Productivity of a Maize-Promiscuous Soybean Intercrop as Affected by Fertilizer in the Southern Guinea Savanna Zone of Nigeria

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Abstract

A 2-year field experiment was conducted to assess the response of a maize-promiscuous-soybean cropping system to different rates of NPK fertilizer (20:10:10) in the southern Guinea Savanna zone of Nigeria. Additions of 100 kg ha^{-1} of fertilizer (equivalent to 20 kg N ha^{-1}) was shown to decrease dramatically the number and dry weights of the promiscuous soybean nodules in both the sole and intercropped systems. Without the addition of fertilizer the proportion of N derived from N_2-fixation was about 40% in the intercropped soybean and 30% in the sole crop. Increasing rates of fertilizer from 0 kg ha^{-1} to 300 kg ha^{-1} (equivalent to 60 kg ha^{-1}) led to an increase in N_2-fixation in the sole crop with about 60% of plant N derived from N_2-fixation. On the other hand, N_2-fixation in the intercrop decreased with increasing rates of fertilizer; and an increase was only obtained with an application of 300 kg ha^{-1} fertilizer. Nitrogen accumulation in shoots and grains of the intercropped maize was shown to be less than that of the sole-cropped maize. Also, P yield in the grains of sole maize was significantly larger than that of the intercropped maize. Grain yields and shoot dry matter were increased by additions of fertilizer, with the component crops in the intercrop systems yielding less than the corresponding monocrops. However, the cumulative yield of the component crops in the intercrop resulted in about 30% more income above those of the sole crops. The most profitable fertilizer level for the maize-intercrop system was shown to be 300 kg ha^{-1}.

Introduction

Typical of most soils of sub-Saharan Africa, agricultural production in the Nigerian savanna is largely limited by low soil fertility. The use of fertilizers to overcome this limitation is hampered by their high cost, which the peasant farmers can hardly afford. One promising alternative that can substantially reduce investment in fertilizers is the inclusion of legumes in the various farming systems. Farmers in the Nigerian savanna are aware of the importance of legumes in soil fertility improvement, and have had a long tradition of cultivating grain legumes in various combinations with cereals (Bala & Osunde, 1995).

Mixed cropping of cereals and legumes is a widespread practice because legumes enable farmers to cope with weed infestation (Akobundu, 1993), erosion and declining levels of soil organic matter and available N (Fujita *et al.*, 1992). Companion crops benefit from such mixtures through N accrual from legume root and nodule senescence and direct N transfer from the legumes (Fujita *et al.*, 1990), while subsequent crops benefit from the N mineralized from the fallen leaves and incorporated stover of the legume (Giller *et al.*, 1997).

Although soybean is not a new crop in the savanna areas of Nigeria, the size of the hectarage that is put to its cultivation has been relatively insignificant. This is largely due to the poor yield obtained from local soybean varieties and the requirement by the exotic varieties for inoculants that are often difficult for smallholder farmers to acquire. The introduction by IITA of promiscuous cultivars of soybean that nodulate freely with indigenous rhizobia has led to widespread adoption and increased cultivation of soybean by smallholder farmers in Nigeria (Osunde *et al.*, 1998).

Deficiencies of nitrogen and phosphorus are a major constraint to grain legume production in most areas of the tropics (Giller & Wilson, 1991). Given favourable conditions, promiscuous soybean can nodulate and fix a considerable amount of nitrogen (Sanginga *et al.*, 1997; Kasasa *et al.*, 1998). This study was, therefore, conducted to assess the fertilizer requirement, productivity and economic returns of cultivating a promiscuous soybean cultivar as an intercrop in a maize-based cropping system in the southern Guinea Savanna of Nigeria.

