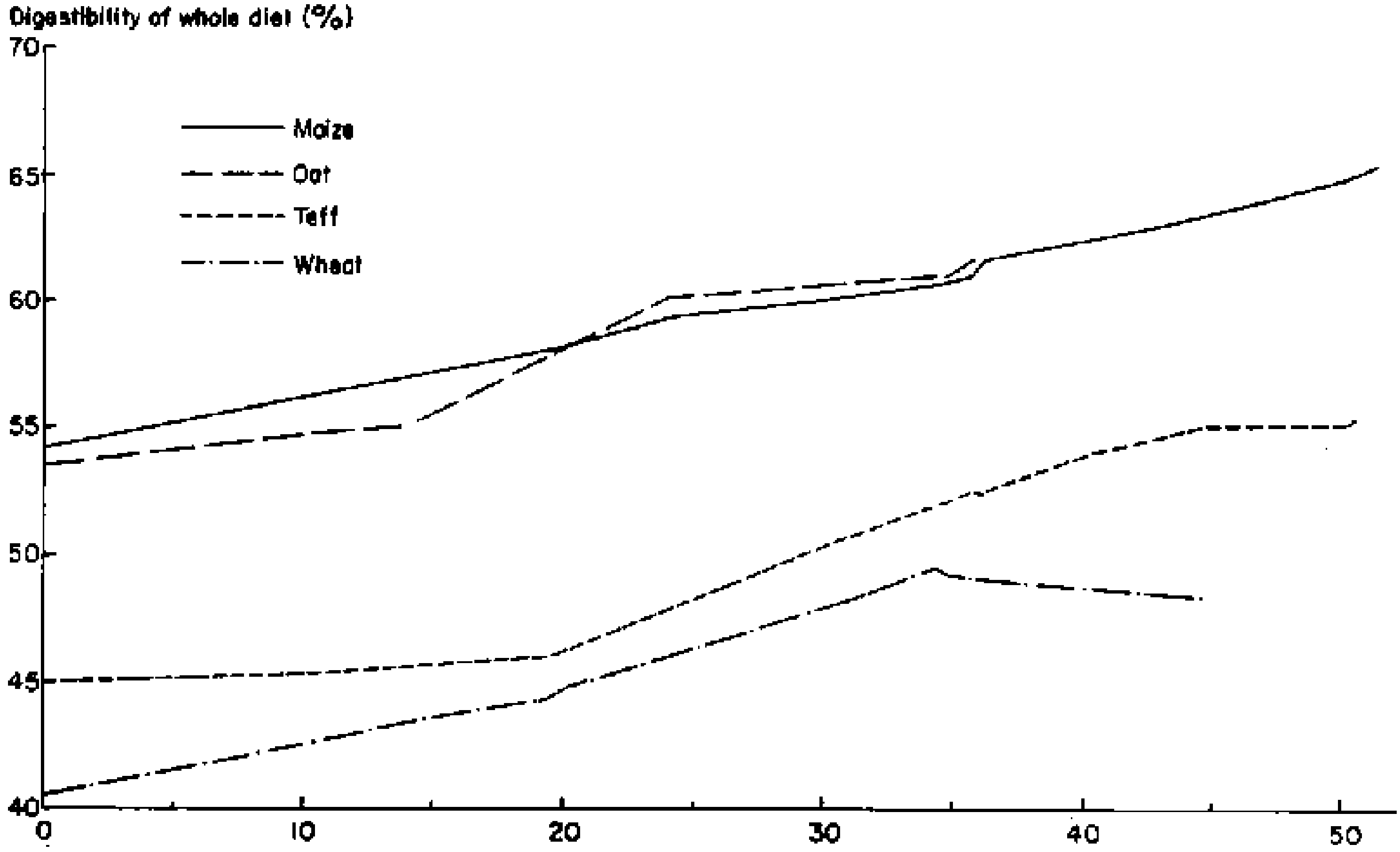
Solving the equation for Y gives 2679 kg. Therefore we need to produce more than 2.5 t of stylo per hectare to meet the N requirement. The amount of legume required will decrease if its N content is high and will increase as the protein content of the feed is raised.

