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EFFECT OF SOYBEAN ON SUBSEQUENT MAIZE GRAIN YIELD IN THE GUINEA SAVANNA ZONE OF WEST AFRICA

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ABSTRACT

Two varieties of soybean (*Glycine max* (L.) Merr.) and a maize (*Zea mays* L.) control crop were grown in replicated trials at 10 sites in the Guinea savana of Nigeria in 1993 followed by a test crop of maize in 1994 with 20 or 60 kg N ha^{-1} to test effect of soybean on subsequent maize grain yield. Maize grain yield increase following soybean was variable but the main effect of previous soybean crop was positive even though the soybean was not inoculated with rhizobia and the aboveground soybean residues, except litter fallen before harvest, were exported from the fields, following the present farmer practice. The yield increase following the medium duration soybean variety (TGx1660-19F) was similar to that from 40 kg N ha^{-1} applied 4 weeks after planting to maize preceded by maize. The increase following the early soybean variety (TGx1456-2E) was significantly ($P<0.05$) smaller than that following the medium duration soybean variety. Total N in the 0 to 10 cm depth of the previous TGx1660-19F plots (0.063%) was significantly greater ($P<0.05$) than in the previous maize plots (0.058%) when analysed for the combined sites. Thus, the effect of previous soybean crop on maize grain yield was due mostly to residual N availability. Additional research is justified to estimate how soybean crop management influences the yield of subsequent maize in the savanna zone.

Key Words: **Crop rotation, residue management, N fertilizer**

RÉSUMÉ

Deux variétés de soya (*Glycine max (L) Merr.*) et une variété de maïs (*Zea mays L.*) en temps que temoin ont été cultivées en essais repliqués sur 10 sites dans la savane Guinéenne du Nigeria en 1993. Ces cultures ont été suivies d'une culture-test de maïs en 1994 avec 20 ou 60 kg N ha^{-1}. L'augmentation de la production en graine de maïs précédée d'une culture de soya par rapport à la production du maïs précédée d'une culture de maïs était variable. L'effet principal de la culture de soya était positif, bien que le soya n'ait pas été inoculé et que le résidu du soya aérien, à l'exception du déchet tombé avant la récolte, ait été exporté des champs à l'exemple des pratiques courantes. L'augmentation de la récolte de maïs précédée de la variété de soja à durée intermédiaire (TGx1660-19F) était semblable à l'augmentation obtenue par application de 40 kg N ha^{-1} sous forme d'urée 4 semaines après la plantation de maïs précédé par du maïs. L'augmentation suivant la variété de soya précoce (TGx1456-2E) était significativement plus faible ($P < 0.05$) que celle suivant la variété de durée intermédiaire. L'azote total à une profondeur de 0-10cm dans les parcelles de TGx1660-19F (0.063 %) était significativement plus élevée ($P < 0.05$) que dans les parcelles témoin (0.058 %) lorsque l'analyse est réalisée tous sites confondus. Par conséquent, l'effet d'une culture de soya sur la récolte postérieure de maïs résulte principalement de la disponibilité résiduelle en azote. Des recherches additionnelles sont justifiées pour estimer comment la conduite de la culture du soja influence la récolte postérieure de maïs dans la zone de savane Guinéenne.

Mots Clés: **rotation de culture, effet résiduelle, équivalence de fertilisation d'azote, crédits d'azote**

INTRODUCTION

Soybean (*Glycine max* L. Merr.) may contribute to the N needs of maize in West Africa. This crop has become increasingly important in Nigeria, and has spread to large parts of the Guinea savanna zone where it is well adapted (Smith *et al.*, 1993a). Although soybean is generally considered to be a crop that depletes soil N (Giller and Cadisch, 1995), this may depend on choice of cultivar and the field history (Peoples *et al.*, 1995b). Soybean may contribute to soil N through biological N_2-fixation, some of which can be available to a subsequent maize crop. It may also absorb less soil nitrate than maize, leaving more for a subsequent crop. This 'nitrate-sparing' effect may be as important as carry over of biologically fixed N (Peoples *et al.*, 1995a). In any case, nitrogen fertilizer recommendations for maize following soybean might be reduced, making maize production more sustainable from an ecological and economic perspective.