Materials and methods

A two-year trial was conducted at the University Farm in Minna during the 1997 and 1998 cropping seasons to evaluate the fertilizer requirement of a late maturing (120 days) promiscuous soybean cultivar (TGX 1660). The soil at the farm was a sandy clay loam, *p*H 5.70, and with an organic matter content of 1.19%. The soil had available P and total N contents of 5.44 mg P kg^{-1} and 0.5%, respectively. Treatments included two cropping systems (maize and soybean cropped sole or intercropped) and four rates of NPK fertilizer (20:10:10) at 0, 100, 200 and 300 kg ha^{-1}. The fertilizer rate at 100 kg ha^{-1} was equivalent to 20 kg N, 10 kg P_2O_5 and 10 kg K_2O; that at 200 kg ha^{-1} was equivalent 40 kg N, 20 kg P_2O_5 and 20 kg K_2O; that at 300 kg ha^{-1} was equivalent to 60 kg N, 30 kg P_2O_5 and 30 kg K_2O and consistent with the recommended NPK rates of 120 kg N, 60 kg P_2O_5 and 60 kg K_2O, respectively, for maize in the Nigerian savanna (Enwezor *et al.*, 1989). The use of such a compound fertilizer does not allow for the control of rates of individual nutrient elements being evaluated; however, this is the only brand produced by the local fertilizer industry and farmers around the Minna area hardly have access to other types of fertilizer. The objective of the study was to evaluate the fertilizers available to the farmers and recommend the most economical rates, hence the choice of this particular brand of fertilizer for the trial.

The experimental design was split-plot replicated three times, with cropping system assigned to the main plots, and fertilizer rates to the sub-plots. Each sub-plot was made up of four ridges each 8 m long, with a 75-cm spacing between ridges. Promiscuous soybean cultivar TGX1660 and hybrid maize variety SUWAN-1-SR were used for the experiment. Maize was sown at a spacing of 45 cm, while soybean was hand-drilled on the same ridges as maize 2 weeks later. Intercropped maize was sown at the same plant population as sole maize. Fertilizer was applied to the maize at the time of sowing soybean. Maize seedlings were thinned to two per stand, while the soybean seedlings were thinned to a spacing of 10 cm, 1 week after emergence. Parameters assayed in both years were nodule number and dry weight at 50% podding and VA-mycorrhizal infection of maize roots at 50% tasselling. Others were shoot biomass, grain yield and grain N and P yields of both crops. During the 1998 season, the proportion of N derived from fixation was estimated at 50% podding using the Ureide method (Herridge & Peoples, 1990). Data were subjected to analysis of variance (ANOVA) and differences between treatment means compared using LSD at 5% level of significance. All analyses were carried out using the Statistical Analysis System programme (SAS, 1989).

Results

Nodulation and nitrogen fixation

Differences in nodule number were due to the main effect of fertilizer in 1997 and 1998 seasons. In both years, the number of nodules at 50% podding was significantly ($P \leq 0.05$) decreased by the application of fertilizer at the rate of 100 kg ha $^{-1}$ (Fig. 1A). Nodule numbers declined from 12 to 9 in 1997, and from 13 to 6 in 1998. Increase in fertilizer rate above 100 kg ha $^{-1}$ also led to a marginal decrease in nodule number except in 1997 when the number at fertilizer rate of 300 kg ha $^{-1}$ was significantly lower than that at 100 kg ha $^{-1}$. Nodule dry weight followed a similar trend as nodule number with fertilizer additions at 100 kg ha $^{-1}$ resulting in a marked decrease in nodule dry weight for both seasons (Fig. 1B). Further additions of fertilizer above 100 kg ha $^{-1}$ had no significant effect on nodule weight.

The proportion of N derived from fixation (%Ndfa) by the soybean crop was measured during the 1998 season, and there was a significant fertilizer × cropping system interaction effect on this parameter (Fig. 1C). The %Ndfa in the control plot was over 40% of total plant N for the intercrop and about 30% for the sole crop, while there was no difference in %Ndfa between the two cropping systems at 100 kg ha^{-1} of fertilizer. At 200 kg ha^{-1}, however, N_2-fixed by the sole cropped soybean was significantly greater than that fixed by the intercropped system. This difference was only marginal at 300 kg ha^{-1} of fertilizer with %Ndfa being about 60% for the sole cropped and 50% for the intercropped soybean.