Voluntary intake and digestibility of rations of cereal residues and legume hay

Nutritive values of cereal crop residues can be increased by chemical methods such as treatment with alkalis or the addition of molasses and urea but such methods are generally out of reach of the small farmer. Addition of legume haulms to cereal crop residues has been shown to increase the voluntary intake or the digestibility of the ration.

Mosi and Butterworth (1985a) found that the addition of 20-25% of *Trifolium tembense* hay to teff *(Eragrostis tef*) straw increased feed intake of sheep by 20-30%. In another study, Mosi and Butterworth (1985b) reported that addition of *Trifolium tembense* hay to teff, oat, wheat and maize straw significantly reduced the consumption of each straw but significantly increased total consumption of dry matter. Increases were also obtained in the apparent digestibility of dry matter, crude protein and P of each mixed diet when compared with each cereal residue alone (Figure 3).

Figure 3. ***Effect of addition of Trifolium tembense hay on digestibility of cereal straws.***



Source: Mosi and Butterworth (1985b)

Studies in Sudan show that supplementation of berseem *(Medicago sativa*) and *Sorghum vulgare* with molasses significantly increased the digestibility of *S. vulgare* by Sudan zebu cattle and desert sheep but had no effect on the dry-matter digestibility of berseem (Ahmed and Ahmed, 1983). Butterworth et al (1985) also reported that legume supplements increased the intake and digestibility of rations based on cereal crop residues. They found that the dry-matter intake of wheat straw was 41 g/kg $LW^{0.75}$ compared with 60 g/kg $LW^{0.75}$ for *Trifolium tembense* hay. The apparent digestibility coefficients of dry matter were 42 and 51% for wheat straw and legume hay, respectively. Thus, if adequate amounts of legume hays can be produced, the nutrition of ruminants will be greatly improved. The increase in digestibility of cereal residue produced will depend on the amount of legume haulms produced under a given intercrop system.

Enhancement of soil fertility

A third aspect of forage legume-cereal intercropping is the maintenance of soil fertility under continuous cultivation. In order to maintain soil fertility under continuous cultivation in SSA, the soil N content will need to be increased. This may involve modification of the traditional cropping system so that it still satisfies the economic need of the farmer while at the same time improving the nutrient status of the soil. The extent to which intercropping a cereal with a forage legume can enhance soil fertility will be evaluated in this section. We shall examine the practice of 'cut-and-carry', in which the tops of both cereals and legumes are removed from the field where they were grown and either fed to livestock or used for other purposes. Where the crop residues are fed to livestock the manure may not necessarily be returned to the same farm.

Dinitrogen fixation

For a legume to attain its potential for biological N fixation the symbiosis between the plant and the *Rhizobium* must be working properly. In particular, the manufacture of carbohydrates in the leaves and their downward translocation to the nodules must be adequate. The quantity of N fixed is very largely dependent on the dry-matter yield of the plant, which in turn is a reflection of the legume genotype and the environmental conditions during growth (Jones, 1977; App et al, 1980). While no data are available on nodulation and N_2 fixation by forage legumes in cereal intercrops, a few studies have been carried out in grain legume-cereal systems. Reddy and Willey (1980) reported that groundnut had fewer nodules and much lower N_2 fixation per plant in a millet-groundnut mixture than when grown alone. Nambiar et al (1983) also found similar effects with respect to nodulation but N_2 fixation was only slightly reduced in a maize-groundnut intercrop with no N applied (Table 7). Graham and Chatel (1983) reported the planting bush bean in an intercrop with maize increased early nodule development by markedly inhibiting N_2 fixation after flowering. On the other hand, Nair et al (1979) observed better nodulation of cowpea intercropped with maize, especially when cowpea was planted between rows of maize, while soya bean and pigeonpea showed reduced nodulation in intercrops (Table 8).