Elsewhere in the world, the N fertilizer recommendations for cereal production take previous legume crop into consideration. The N credit from one crop of soybean to the following year's crop grain sorghum in Missouri was 40 to 80 kg ha^{-1} depending on soil type (Hanson *et al.*, 1988), in a mechanised system in which soybean residues were returned to the soil. However, in West Africa soybean is harvested by pulling the plant out of the ground and carrying it for threshing; soybean crop residues are rarely returned to the soil. Eaglesham *et al.* (1982) measured N fixation and seed content of soybean and predicted net depletion of soil N by two varieties of soybean. They did not, however, measure root N content or subsequent effect on a test crop. MacColl (1989) observed an average N fertilizer equivalence of only 7 kg ha^{-1} during five years at two sites in Malawi, but soybean was reported to be poorly nodulated.

Soybean cultivars very likely influence the contribution of N to the subsequent maize crop. Work with cowpea has shown that the contribution to soil N theoretically increases with the duration of the legume crop as N harvest index decreases (Eaglesham *et al.*, 1982). Stoop and van Stavern (1982) demonstrated that the impact of residual legume N on subsequent millet grain yield increases with increasing maturity cycle of the preceding cowpea. This effect can be hypothesised also for soybean. The purpose of this study was, therefore, to estimate the value of residual soybean N on subsequent maize grain yield under the prevailing situation of soybean residue exportation at 10 sites in the Guinea savanna of northern Nigeria.

MATERIALS AND METHODS

Five trials each were conducted in northern Guinea savanna (NGS) and southern Guinea savanna (SGS) of Nigeria in northern and southern Kaduna State, respectively. The rainfall pattern is monomodal and was adequate during the cropping period (June to September) for soybean growth in 1993 (870 mm in NGS and 1030 mm in the SGS). However, during the maize test crop in 1994, rainfall was low in the NGS (700 mm) and excessive in the SGS (1150 mm). Soil properties in the two zones are presented in Table 1.

In 1993, soybean and maize crops were established in a randomised complete block design with four replications. Cultivars of soybean were TGx1456-2E (100-105 days to maturity) and TGx1660-19F (115-120 days to maturity). Soybean seed were not inoculated with rhizobia. Spacing for soybean and maize was 0.6 m on 15-20 cm high ridges. Plot size was 2.4 m wide (4 rows per plot) and 6 m long. Aboveground soybean and maize residues, except litter fallen before harvest, were not returned to the plots.

Before sowing in 1994, the soil was sampled to 10 cm depth in the ridges of each plot. These samples were air-dried, crushed, and passed through a 0.5-mm seive. They were analysed for total N using a semi-macro Kjeldahl digestion (Bremner, 1965) in 250-ml flasks and an aluminum block digestor. Three 25 to 30 cm high ridges (0.8 m apart) were made in each plot. Basal fertilizer was applied at the rate of 20-8-17 kg N-P-K ha^{-1} and incorporated in the ridges.

The International Institute of Tropical Agriculture (IITA) maize hybrid 8321-18 was sown early to mid-June and thinned to one stand per 20 cm apart at two weeks after planting (WAP). At 4 WAP, 40 kg N ha^{-1} as urea was incorporated into the ridges in two of the four replications at weeding. In the other two replications, no urea was applied. Thus, the two rates of inorganic N were 20 and 60 kg ha^{-1}.

Choice of N rate was constrained by the need to have an acceptable yield on the collaborating farmers' fields. A minimum acceptable rate was perceived to be 20 kg ha^{-1}. A rate which usually gives reasonable returns is 60 kg ha^{-1}.

At physiological maturity, all ears in the central row, excluding the first and last hill (5.6 m length), were harvested in each plot. Grain from the harvested row was weighed after air-drying and shelling early in the dry season.

Data on total soil N and maize grain yields were subjected first to analysis of variance individually for each location. For soil N, the treatments were the three previous crops in four replications. For grain yield, the treatment design was a factorial with two N rates and three previous crops, with two replications per location. The 10 locations were then combined for analysis of variance and previous crop means compared for both grain yield and total soil N.