N accumulation

In both seasons, N accumulation in the above ground dry matter of maize varied depending on the amount of fertilizer added. Increasing the rate of fertilizer led to an increase in N uptake by maize with fertilizer application at 300 kg ha^{-1} producing twice as much N yield in maize shoot as the control (Fig. 2A). Although the difference in N uptake between the two cropping systems was not significant, the stover N yield for the sole-cropped maize was, nonetheless, slightly higher across the range of fertilizer rates used (data not shown).

The fertilizer × cropping system effect significantly affected the N content of soybean grains (Fig. 2B). In the two seasons, accumulation of N was greater in grains of the sole-cropped soybean than in those of the intercrop, and this increased as the fertilizer rates increased (Fig. 2B). Irrespective of the cropping system, soybean grain N content at a fertilizer rate of 300 kg ha^{-1} was similar to the N content at 200 kg ha^{-1}. Variation in N accumulation of maize grains was due to a fertilizer effect in the 1998, but not in the 1997 season, with

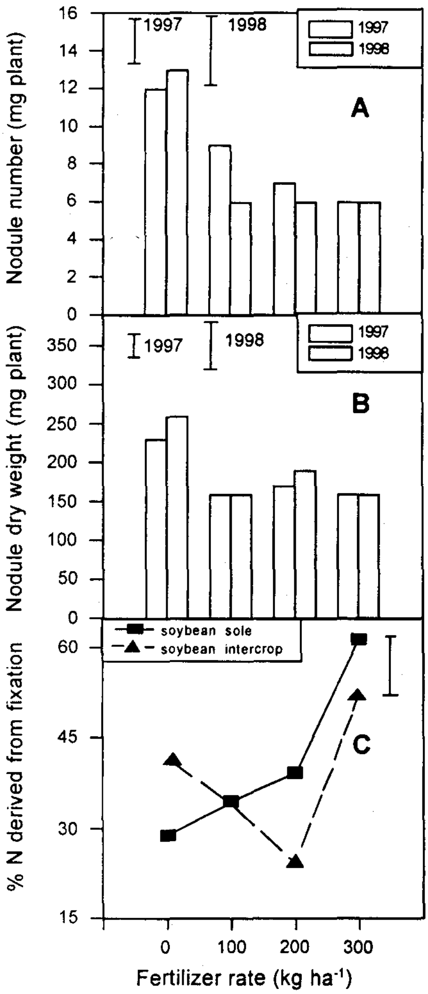

Fig. 1. Effect of NPK fertilizer on nodule number (A), nodule dry weight (B) and biological nitrogen fixation (C) in promiscuous soybean for two cropping seasons. Nitrogen fixation data is for the 1998 season only. Vertical bars are LSD values ($P \leq 0.05$) for comparisons between treatments within corresponding cropping seasons.

additions at 300 kg ha^{-1} resulting in the largest grain N content (Fig. 2C). There was, in addition, a cropping system effect on maize grain N content. In both seasons, the grain N content of the intercropped-maize was smaller than that of the sole-crop (Fig. 2D).

Dry matter accumulation

Although the difference in dry matter accumulation between the sole- and the intercropped soybean was not significant in the 1997 season, the difference was, however, significant in the 1998 season (Fig. 3A). In both seasons, the sole crop produced more biomass than the intercrop. However, except for the sole-cropped soybean of the 1998 season, larger applications of fertilizer only led to slight increases in dry matter yield of soybean in both cropping systems. Increasing fertilizer rates led to production of more biomass in maize (Fig. 3B). In both years, application of fertilizer at 100 kg ha^{-1} produced similar biomass in maize as 300 kg ha^{-1}. Although cropping system had no significant effect on maize stover yield, the dry matter of the sole maize was slightly greater than that of the intercropped maize in both years (data not shown).

