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Full Length Research Paper

Effect of phosphorus application and soybean cultivar on grain and dry matter yield of subsequent maize in the tropical savannas of north-eastern Nigeria

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Soybean can contribute to soil N, which may partly be used to improve maize production in northeast Nigeria. However, the efficiency of soybean to fix N can be limited by soil P deficiency. This study evaluated the effect of P application and soybean cultivars on dry matter and grain yield of subsequent maize for two years (2005 - 2006) at Miringa and Azir. Experimental design was a split-plot with three replications. The main plots contained P levels of 0, 20 and 40 kg P/ha and subplots had four soybean cultivars. Maize was planted in the harvested soybean plots. Application of P to soybean at 20 and 40 kg/ha significantly increased dry matter and grain yield of succeeding maize. Differences in grain yield were significant between all P rates in Miringa (2005) and Azir (2006) but only between 0 and 40 kg P/ha in Azir (2005) and Miringa (2006). The grain yields of maize following late-maturing soybean cultivars were significantly higher than those following the early maturing cultivars in 2005. The maize yield increases could however, not be explained by total soil N, available P, and N and P uptake. Other rotation effects beyond N supply by the preceding soybean may be responsible for the yield increases of maize.

Key words: Maize, phosphorus, soybean, rotation.

INTRODUCTION

Soybean (*Glycine max* [L.] Merr.) is becoming increasingly popular in the Guinea savanna of Nigeria because of its high nutritive value (Singh et al., 2003) and its contribution to soil fertility improvement through biological nitrogen fixation (Carsky et al., 1997; Sanginga et al., 2002). Provision of sufficient N is critical for cereal production in the West African savanna (Carsky et al., 1999). Land-use intensification in the northern Guinea savannas has resulted in serious land degradation and nutrient depletion (Oikeh et al., 2007). Nitrogen is the nutrient that most often limits maize yield in the Guinea savanna (Carsky and Iwuafor, 1995) but due to high cost and poor infrastructure, the availability of N fertilizers is limited. Integrated N management can take advantage of biological nitrogen fixation to reduce fertilizer N requirements (Greenland, 1985). Soybean can contribute to soil N through biological nitrogen fixation, some of which can be made available to subsequent maize crop (Carsky et al., 1997; Sanginga et al., 2002). Sanginga et al. (2002) reported that maize growing after soybean yielded 1.2 - 2.3 times more than maize grown after maize in the Nigeria savannas. These authors further reported that the first crop of maize grown after soybean accumulated between 10 and 22 kg N/ha.

Legumes require P for adequate growth and N fixation and their effectiveness in soil improvement can be hindered by P deficiency (Giller and Cadisch, 1995). Phosphorus (P) deficiency can limit nodulation by legumes and P fertilizer application can overcome the deficiency (Carsky et al., 2001). Soil P levels are very low in the savannas of northeast Nigeria. Kwari (2005) reported that P levels were low (below critical values for northern Nigeria; Mehlich III extractable P <7 mg/kg) in 78% of fields surveyed in the SGS, in 92% in the NGS, and 93% in the SS.