Table 7. Effect of intercropping and nitrogen fertilizer (kg/ha) application on nodulation and nitrogen fixation of groundnuts.

		Nodules/plant	Nodule wt. mg/plant	N_2 fixation umoles C_2H_2/plant per hour
Sole groundnut		171	124	21.1
Groundnut + maize: No N		160	117	20.2
	N_{50}	165	93	9.4
	N_{100}	150	78	7.0
	N_{150}	134	65	3.5
SE		15.4	11	1.9

Source: Nambiar et al (1983)

If N_2 fixation and nodulation are significantly reduced in intercrops this would mean a greater demand on soil N by both legume and cereal.

Nitrogen content of roots

A few estimates have been made of the amount of N in forage legume roots in pure legume stands. Henzell (1981) reported a range of 15-111 kg N/ha in temperate legume roots. The amount left in roots appeared not to be related to the total N fixed but rather was genetically determined. Burton (1976) found that 50% of the total N in *Trifolium pratense cv.* Ken Star was in the roots but for other legumes the value was between 12 and 20%. Estimates of root N in tropical environments are a bit lower than those reported for temperate regions. Musa and Burhan (1974) reported a range of 16-22 kg N/ha for legumes grown in the Gezira, Sudan.

Table 8. Effect of intercropping on nodulation of legumes at various nitrogen levels.

Cropping system	N applied (kg/ha)				Mean
	0	40	60	120	
	Nodules/plant				
Cowpea (pure)	16	23	21	17	19
Cowpea in maize (inter-row)	25	29	33	30	29
Cowpea in maize (intra-row)	19	20	20	17	19
Soyabean (pure)	33	39	48	37	39
Soyabean in maize (inter-row)	24	39	50	26	35
Soyabean in maize (intra-row)	25	30	39	31	31
Pigeon pea (pure)	15	25	19	21	20
Pigeon pea in maize (inter-row)	13	18	24	18	18
Pigeon pea in maize (intra-row)	15	24	17	17	18
Mean	21	27	30	24	

Source: Nair et al (1979)

These workers also cited the work of Oke (1967), who found that *Calopogonium mucunoides* and *Pueraria phaseoloides* retained 10 and 20%, respectively, of plant N in the root system in a Nigerian soil. Also Whiteman (1971) reported that 20 and 29% of the N fixed by *Desmodium uncinatum* and *Phaseolus atropurpureus,* respectively, in Australia was retained in the root system (Table 9).

It appears that in monocrops the average amount of N from the root system will range from 20 to 50 kg N/ha. Instantaneous sampling of roots may in some instances lead to

underestimation of root contribution to soil N. This could happen in cases where nodules are continually shed and new ones grown. Musa and Burhan (1974) observed some variability in nodule persistence. Nodules of *Dolichos lablab, Vigna unguiculata* and *Phaseolus trilobus* Ait were reported to be weakly attached to roots and were shed following cutting but groundnuts had permanent nodules. The question that needs to be addressed is how much root N is available under intercropping.

Table 9. Amount of nitrogen in sole-crop legume roots and tops grown for forage.

Legume	Tops	Roots	Total	Root N as % of total
	kg N/ha			
Lupinus angustifolius cv Frost[a]	383	47	430	10.9
Tritolium incarnatum cv. Chief[a]	211	15	226	6.6
T. pratense cv. Ken star[a]	175	111	286	38.8
T. repense cv. SI[a]	209	46	255	18.0
T. subterraneum cv. Mt. Barker[a]	199	48	247	19.4
I. vesiculosum cv. Meechee[a]	253	38	291	13.1
Vicia hirsuta[a]	326	69	395	17.5
Phaseolus trilobus Ait (Phillipesara)[b]	203	16	219	7.3
Clitoria ternata (Clitoria)[b]	185	22	207	10.6
Dolichos lablab L. (Lubia)[b]	181	18	199	9.0
Arachis hypogaea L.[b]	193	17	210	8.1
Desmodium uncinatum[c]	86	35	121	28.9
Phaseolus atropurpureus[c]	121	30	151	19.9