RESULTS

Maize grain yields across the 10 sites were highly variable (Table 2). For example, yield of maize grain with 20 kg N ha^{-1} following previous maize crop ranged from 1.1 to 4.3 t ha^{-1}. The response to an additional 40 kg N ha^{-1} as urea applied 4 weeks after sowing ranged from -240 to +2280 kg ha^{-1}. Average increase in yield due to application of 40 kg N ha^{-1} was 36% in the northern and 67% in the southern sites. Maize grain yields following the soybean treatments were also highly variable.

The effect of previous soybean crop on maize grain yield at each site was rarely statistically significant. This could have been due to presence of only two replications per site. At the fertilizer rate of 20 kg N ha^{-1}, maize yield following medium duration soybean exceeded yield of maize after maize in eight out of 10 locations (Table 2). Average maize grain yield increase following medium duration soybean was 33% in the northern and 76% in the southern sites. The effect of the early soybean variety was not as consistent, exceeding previous maize in seven of 10 locations. Average yield increase due to the previous early soybean was 16% in the northern and 32% in the southern sites. At the 60 kg N ha^{-1} fertilizer rate, the effect of previous soybean was less consistent. Maize yield after soybean exceeded maize after maize at six of the 10 sites for the medium duration variety and five of 10 sites for the early variety.

In a combined analysis of variance over all sites (Table 3), the main previous crop effect was statistically significant ($P<0.05$) in spite of high variability. Over both fertilizer rates, maize yield following medium duration soybean was 27% greater than for maize after maize (Table 2) Maize yield after early soybean was 16% greater than after maize but the difference was not statistically significant.

The interaction between previous crop treatments and fertilizer rate was weakly significant ($P=0.15$). This interaction is evident in Table 2 where the response to fertilizer was 1.1

TABLE 1. Soil properties in soybean rotation trial sites

Property	NGS	SGS	Difference[a]
pH (KCl)	5.76 (0.48)	5.30 (0.45)	N.S
pH (H_2O)	6.28 (0.11)	6.32 (0.16)	N.S
Total N (g kg^{-1})	0.67 (0.08)	0.75 (0.08)	N.S
Bray1-P (mg kg^{-1})	18.3 (5.4)	10.0 (6.0)	0.051
Sand (%)	48 (7.1)	69 (2.3)	0.0002
Silt (%)	43 (5.5)	19 (1.7)	0.0001
Clay (%)	10.0 (2.0)	13.6 (1.7)	0.015
Exchangeable (cmol kg^{-1})			
Ca^{2+} (cmol kg^{-1})	2.64 (0.38)	2.14 (0.72)	N.S
Mg (cmol kg^{-1})	0.88 (0.08)	0.82 (0.37)	N.S
ECEC (cmol kg^{-1})	4.26 (0.52)	3.74 (1.15)	N.S

NGS = northern Guinea savanna; SGS = southern Guinea savanna.

[a]Probability of detecting a significant difference between NGS and SGS means.

ha^{-1} in the previous maize, 1.0 t ha^{-1} in the previous early soybean, and 0.3 t ha^{-1} in the previous medium soybean crop. The reduced response to inorganic N indicates that N nutrition was less of a constraint to maize following medium duration soybean.

The effect of previous crop on total soil N at 0 to 10 cm depth is presented in Table 4 for each site. Total N in the previous TGx1660-19F (medium duration soybean) plots was higher than in the maize plots at all 10 locations, although the differences at each site were rarely statistically significant. In the early soybean variety plots, total soil N was higher than in the previous maize plots at six locations and lower at two locations. In the combined ANOVA over all sites, total soil

TABLE 2. Effect of 1993 maize or soybean crop and fertilisation (20 or 60 kg N ha^{-1}) on 1994 maize grain dry matter yield (kg ha^{-1}) at 10 locations in the northern (1 to 5) and southern (6 to 10) Guinea savanna of Nigeria