Soybean cultivars very likely influence the contribution

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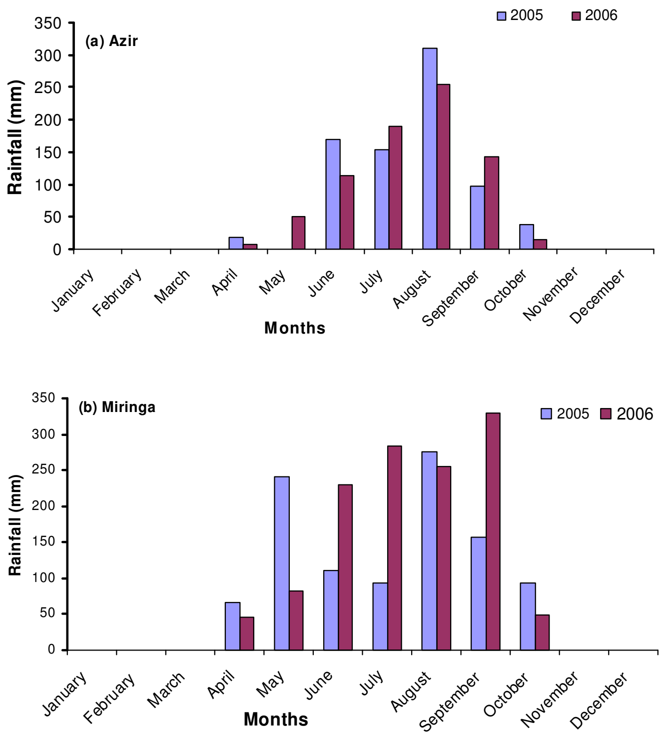

Figure 1. Mean monthly rainfall in 2005 and 2006 at Azir and Miringa.

of N to the subsequent maize crop (Carsky et al., 1997). Eaglesham et al. (1982) showed that the contribution to soil N theoretically increases with the duration of the legume crop as N harvest index decreases. Sanginga et al. (1997) also demonstrated that the N contribution depended on the soybean genotype and maturity period. The purpose of this study was to determine the effects of phosphorus fertilization of early and late maturing soybean cultivars on dry matter production and grain yield of subsequent maize in the northern Guinea and Sudan savanna zones of north-east Nigeria. Results from this study may provide the basis for improving maize yields when grown after soybean in the P deficient soils of north-east Nigeria through application of P fertilizer to soybean to enhance its ability to fix N for the subsequent maize.

MATERIALS AND METHODS

The study was carried out at two sites: Miringa (10˚ 73′ N, 12˚ 14′ E) in the northern Guinea savanna (NGS) and in Azir (12˚ 87.78′ N, 11˚ 1.8′ E) in the Sudan savanna (SS). The climate of the two sites is typical of the West African savanna climate, divided into distinctly marked dry and wet seasons. Average annual rainfall is 1100 - 1300 mm in Miringa falling between May and early October and 600 – 800 mm in Azir falling between June and September (PROSAB, 2004). Temperatures are high in both of the study sites, reaching a maximum of 40°C, especially in April, and a minimum of 18°C in December and January. The total rainfall received during the period of the experiment in both sites is presented in Figure 1. The soils in both experimental sites were Alfisols formed on basalt in Miringa and on argillaceous sediments in Azir (Kwari et al., 1999).

Table 1. Characteristic of soils of two experimental locations in Azir and Miringa, northeast Nigeria.

Soil properties	Azir	Miringa
Sand (%)	46.2	26.2
Silt (%)	32.5	42.5
Clay (%)	21.3	31.3
Textural Class	L	CL
pH 1:2.5 (H_20)	6.06	5.67
Organic C (%)	0.94	1.58
Total N	0.084	0.154
Available P (mg/kg)	2.4	1.7
Exchangeable K (cmol/kg)	0.46	0.31
Available Zn (mg/kg)	0.168	0.075
Available Cu (mg/kg)	0.098	0.130