Sources: [a]Henzell (1981), [b]Musa and Burhan (1974), [c]Whiteman (1971)

Mineralisation of nitrogen in legume roots

The rate of mineralisation of N in legume roots is a function of the N content of the roots, which varies considerably between legumes (Nnadi and Balasubramanian, 1978). Roots with an N content of 2% or more are likely to mineralise fast. Henzell and Vallis (1977) cited Bartholomew's (1965) figure of 60% decomposition of legume residue in the first year and 10% per annum for the remainder. Since the yield of legume haulms in intercrops is about 25% of the sole-crop potential one would expect a corresponding decrease in the root system. Thus, assuming 25% of the 20-50 kg N/ha average of sole crop legume roots is found in mixtures, this is equivalent approximately to 5-12 kg N/ha. If 60% of this is mineralised in the first year it will yield about 3 to 7 kg N to a subsequent crop.

Residual effects

The contribution of N by a forage legume to a subsequent crop is less controversial than current transfer of N. It is generally agreed that some quantity of N will result from root and nodule decay (Henzell and Vallis 1977). The amount of N left in the soil will depend on the type of intercropping practiced, since each method has a different effect on growth of the legume and consequently, on the amount of N fixed. Waghmare and Singh (1984b) in India reported that the N requirement of a non-legume crop can be considerably reduced after intercropped fodder legume (Table 10). This large residual effect does not agree with the earlier discussion on the contribution of legume roots to soil N. However, it is not clear whether the presence of legume roots could increase mineralisation of cereal roots and native soil organic matter by decreasing the overall C/N ratio. Such an effect could explain the results Waghmare and Singh (1984b) and others. The data of Nair et al (1979) are more within the range of yield increases expected from residual effects of intercropped legumes.

Table 10. Grain yield of wheat in relation to preceding intercrops.

Treatment	Wheat grain yield (t/ha)		
	1978	1979	Mean
Sole sorghum	3.40	3.61	3.51
Sorghum + green gram	4.05	3.75	3.90
Sorghum + groundnuts	4.33	4.01	4.17
Sorghum + grain cowpea	4.30	4.03	4.17
Sorghum + fodder cowpea	4.69	4.11	4.40
Sorghum + Soyabean	3.61	3.47	3.54