Grain yield

Differences in grain yields between maize treatments showed similar trends in both 1997 and 1998 seasons (Fig. 4). For sole-cropped maize, addition of fertilizer at 100 kg ha^{-1} resulted in yields that were four times and twice those of the control in 1997 and 1998, respectively. Fertilizer additions above 100 kg ha^{-1} either led to no further increase, or resulted in only marginal increases in both years. In 1997, addition of fertilizer to the intercropped maize at 200 kg ha^{-1} led to a significant increase in grain yield above that of the control. However, 300 kg ha^{-1} of fertilizer was needed to bring about significant increase in grain yield during the 1998 season. In both years, grain yield of the sole-cropped maize at 100 kg

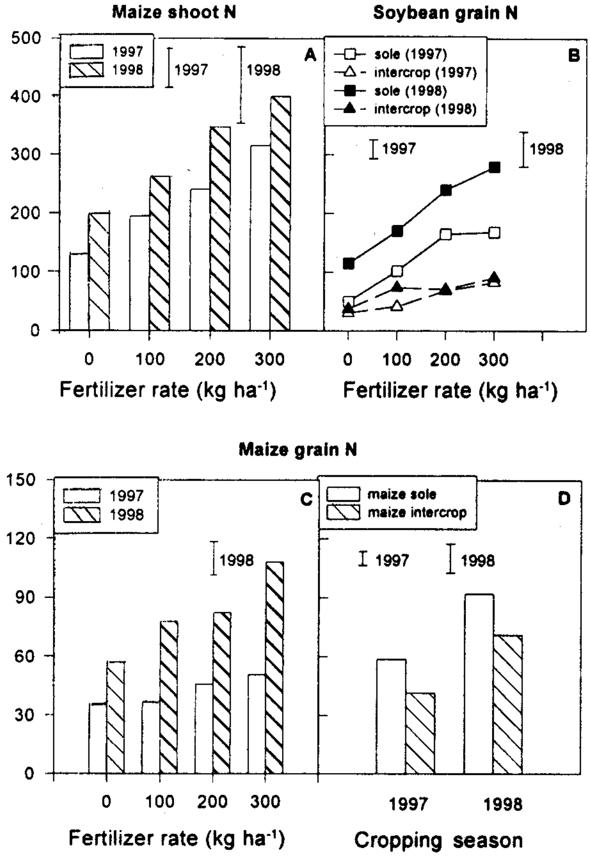

Fig. 2. Fertilizer and cropping systems effect on N accumulation in stover and grains of maize and promiscuous soybean for two seasons. Vertical bars are LSD values ($P \leq 0.05$) for comparisons between treatments within the corresponding seasons.

ha^{-1} was significantly higher than that of the intercrop. The yield of the sole maize was also slighty better at 200 kg ha^{-1}, while no difference was obtained at 0 or 300 kg ha^{-1}. Differences between grain yields of the soybean treatments were affected by the interaction between fertilizer and cropping system in 1997, while only the main effects of these factors were significant in 1998. However, the trends in both years were largely similar, with grain yields of the sole crop being consistently greater than those of the intercrop across the range of fertilizer rates used (Fig. 4).

Arbuscular mycorrhizal infection and P accumulation

The level of arbuscular mycorrhizal fungal (AMF) infection of maize roots declined with increasing rates of fertilizer (Fig. 5A). In the 1998 season, AMF infection was significantly reduced from about 33% at 0 kg ha^{-1} of fertilizer to about 23% at 100 kg ha^{-1}. A similar trend was observed in 1997 although the decline due to fertilizer addition was not as large as in 1998. Differences in P accumulation in grains of maize and soybean were affected by cropping system and fertilizer addition. In both seasons, P yields in grains of the intercropped maize (Fig. 5B) or soybean (Fig. 5C) were significantly smaller than those of their respective sole crops. The proportion of P in grains of sole-cropped soybean was three times that of the intercrop in both seasons (Fig. 5C).