Two late-maturing (TGX 1448-2E, 125 days, and TGX 1904-6F; 120 days) and two early-maturing (TGX 1485-1D, 100 days, and TGX 1830-20E; 104 day) soybean varieties were planted in 2004 (5 July in Miringa and 8 July in Azir) and 2005 (12 June in Miringa and 26 June in Azir) and fertilized with P at three rates. To avoid confounding residual effects from P, separate but adjacent plots within each site were used in each year. Selected chemical properties before cropping with soybean are presented in Table 1. The experiment was laid out in split-plot design with three replications. P treatments of 0, 20, and 40 kg P/ha were assigned to the main plots while the soybean cultivars were assigned to the subplots. Each subplot consisted of four rows 0.75 m apart and 5 m in length. Planting and management of the soybean crops have been reported by Kamara et al. (2007). Before the trials were established, the land was cleared, tilled with a disc harrow, and ridges prepared using work-bulls mounted with mouldboard ploughs. In each plot, five seeds of soybean were planted/hill at a spacing of 0.20 m to give a population of 333,333 plants/ha. Each plot received a basal application of 30 kg K/ha as muriate of potash. No N fertilizer was applied. To obtain a localized P fertilizer effect, single super phosphate was applied manually in furrows made at the top of ridges to a depth of 6 - 8 cm before planting the seeds on the same day. Immediately after sowing, paraquat (1:1-dimethly-4,4'-bipyridinium dichloride) was applied at the rate of 276 g a.i/litre to control weeds. This was followed by hand weeding three weeks later. At harvest, the soybean plots were cut from the root collar using cutlass, threshed and the residue returned to each of the plots. The soybean residues returned to the plots remained on the plots until maize planting since the experiments were performed in isolated areas where animals did not have access to the plots to remove the residues from the plots. Data on soybean growth parameters and yield have been reported by Kamara et al. (2007).

Composite topsoil (0 - 15 cm) samples were taken from the soybean plots with an auger in May in 2005 and 2006 before planting of maize. Each topsoil sample comprised five sub-samples taken along three transects across the plot and mixed together. The soil samples were crushed using a pestle and mortar and passed through a 2 mm sieve and stored in sealed polythene bags for analysis. The soil samples were analyzed for texture, pH, organic carbon, and total N as described by Van Reeuwijk (1992). Exchangeable K, available P, Zn and Cu were extracted with Mehlich-3 solution (Mehlich, 1984). The K in solution was determined on flame photometer and the P on a spectrophotometer. The Zn and Cu were determined on an atomic absorption spectrophotometer.

Prior to planting of maize, the soybean plots were ridged using a hand hoe to avoid contaminating neighbouring plots. The time lapse between soybean harvest and soil sampling was 7 months in each of the two years. Maize variety, Across 94 TZE COMP5-W was planted in the harvested soybean plots on June 19th in 2005 and July 15th in 2006 in Miringa. In Azir, maize was planted on June 20th in 2005 and June 25th in 2006. Maize was planted at 0.25 m between plants on 5 m long ridges spaced 0.75 m apart to give a plant population of 53, 333 per ha. Immediately after sowing, paraquat (1:1-dimethly-4,4'-bipyridinium dichloride) was applied at the rate of 276 g a.i/litre to control weeds. The maize crop was not fertilized with phosphorus but was top dressed with nitrogen at 50 kg N/ha as urea at four weeks after planting (WAP). Weeds were controlled manually at eight WAPs.

Plants were harvested from the two middle rows at physiological maturity. At harvest, ten plants were sampled and partitioned into leaves, stems, and ears and the components were oven dried at 60°C for 76 h. Total dry matter was determined by adding the dry weight of the plant parts. The nitrogen and phosphorus contents of each plant part were determined using an auto-analyser after digesting with concentrated H_2SO_4. Total N and P uptake were determined by multiplying percent N and P contents of each plant part with its dry matter and summing them. Grain yield was determined from plants harvested from the two middle row of each plot. Ears harvested from each plot were shelled and the percentage grain moisture was determined using a Dicky-John moisture tester (Model 14998, Dicky-John Corporation, Auburn, USA). Grain yield adjusted to 12% moisture was computed from the shelled grain.

Statistical analysis

All data were subjected to an ANOVA using the PROC Mixed procedure (Littell et al., 1996) of SAS (SAS Institute, 2001) with the variety analyzed as subplot and P level as main plot. Block was treated as a random factor; P levels and soybean varieties were treated as fixed factors in determining the expected mean square and appropriate F test in the ANOVA. Differences between means were compared using t-test based on standard error of the difference (s.e.d).