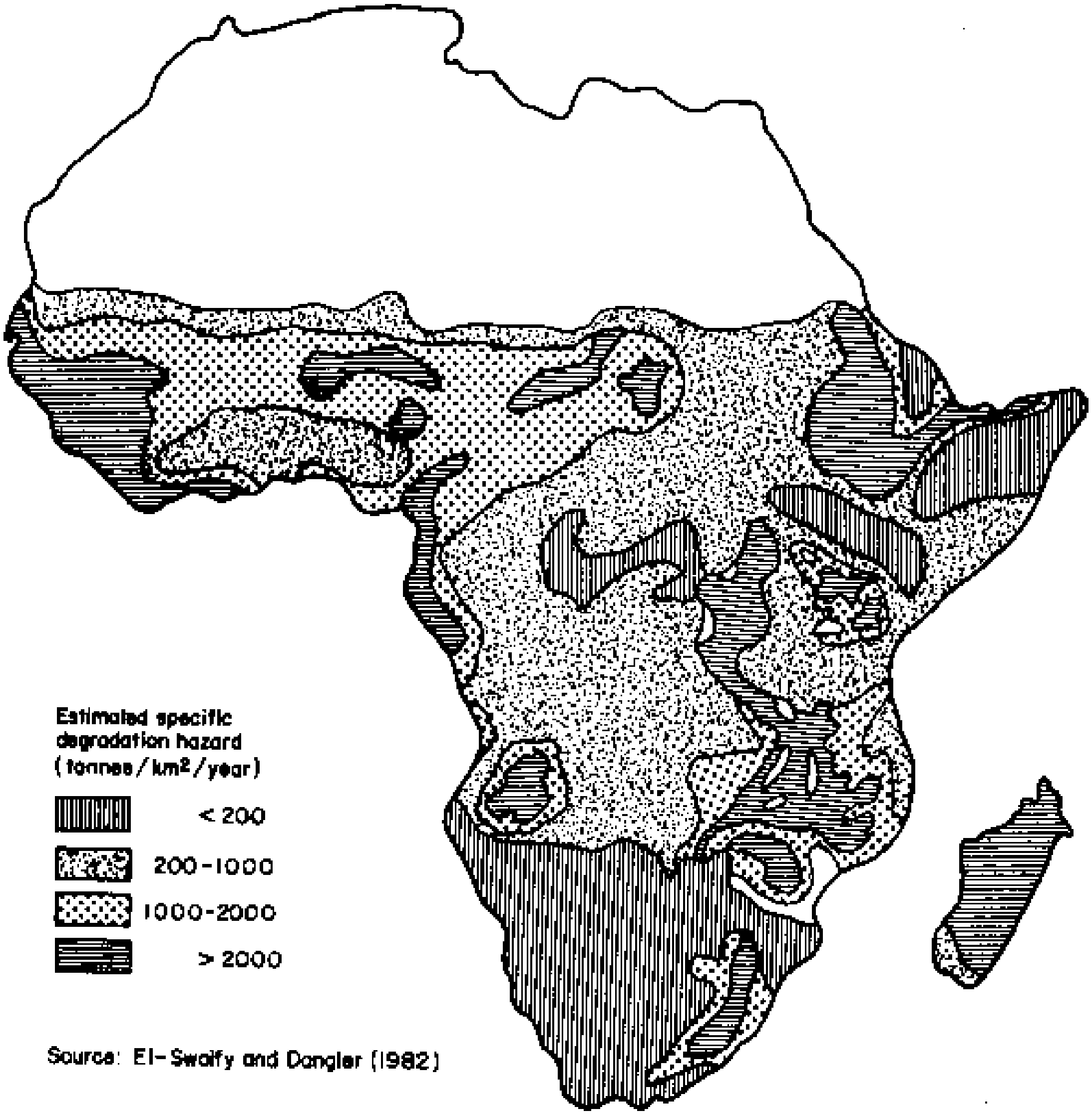
Source: Waghmare and Singh (1984b)

Though studies of the residual effects of forage legumes are usually focused on their N contribution, there may also be other benefits. Williams and David (1976), cited by Graham and Chatel (1983), reported that subterranean clover increased available P and organic-matter levels and rendered Zn, Fe, Cu. and Mn more available. The advantage of such effects on associated cereals is obvious.

Erosion control

Jones and Wild (1975) suggested that erosion might be low under subsistence agriculture because of the predominant practice of intercropping and semi-sequential or relay cropping. However, as cropping intensity increases, the risk of soil erosion increases especially in marginal lands. Recent estimates of erosion hazards in Africa put soil losses at very high rates, e.g. Allen (1980)estimated that losses in Ethiopia amounted to nearly 1000 million tonnes per year. Soil erosion has been identified as a serious problem on Alfisols in West Africa. These soils are characterised by unstable structure that forms a crust when exposed to raindrop impact (Lal, 1980). Estimated soil losses in sub-Saharan Africa are shown in Figure 4.

Figure 4. ***Fournier's rainfall erosion hazard classes within Africa south of the Sahara (modified).***



Soil loss under intercropping has been shown to be less than under monocropping (Aina et al, 1977). Runoff and soil erosion have been found to be proportional to the time required for full canopy to develop (Aina et al 1977), hence the use of fast-growing forage legume crops which produce early ground cover is beneficial for the protection of the soil.