Economic analysis

An analysis of the net income accruable to the farmer, based on the gross income and expenditure, is presented in Table 1. For sole maize, the most profitable return was obtained with fertilizer application at 100 kg ha^{-1}, while fertilizer rate of 200 kg ha^{-1} gave the best returns for monocropped soybean. The best returns for the intercrop system was generated by the application of 300 kg ha^{-1}. Although the returns from sole crops were higher than those of their respective intercrops, the cumulative net

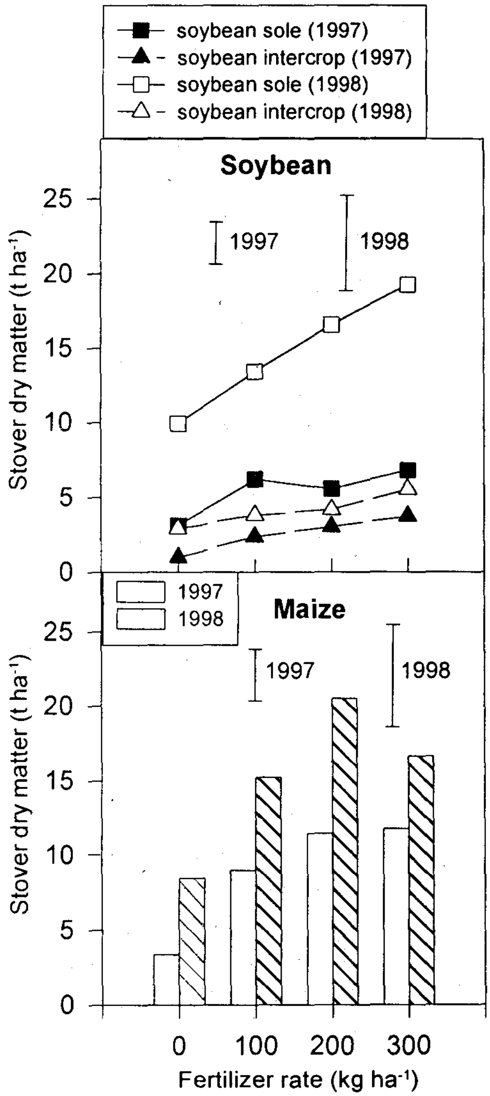

Fig. 3. Effect of NPK fertilizer on stover dry matter for sole- and intercropped maize and soybean during two cropping seasons. Vertical bars are LSD values ($P \leq 0.05$) for comparison between and within treatments in respective cropping seasons.

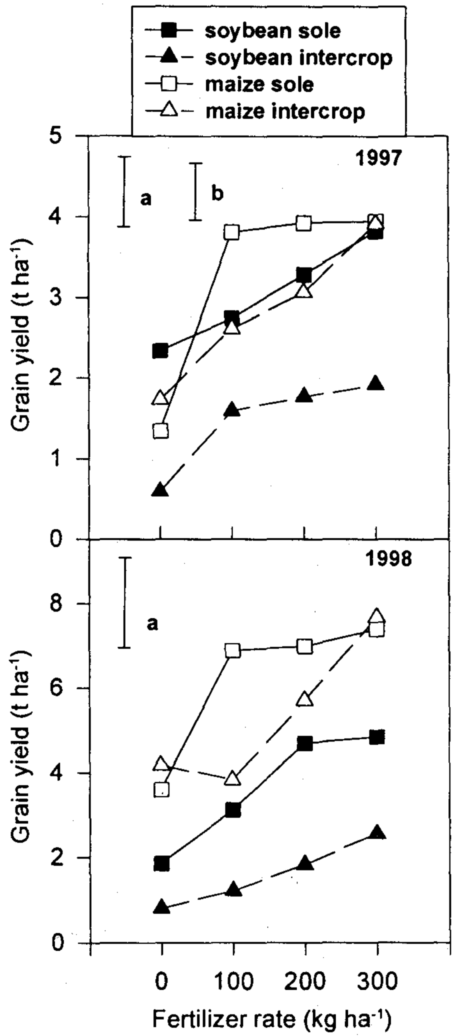

Fig. 4. Effect of NPK fertilizer on the grain yields of maize and soybean planted sole- or intercropped for two cropping seasons. Vertical bars are LSD values ($P \leq 0.05$) for comparisons within and between maize (a) and soybean (b) treatments.

income for the two crops in the intercropping system was higher than those of the individual monocrops.