RESULTS AND DISCUSSION

Effect of P application and soybean cultivar on soil nutrient status and N and P uptake of maize

The effects of P application and soybean cultivar on soil nutrient status at two locations are presented in Tables 2 and 3. In both years, organic carbon, total N and available P contents were significantly higher in Miringa than Azir. However, the effect of P application and soybean cultivars on soil organic carbon, total N and available P were only significant in 2006 where organic carbon content decreased less in the 20 kg P/ha treatment than in the 0 and 40 kg P/ha treatments in Azir.

The higher organic carbon, total N and available P contents in Miringa than Azir could be attributed to more rainfall and vegetation cover since Miringa is in northern Guinea savanna while Azir is in Sudan savanna zone and rainfall and vegetation cover decreases from the south to the north (Kwari et al., 1999). Probably, there is also higher rate of decay of organic matter in Azir than Miringa because of higher temperature and loamy soil texture in Azir (Kwari, 2005). Soil organic carbon was not influenced by P application and soybean cultivars probably because the residues returned to the soil after harvest could not decompose substantially during the dry season prior to the planting of maize at the beginning of the rainy season when soil samples were collected for analysis.

Total soil N was not enhanced by P application and soybean cultivar in this study. This corroborates with the results of Eaglesham et al. (1982) and Osunde et al. (2003) that legumes do not always improve soil N status. Soil N status is enhanced when the amount of fixed N_2 returned by legumes to the soil exceed the amount of soil N in the harvested grain. However, some of the N_2 fixed is partitioned either into seed or vegetative parts at crop maturity and harvested in the seed. Sometimes, the N contribution of soybean grown in rotation with maize may be negative if the amount of fixed N_2 returned to the soil is less than the amount of soil N in the grain or vegetative parts at crop maturity. Others studies (Abbas et al., 1993; Chien et al., 1993) reported that P application to soybean grown in P deficient soils, as in this study area, increased N_2-fixation and enhanced soil N balance, especially when late-maturing varieties are used (Ogoke et al., 2003). Despite using soybean cultivars of different maturity classes in this study, no significant differences were observed in the total N probably because apart from the N removed in the seed, the residues which were incorporated into the soil could not decompose during the dry season. However, Sanginga et al. (2002), Singh et al. (2003) and Ogoke et al. (2003) reported that medium- to late-maturing soybean varieties with high N_2-fixation and low N harvest index contributed more to N status of the soil than early-maturing varieties with high N harvest index. This was attributed to total N content, above-ground N_2 fixed and N remaining in the haulms being higher in the medium and late maturing varieties than in early varieties.

The effects of phosphorus application and soybean cultivar on soil P status were not significantly different and residual P values in the soil were variable. This could be attributed to adsorption reactions between part of the applied P especially with silicate clays, hydrous oxides and even Fe and Al resulting in low soil test P levels. Such adsorption reactions are important in mildly acid soils (pH 5.5-7.0) as is the case on both sites. In addition, part of the P applied might have been absorbed by the soybean crop without adding to the soil P status. Soil test P levels can be raised if rates of P applied exceed the rates of P removal by the crop (Synder, 2000). A 2.5 t/ha yield of soybean consumes about 20 kg P/ha (Javaheri and Baudoin, 2001). The soil test P values of 2.66 and 3.57 mg/kg in control plots in Azir and Miringa (Table 2) when expressed in kg/ha were 5.32 kg/ha and 7.14 kg/ha, respectively. These values were much lower than the 20 kg P/ha that may consumed by a 2.5 t/ha yield of soybean as stated above. Barbagelata et al. (2002) established 9.5 mg/kg (19.0 kg/ha) as the critical soil test P level for

Table 2. Effect of P application and soybean cultivar on soil nutrient status in 2005 at Azir and Miringa, northeast Nigeria.