Location	Maize yield following previous crop					
	Maize		Early soybean		Medium soybean	
	20N	60N	20N	60N	20N	60N
1	3440	4220	4080	5940	5850	5200
2	1720	2790	3380	3430	3440	3730
3	4320	5290	3790	4500	4100	5190
4	2230	4500	2730	4450	2950	3570
5	1930	1680	1910	3330	1860	2280
NGS mean	2730	3700	3180	4330	3640	4000
6	1790	2340	2960	4240	3910	4580
7	1120	2570	1340	1790	1900	1560
8	2680	3960	3240	5020	5580	5300
9	2620	4130	3910	2680	4020	3290
10	1670	3460	1560	3460	2010	3790
SGS mean	1980	3290	2600	3440	3480	3700
Combined mean	2920a		3390 ab		3710b	
SE (Fertilizer main effect)			107			
(Previous crop main effect)			169			
(Fertilizer *previous crop interaction)			285			

Combined means in a row followed by the same letter are not significantly different at $P<0.05$.

TABLE 3. Analysis of variance for maize grain yield over 10 Guinea savanna locations

Source	Degrees of Freedom	Mean Square	F Value	P
Location (L)	9	12014186	3.94	0.022
Reps (L)	10	9734421	0.32	
Fertilizer (A)	1	19696020	6.46	0.029
LA	9	933240	0.31	
Error	10	3047729		
Previous crop (B)	2	6188041	5.79	0.006
LB	18	1129699	1.06	0.42
AB	2	2092206	1.96	0.15
LAB	18	607685	0.57	
Error	40	1068318		

N in 0 to 10 cm depth was significantly greater ($P<0.05$) following soybean than following maize. The average difference was 8.5% for the medium soybean and 6.1% for the early soybean (Table 4). Using these values and the bulk density of 1.4 kg dm^{-3} commonly observed in the zone (Adeoye, 1986; Adeoye and Mohamed-Saleem, 1990), the mean additional total N present in the soil (0-10 cm depth) would be 49 kg ha^{-1} following medium soybean and 35 kg ha^{-1} following early soybean. Using the estimates of increased total soil N calculated above, a graph was drawn of the maize yield as a function of the rise in total soil N from the previous soybean crop and the 1994 fertilizer N application. The graph (Fig. 1) reveals that, regardless of the treatment maize grain yield follows a linear N response curve which indicates again that N was the major limitation to maize yield in these trials and that the major benefit of the previous soybean crop was due to greater N supply.

DISCUSSION

Benefits of soybean rotation unrelated to N supply are sometimes evident, such as when the yield of cereal with optimum fertilizer N is less than yield following soybean (Hanson *et al.*, 1988). In the intensified maize cropping systems found in the Nigerian savanna, non-N benefits from soybean may be from reduced nematode and *Striga hermonthica* parasitism. Weber *et al.* (1995) observed reduced incidence and severity of nematode damage on maize plants following soybean (TGx923-2E) compared with a previous cereal crop. *Striga hermonthica*, a serious parasitic weed of maize, can also have it's seed bank reduced by soybean (Parkinson *et al.*, 1987; Alabi *et al.*, 1994). In this set of trials, however, *S. hermonthica* numbers were low (0 to 2 m^{-2}) in all of the southern locations and one northern location. They ranged from 3 to 10 m^{-2} in the other northern sites. The effect of previous crop on *S. hermonthica* parasitism was not observed probably because of variable *S. hermonthica* densities in the experimental sites.

There is evidence showing that N supply was the major influence of soybean on subsequent maize in these trials. Firstly, N was clearly a constraint as shown by the response of maize to a 40 kg N ha^{-1} increment. Secondly, yield response to inorganic N was reduced following soybean, especially the medium duration soybean. The N contribution of previous soybean to maize was

TABLE 4. Effect of previous crop on total soil N (g kg^{-1}) before maize planting in 1994 at 10 locations in the northern (1 to 5) and southern (6 to 10) G a savanna of Nigeria

	Previous crop		
Location	Maize	Early soybean	Medium soybean
1	0.60	0.60	0.63
2	0.63	0.70	0.76
3	0.52	0.59	0.58
4	0.54	0.66	0.58
5	0.41	0.45	0.45
NGS mean	0.54	0.60	0.60
6	0.65	0.71	0.67
7	0.55	0.55	0.57
8	0.67	0.64	0.73
9	0.50	0.52	0.53
10	0.72	0.70	0.77
SGS mean	0.62	0.62	0.65
Combined mean	0.578a	0.613 ab	0.627 b
SE (Previous crop main effect)		0.010	

Previous crop combined means in a row followed by the same letter are not significantly different at $P<0.05$.

also inferred from the lack of a response of the subsequent maize crop to N fertilizer by Gallo *et al.* (1983). Finally, maize yield (Table 2) and total soil N content (Table 4), taken over the ten sites combined, were significantly higher following medium duration soybean than following maize. For both response variables, early soybean had an intermediate effect.