Green manuring in intercrops

Although green manuring is an age-old practice in Asia (Singh and Das, 1984) it is hardly used in SSA. The problems associated with the use of green manures have been dicussed by Jones and Wild (1975) and Nicholaides et al (1984). The major drawbacks are the high labour requirement for incorporation and the loss of one season required to produce the green manure. These problems could be minimised by planting a fast-growing forage legume between rows of widely spaced (about 90 cm) long-duration crops. The green manure can be hoed up and allowed to decompose *in situ*. The technique of greenleaf manuring is crucial in alley cropping and has been shown to yield 75, 2.9 and 2.6 kg of N, P and K/ha per year respectively (Singh and Das, 1984) and well over 100 kg N/ha per year (Kang and Duguma, 1984).

Competition in forage legume-cereal systems

Light

The individual yields of forage legumes and companion crops are generaly lower in intercropping experiments than in monocrops. The decrease in biomass production has been attributed to competition for light, moisture and nutrients. Several workers (Willey, 1979; Reddy and Willey, 1979;

Baker and Yusuf, 1976) considered light to be the most important factor in competition, particularly when the crops are of different durations.

More efficient use of light can also be attained by careful spatial arrangements of multi-storey cropping with tall and short crops, provided the short crops are adapted to low light intensities. Light also has an important effect on the reproduction of some species. Jones and McCown (1983) reported that Caribbean stylo *(Stylosanthes hamata* cv. Verano) produced little seed in an intercrop with maize due to its failure to flower in the shade of a full maize canopy (50,000 plants/ha in 75 cm rows), whereas *Alysicarpus vaginalis* produced 2000-4000 seeds/m^2.

Nutrients and soil moisture

According to Kurtz et al (1952), below-ground competition is mostly limited to competition for moisture and mobile nutrients such as nitrate. Competition for immobile nutrients, such as P, does not normally occur except in limited regions where the root systems of the intercrops are in actual contact. The use of a forage legume that can fix large amounts of N would reduce one of the major sources of competition.

In the semi-arid areas or in relatively dry years in the humid region, competition for water can be severe. Thus Kurtz et al (1952) observed that, in a season when moisture was limiting, yield of maize intercropped with alfalfa and lading clover was greatly reduced even with adequate N fertilization. Growing crops with different rooting patterns, and which thus exploit different soil layers, would reduce competition for water and nutrients.

Different views have been expressed regarding the relative importance of above- and below-ground competition (Ready and Willey, 1979; Snaydon and Harris, 1979). Conflicts could be resolved by examining resource utilisation at different fertility levels in greater detail.

Minimising competition in forage legume-cereal mixtures

Farmers will tolerate only small reductions in the grain yield of cereal crops due to intercropping with forage crops, since cereal grain is the first priority of the farmer. A decrease of 10-15% relative to the cereal monocrop may be acceptable to the subsistence farmer. Some agronomic practices that can help minimise competition and increase the productivity of intercrops are discussed below.

Time of sowing: The time of sowing is critical for optimal production of cereal grain and forage. The best time depends on the cereal and the legume in question and needs to be determined experimentally. Mohamed-Saleem (1984a) found that planting *Stylosanthes guianensis cv.* Cook or *S. hamata* cv. Verano on the same day as an unimproved sorghum variety reduced grain yield by over 70%, but the reduction was less if the legume was sown 3 weeks after the cereal. In another trial, it was observed that an improved, medium-duration sorghum cultivar, SK 5912, sown on the same day as *Centrosema pascuorum, Alysicarpus vaginalis* and *Macroptilium lathyroides* did not suffer significant yield reductions.

Kanyama and Edje (1976) in Malawi reported only 4% decrease in grain yield of maize when *Stylosanthes guianensis* cv. Schofield was sown 5 days after the cereal (Table 6). Delaying the sowing of the legume increased maize yield but drastically reduced the yield of the legume. Thomas and Bennett (1975a), working in Malawi, observed that undersowing maize with a mixture of Rhodes grass and silverleaf desmodium *(Desmodium uncinatum*) after the first weeding of the maize reduced grain yield by 6.5%. Experiments in northeast Thailand with rice have shown that undersowing a medium-duration variety gave little or no difference whether the rice was undersown simultaneously or 10 days later (Shelton and Humphreys, 1975b).