Treatment	Organic Carbon (%)			Total N (%)			Available P (mg/ kg)		
	Azir	Miringa	Mean	Azir	Miringa	Mean	Azir	Miringa	Mean
P Level									
0	0.68	1.28	0.98	0.08	0.11	0.10	2.66	3.57	3.11
20	0.77	1.27	1.02	0.08	0.10	0.09	2.35	4.13	3.24
40	0.66	1.16	0.91	0.07	0.15	0.11	2.94	3.88	3.41
Variety									
TGX1448-2E	0.73	1.08	0.90	0.07	0.11	0.09	2.89	3.67	3.28
TGX1485-1D	0.70	1.35	1.03	0.09	0.14	0.11	2.64	3.62	3.13
TGX1830-20E	0.71	1.31	1.01	0.08	0.11	0.09	2.60	4.07	3.33
TGX1904-6F	0.67	1.21	0.94	0.08	0.14	0.11	2.47	4.07	3.27
Mean	0.70	1.24		0.08	0.12		2.65	3.86	
SED Location		0.05			0.01			0.35	
SED P level		0.11			0.01			0.43	
SED Variety		0.08			0.01			0.50	

Table 3. Effect of P application and soybean cultivar on soil nutrient status in 2006 at Azir and Miringa,,northeast Nigeria.

Treatment	Organic Carbon (%)			Total N (%)			Available P (mg/ kg)		
	Azir	Miringa	Mean	Azir	Miringa	Mean	Azir	Miringa	Mean
Plevel									
0	0.46	1.09	0.77	0.12	0.19	0.15	2.67	3.37	3.02
20	0.70	1.01	0.85	0.12	0.18	0.15	2.66	2.90	2.78
40	0.48	1.02	0.75	0.11	0.17	0.14	2.74	3.52	3.13
Variety									
TGX1448-2E	0.54	1.13	0.83	0.12	0.19	0.15	2.51	3.44	2.98
TGX1485-1D	0.55	1.07	0.81	0.11	0.19	0.15	2.79	3.30	3.04
TGX1830-20E	0.53	0.94	0.73	0.12	0.17	0.15	2.69	3.08	2.88
TGX1904-6F	0.56	1.03	0.79	0.12	0.16	0.14	2.77	3.22	2.99
Mean	0.54	1.04		0.12	0.18		2.69	3.26	
SED Location		0.04			0.01		0.20	0.20	
SED P level		0.09			0.01		0.36	0.36	
SED Variety		0.05			0.01		0.29	0.29	

soybean in Entre Rios Province, Argentina.

For soils with low soil test P levels as in the study area, repeated fertilizer application may be required to build up residual P. Buerkert et al. (2000) reported that a three fold application of 13 kg P/ha as broadcast was required to raise the Bray P concentration in the upper 0.2 m of the soil from 2.8 to 5.6 mg P/kg. Therefore the single application of 20 and 40 kg P/ha on these P-deficient soils could not possibly lead to a build up of sufficient soil P status. Also, the P applied to soybean in the previous year did not exhibit residual effect in the soil test P levels may be partly because of fixation of P by the soils which are medium-textured (Kwari et al., 1999). The variability in soil P after application to soybean cultivars in the previous year could be attributed to fertilizer placement instead of broadcast. Cope and Evans (1985) reported that banding of fertilizers as opposed to uniformly broadcast fertilizer, results in variability in fertility over short distances.

The effects of P application and soybean cultivar on N and P uptake by maize at two locations are presented in Table 4. Maize N uptake was significantly higher in Azir than in Miringa. However, P uptake by maize did not significantly differ between locations. The higher N uptake by maize in Azir than in Miringa may be attributed to the loamy soil texture at Azir which provided a more favourable rooting environment for enhanced N exploittation via mass flow by maize as opposed to the clay loam texture in Miringa, which is sometimes shallow. Nitrogen is accessed by plant roots via mass flow and unrestricted rooting environment would enhance its uptake. Also, higher N mineralization from soybean resi-

Table 4. Effect of P application and soybean cultivar on maize N and P uptake in 2006 at Azir and Miringa, northeast Nigeria.