Discussion

Nodulation, N_2-fixation and N accumulation

The soybean crop successfully nodulated with local rhizobial population in both years even though the site has had no previous history of rhizobial inoculation. The nodules when cut open were pinkish red in colour

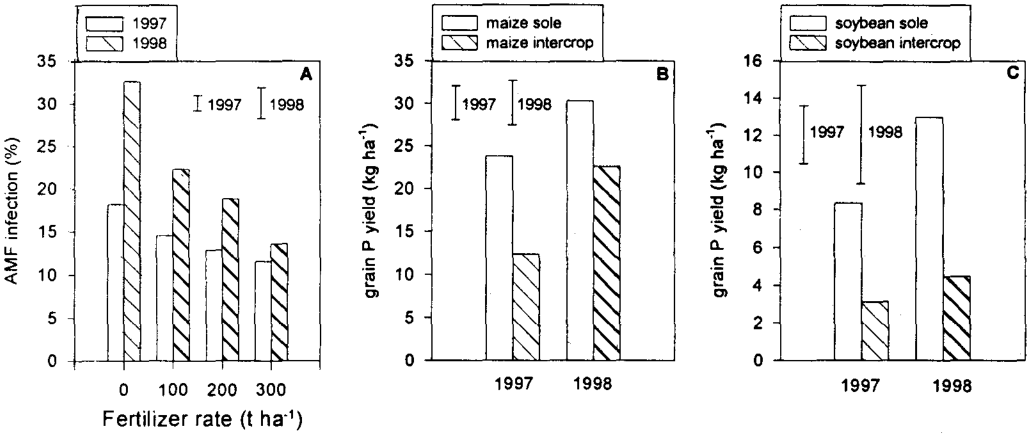

Fig. 5. Arbuscular mycorrhiza-fungal infection (AMF) of maize roots (A), maize grain P content (B) and soybean grain P content (C) as affected by NPK fertilizer and cropping systems in two seasons. Vertical bars are LSD values ($P \leq 0.05$) for comparisons between treatments in respective cropping seasons.

indicating active N_2-fixation. This further confirms cultivar 1660-19F as a promiscuous line that is capable of effective nodulation with indigenous rhizobia (Abaidoo *et al*., 1999; Sanginga *et al*., 2000). The significant reduction in the number and weight of soybean nodules due to the application of NPK fertilizer at 100 kg ha^{-1} (equivalent to 20 kg N ha^{-1}) was unexpected. This is because although high N doses depress nodulation and N_2-fixation (Ofori & Stern, 1987; Fujita *et al*., 1992), a starter dose of 20 kg ha^{-1} to soybean and cowpea is a recommended practice in the Nigerian savanna (Enwezor *et al*., 1989). This is because the soils are generally low in nitrogen, and application of the NPK fertilizer should, at least at the low rate, increase rather than decrease nodulation.

Although nodulation was inhibited by fertilizer application, increase in fertilizer additions led to an increase or a decrease in N_2-fixation depending on the cropping system and fertilizer rate (Fig. 1C). This shows that the relationship between nodule number or weight, on one hand, and N_2-fixation, on the other, is not necessarily a direct one. For this reason, N_2-fixation measurements are needed to validate qualitative nodule parameters when selecting promiscuous soybean varieties for high N_2-fixation traits (Abaidoo *et al*., 1999; Sanginga *et al*., 2000).