The indication from the few time-of-planting studies is that sowing a forage legume simultaneously with a fast-growing cereal has no effect on cereal yield, but more work is required with different crop species. Large-seeded legumes, such as lablab, which germinate fast are likely to compete more with cereals if sown at same time than small-seeded ones such as *Trifolium* and *Medicago* species.

Planting pattern: Apart from the time of sowing, it may also be necessary to manipulate planting patterns in order to maintain cereal yields. An approach that appears promising involves leaving two cereal stands per hill at wide spacing (0.3 m) and planting the intercrop legume on alternate rows.

This system allows the cereal to be maintained at or near the optimum monocrop population and, if necessary, a third intercrop to be planed between the sorghum hills. Using the above technique, Mohamed-Saleem (1984a) found that inter-row sowing of *Stylosanthes guianensis* reduced grain yield by about 10% compared with pure sorghum plots.

Where fields are ridged, furrows are normally not planted. This need not be the case. Thomas and Bennett (1975b) compared broadcasting forage seeds with drilling on ridges or in furrows. They found that drilling a mixture of silverleaf desmodium and Rhodes grass on ridges or in furrows after the first weeding of maize produced maize yields similar to those achieved when the same amount of forage seeds was broadcast, but gave significantly higher legume dry-matter yields (Table 11). Drilling in the furrow has the advantage that a hand-operated planter can be used.

Table 11. Effect of different methods of undersowing silverleaf desmodium on yields of intercrops.

Treatment	Maize		Legume stover
	Grain	Stover	
	(kg/ha)		
Maize only	2891	5699	-
Legume drilled on top of ridge	2799	5464	577
Legume drilled in furrow	2666	5254	559
Legume broadcast	2869	5524	370

a. Legume undersown 3 weeks after maize.
Source: Thomas and Bennett (1975b)

Ridging can accelerate water erosion if the ridges are not on the contours, and planting forages in furrows would help check such erosion hazards.

Planting density: In cereal-forage intercrops it is important that the population of the cereal crop be as close as possible to its maximum monocrop population, and the density of the forage legume should not be so high as to substantially decrease grain yield. At high density (81 plants/m), stylo substantially reduced the grain yield of the rice intercrop (Shelton and Humphreys, 1975a). Similar effect of high lupin rates on wheat yields have been observed by Gardner and Boundy (1983).

Conclusions and research needs

This review shows that very little work has been done on -forage legume-cereal mixtures in sub-Saharan Africa or indeed elsewhere. A lot of the basic information required for proper understanding of crop interactions is lacking.

Forage legumes that are suitable for intercropping with cereals need to be identified. The characteristics of such legumes should include:

1. Ability to tolerate shade and still produce high dry-matter and seed yields.

2. Ability to develop canopy rapidly.

3. Annual growth habit, since annuals will fit into the farming systems of SSA better than perennials.

4. Non-climbing habit, as climbing species increase lodging and decrease yield of the cereal. However, climbers with narrow leaves such as vetch may be appropriate.

5. High crude protein content

Dual-purpose legumes, such as cowpeas, groundnuts and lablab which can produce grain and large amounts of fodder could fit into the system.

The contribution of forage legumes to the N economy of soils has received practically no attention. Specific areas that require attention are:

1. Residual effects of intercrops
2. Nodulation and nitrogen fixation
3. Current transfer of N to companion cereals in N deficient soils
4. Selection or breeding of legumes that have high N content in roots as well as increased root mass.
Attempts in this direction have been made by Barnes et al (1984).

There is also a need to determine the optimum planting times and densities as well as the best planting patterns for major cereal-forage legume mixtures. The aim should be to maximize the yields of both intercrops. Fertilization schedules for promising cereal-forage legume combinations need to be determined.

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