The positive effect of previous soybean observed in these trials could have been partially due to previous soybean absorbing less soil N than previous maize, generally known as 'nitrate sparing' effect (Peoples *et al.*, 1995a). In addition, there was probably additional N fixed and left in the soil for the subsequent maize crop. Unfortunately, N contents of roots and litter of the previous soybean and maize crops were not determined, so the importance of the two effects could not be quantified. In a related pot trial using soil from the same sites, total N fixed (aboveground plus belowground) was about 163 mg pot^{-1} for TGx1456-2E and 255 mg pot^{-1} for TGx1990-19F. The latter had much more nodule mass at soybean maturity (R. Abaidoo, unpublished). Thus, the potential difference in N fixation between the two varieties is clear and corresponds to our observed effects on soil N and maize grain yields.

One may estimate the amount of N contained in the below-ground and above-ground litter at maturity to try to account for the increase observed in total soil N. The soybean N content in our field study was reliably determined at full bloom. At that time, mean aboveground N content was 27 kg ha^{-1} for both varieties in the southern sites. In the northern sites, it was 34 kg ha^{-1} for TGx1456-2E and 30 kg ha^{-1} for TGx1660-19F. In a related greenhouse study, Abaidoo (unpublished) estimated the increase in above-ground N content between full bloom and maturity to be 170% in TGx1456-2E and 240% in TGx1660-19F. Thus, above-ground N content at maturity can be estimated at approximately 80 kg ha^{-1} for TGx1456-2E and 100 kg ha^{-1} for TGx1660-19F. Hanway and Weber (1971) found N content in fallen leaves and petioles to be 20 to 30% of total above-ground N in several varieties, years, and fertilizer treatments. The N content of fallen leaves and petioles may, therefore, be estimated