The changes in the proportion of N derived from fixation (%Ndfa) and other yield parameters with increase in the application of fertilizer was in contrast to previous reports that cultivar 1660-19F did not respond to N fertilizer (Sanginga *et al*., 2000). Unlike the previous study, however, this study included varying rates of P and K in addition to N. Hence, the increase in %Ndfa with progressive addition of fertilizer to the sole-cropped soybean appeared to be a consequence of improved crop vigour due to the application of P and K in addition to N. The reduction in %Ndfa in the intercropped system, on the other hand, was consistent with the finding that N_2-fixation in determinate soybean decreased when it was intercropped with sorghum (Fujita *et al*., 1990).

In the case of the intercrop, fertilizer was applied at the same time as the soybean was

0	3600	7500	0	1700	0	8400	12500	108000	29900
100	6890	7500	3000	1700	1500	8400	22200	206700	44300
200	6990	7500	6000	1700	1500	8400	22500	209700	47600
300	7090	7500	9000	1700	1500	8400	22800	212700	50900
					Maize-Soybean intercrop				
0	4950	13500	0	2550	1500	5600	16450	179700	38100
100	5010	13500	3000	2550	1500	5600	16050	198300	42200
200	7480	13500	6000	2550	1500	5600	22950	296800	52100
300	10200	13500	9000	2550	1500	5600	30350	407200	62500
					Sole soybean				
0	1850	6000	0	200	1500	5600	5300	129500	17850
100	3120	6000	3000	200	1500	5600	7700	218400	24750
200	4690	6000	6000	200	1500	5600	9900	328300	30950
300	4840	6000	9000	200	1500	5600	11100	338800	34150

[1] Current market prices (per kg) of maize and soybean in Minna township are 30 and 70 Naira (₦), respectively.

sown when the maize crop was already 3 weeks old. The fertilizer applied resulted in significant increase in the vegetative growth of maize (Fig. 3); this might have led to shading of the soybean crop, which could have reduced N_2-fixation by the component legume (Nambiar *et al.*, 1983; Wahua & Miller, 1978). In addition, the 60 kg N ha^{-1} applied to the component maize plant was far below the recommended rate of 120 kg N ha^{-1} for maize in the southern Guinea Savanna of Nigeria (Enwezor *et al.*, 1989) The maize could have taken up much of the applied fertilizer N before the soybean had access to it. This, perhaps, led to decreased vigour of the soybean plant and, consequently, its N fixing ability compared with the performance of the sole cropped soybean that had no competition for the applied N.

The results from both cropping systems appear, however, to suggest that the benefit accruable from the N_2-fixation potential of the promiscuous soybean crop is better enhanced with adequate fertilization. The %Ndfa range of 30-60% observed in the sole-cropped soybean was within the range (10-65%) reported by Okereke & Unaegbu (1992) for 80 soybean genotypes from the IITA soybean germplasm, but markedly lower than the 77-84% range measured at podfill by Abaidoo *et al.* (1999) for 10 cultivars from the same IITA germplasm. Contrary to the report by other workers that N yields of non-legumes increased by intercropping with legumes (Barker & Blamey, 1985; Singh *et al.*, 1986), N yield in the shoot and grains of the intercropped maize was consistently lower than yield of the monocropped maize (Fig. 2). This seems to indicate that there is little or no N benefit to the intercropped maize; rather, the maize was subjected to competition for N with the legume as reflected by the relatively lower N yield of the intercropped soybean and maize compared with their sole crops (Fig. 2). However, there have been claims that N_2 fixed by a legume may be available to the associated non-legume in the current season (Eaglesham *et al.,* 1981; Brophy & Heichel, 1989), although such transfers vary depending on the proximity of the legume to the companion crop (Fujita *et al.*, 1990; Fujita *et al* 1992).

Phosphorus accumulation and AMF infection

Arbuscular mycorrhizal fungi (AMF) are known to improve the P nutrition of plants (Ganry *et al.*, 1982; Bolan *et al.*, 1987; Nwoko & Sanginga, 1999) and nutrient or environmental stresses may induce a greater need for mycorrhizal colonisation (Sanginga et al., 1999). Since soybean has a large P requirement, especially for pod-filling (Cassman *et al.*, 1981), it was decided to find out what effect intercropping would have on percentage AMF colonization and grain P content of the intercropped maize relative to the sole crop. Both intercropped maize and soybean had smaller P yield in the grains than their respective sole crops, an indication of competition for P by the component crops in the intercrop system. However, this did not result in a significant difference in the degree of AMF root colonization between the intercropped and the sole crop maize. This is consistent with earlier report that cropping system had no effect on AMF infection of a maize crop (Sanginga *et al.*, 1999). There was, however, a fertilizer effect with incremental additions of fertilizer leading to a progressive reduction in AMF infection (Fig. 5A).

Although large P concentrations may depress AMF infection (Nwoko & Sanginga, 1999), the highest fertilizer rate used in the study was 300 kg ha^{-1}, which was equivalent to 30 kg P_2O_5 ha^{-1}. This compares favourably with the usual P recommendation of 40 kg P_2O_5 ha^{-1} for soybean in the Nigerian savanna (Enwezor *et al.*, 1989).

Dry matter accumulation and grain yields

Application of fertilizer led to significant increases in dry matter accumulation and grain yields although the requirements for the cropping systems differed. Grain yields of the sole-cropped maize at fertilizer rate of 100 kg ha^{-1} did not differ from that at 300 kg ha^{-1}, while yield in the intercropped maize required at least 200 kg ha^{-1} of fertilizer to give similar yields as the 300 kg ha^{-1} rate. The absence of competition from maize and increases in N_2-fixation and N accumulation in the sole-cropped soybean translated into larger dry matter and grain yields than those of the intercropped soybean. While the grain yields of intercropped maize at 300 kg ha^{-1} fertilizer did not differ from that of its sole crop, the yield of intercropped soybean, even at this fertilizer rate, was significantly less than that of its monocrop. This appears to indicate that the competition for resources in the intercropped system has a more negative effect on the legume than the cereal, perhaps, because of a shading effect of the cereal on the legume as observed by other workers (Nambiar *et al.*, 1983; Wahua & Miller, 1978).

Previous reports have shown that monocropped legumes generally have higher yields than in intercropping systems (Fujita *et al.*, 1990). However, land equivalent ratio and monetary gains are better when cereals are intercropped with legumes than when they are monocropped (Yunusa, 1989; Mandal *et al.*, 1990). In the study, except for nodule number and weight, sole crops consistently had larger yield parameters than their corresponding intercrops. However, the combined grain yields of the two intercropped species were better than the individual sole crops, and this was reflected in the 33% average net income increase obtained from intercropping above the average income that would have been obtained from a monoculture (Table 1). The monetary benefit was enhanced by the lower labour cost incurred for two weedings in the intercrop in contrast to three weedings in the maize monocrop. For the maize-soybean intercrop, the best yield and monetary gain was obtained with a fertilizer rate of 300 kg ha^{-1}.

Seasonal variations in yield

Although seasonal variation was not a factor in the experimental design, and, hence, not subjected to statistical analysis, there was consistent trend showing yield and yield parameters of the 1998 season to be greater than those of 1997. This was, perhaps, as a result of the drought spell that set in soon after planting in the 1997 season lasting for about 4 weeks. This could also explain the relatively greater percentage mycorrhizal infection of maize roots in the 1997 season than in 1998 since mycorrhiza are reported to increase the volume of soil from which a plant absorbs nutrients and moisture (Bagyaraj, 1984).

Conclusion

Although no direct evidence of N benefit for the intercropped maize was observed, the study has shown that intercropping maize with a promiscuous soybean cultivar is more profitable to the farmer than monocultures of the component crops. In any case, N benefit to a subsequent crop grown on the field can be expected as a result of decomposition of senesced roots, nodules and leaves of the component soybean (Giller *et al*., 1997). Since most farmers harvest both legume grains and stover, it will be interesting to see if the N benefit from the senesced parts of the legume will be enough to support production without returning the legume stover to the field; this will form the thrust of future trials.

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