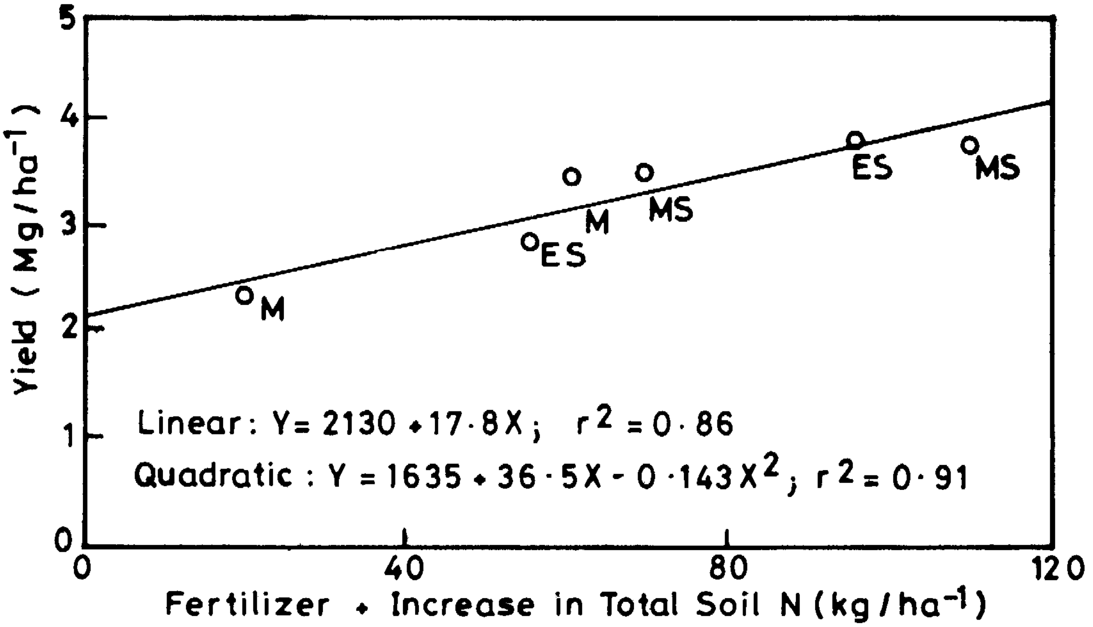

Figure 1. Response of 1994 maize grain to N fertilizer applied in 1994 and to previous soybean crop based on increases in total soil N in 0 to 10 cm depth (M=previous maize, ES=previous early soybean, MS=previous medium soybean).

at approximately 20 and 25 kg ha^{-1} for the two varieties. In the greehouse trial referred to above, Abaidoo (unpublished) estimated N content in roots at maturity to be slightly greater than 10% of total above-ground N content. Total above- and below-ground litter can, therefore, be estimated at 28 kg ha^{-1} for TGx1456-2E and 35 kg ha^{-1} for TGx1660-19F. Thus, it appears, without the benefit of direct measurement, however, that roots and litter alone may have been responsible for a large part of the increase in total soil N observed, and that soil nitrate sparing by soybean may have accounted for about 20%.

Assuming that N supply was the major benefit, N fertilizer equivalence (or N credit) of a previous crop can be estimated (Lory *et al.*, 1995) by comparing maize grain yield following soybean with only 20 kg ha^{-1} to that following maize with 20 and 60 kg ha^{-1} (Table 2). The maize grain yield with 20 kg N ha^{-1} following medium duration soybean is similar to maize after maize with 60 kg N ha^{-1}. Therefore, N application to maize following medium duration soybean can be reduced by approximately 40 kg ha^{-1}. Similarly, N fertilisation to maize following early soybean can be reduced by 15 to 20 kg N ha^{-1}. A more precise estimation of N credits from previous legumes should be done using a full range of N fertilizer levels, which was not possible because of space limitations on collaborating farmers' fields.

It should be noted that the N fertilizer equivalence value observed in these trials is substantially larger than was reported by MacColl (1989) in Malawi and Bowen *et al.* (1988). A large N contribution may be achieved by good soybean growth and residue return to the soil, typical of the system studied by Hanson *et al.* (1988). A small contribution was related to poor nodulation and growth of the soybean in Malawi (MacColl, 1989). It can also be related to the previous control treatment. For example, Bowen *et al.* (1988) used a bare fallow plot as a control in which 247 kg ha^{-1} of inorganic N accumulated in the soil profile compared to 124 kg ha^{-1} under soybean. Resulting N uptake (and yield) of maize was similar following both treatments, indicating substantial N supply by soybean residues that was not reflected by the maize test crop.

Maize grain yields in the SGS were generally lower than those of NGS (Table 2) although soil N was not significantly different (Table 1). Response to inorganic N following maize was greater in the SGS (67%) than NGS (36%). Response to previous soybean was also greater in the SGS. At the 20 kg N ha^{-1} rate, response to previous medium duration soybean was 76% in the SGS and 33% in the NGS. Corresponding values following the early soybean are 32% in the SGS and 16% in the NGS. Lower maize yields in the SGS may have been caused by lower plant available P (Table 1). However, the levels of P were generally in the adequate range. Rather, the cause of lower yields in the SGS is likely to be the sandy soil texture (Table 1) and higher rainfall, which favoured leaching of soil nitrate beyond plant roots.

In conclusion, this study estimated the effect of two cultivars of soybean and a maize control on subsequent maize yields. The difference between previous soybean and previous maize was impressive considering that the standing soybean residues were exported from the fields. Although precise recommendations can not be made about choice of soybean cultivar and management, testing of soybean in rotation with maize merits encouragement because the system poses very little economic risks to producers where a market for soybean exists such as in Nigeria. Choice of soybean cultivar, and mangement of the crop and its residues will influence the residual N contribution to subsequent maize. Therefore, future studies should focus on the roles of cultivar characteristics, soybean crop management, and soybean residue management on subsequent maize yields in rotation systems. Estimation of root and litter N contents should be included wherever possible.

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