Treatment	N uptake (g/plant)			P uptake (g/plant)		
	Azir	Miringa	Mean	Azir	Miringa	Mean
P Level						
0	1.14	0.90	1.02	0.72	0.63	0.68
20	1.38	0.93	1.15	0.91	0.58	0.75
40	1.34	1.04	1.19	0..80	0.78	0.79
Variety						
TGX1448-2E	1.34	0.95	1.14	0.88	0.69	0.78
TGX1485-1D	1.28	0.92	1.10	0.79	0.64	0.71
TGX1830-20E	1.26	1.05	1.16	0.74	0.71	0.73
TGX1904-6F	1.27	0.89	1.08	0.84	0.62	0.73
Mean	1.29	0.95		0.81	0.67	
SED Location		0.106			0.088	
SED P level		0.130			0.096	
SED Variety		0.073			0.075	

Table 5. Effects of P application and soybean cultivar on total dry matter and grain yield of maize in 2005 and 2006 at Azir and Miringa, northeast Nigeria.

Treatment	Total dry matter (g/plant)				Grain yield (kg/ha)			
	Azir		Miringa		Azir		Miringa	
	2005	2006	2005	2006	2005	2006	2005	2006
Phosphorus level								
0	97.5	115.8	103.1	96.2	2023.1	2605.8	1991.4	2352.69
20	84.7	137.3	122.3	96.7	1999.1	2925.5	2432.3	2470.46
40	107.6	134.0	124.5	106.9	2863.7	3184.7	2557.9	2579.78
Variety								
TGx 1448-2E	101.1	132.1	128.7	102.0	2439.6	3193.3	2554.9	2508.95
TGx 1485-1D	95.1	125.9	109.4	95.4	2147.0	2911.8	2109.2	2504.46
TGx 1830-20E	93.0	127.5	108.6	107.1	2208.6	2803.2	2174.9	2297.93
TGx 1904-6F	97.2	130.6	119.7	95.2	2386.1	2713.1	2469.8	2559.24
SED P level	6.71	12.35	6.15	6.67	157.50	212.64	109.45	173.58
SED Variety	7.10	9.57	6.29	7.68	141.25	175.24	117.26	131.26

dues and soil organic matter in the loamy soil texture in Azir than in the clay loam texture in Miringa may have enhanced N uptake in Azir.

Maize N and P uptake were not significantly influenced by P application and soybean cultivars. This was supported by lack of improvement of the soil N and P status after P application to the soybean cultivars.

Effect of P application and soybean cultivar on dry matter and grain yield of maize

Application of P to four soybean cultivars significantly increased dry matter and grain yield of succeeding maize in both locations in the two years (Table 5). Differences in dry matter were significant between 0 and 40 kg P/ha in Azir (2005) and in Miringa (2006). In Azir (2005), application of 40 kg P/ha produced significantly higher dry matter yield than 0 and 20 kg P/ha but dry matter yield in the 0 kg P/ha treatment was higher than in the 20 kg P/ha treatment. In Miringa (2006), the dry matter yield in the 40 kg P/ha treatment was significantly higher than in the 0 and 20 kg P/ha treatments. The dry matter yields in the 0 and 20 kg P/ha treatments were not significantly different from each other. However, in Miringa (2005) and in Azir (2006) differences in dry matter were significant only between 0 and 20 kg P/ha.

Application of 20 kg P/ha produced significantly higher dry matter yield than 0 kg P/ha but the differences in dry matter yields between 20 and 40 kg P/ha were not significant.

Differences in grain yield were significant between all P rates in Miringa (2005) and in Azir (2006). Maize grain yield in the 40 kg P/ha treatment was higher than in the 20 kg P/ha treatment which in turn was higher than in the 0 kg P/ha treatment. Differences in grain yield were significant between 0 and 40 kg P/ha in Azir (2005) and in Miringa (2006). In Azir (2005), application of 40 kg P/ha produced significantly higher grain yield than 0 and 20 kg P/ha and the differences in grain yield between 20 and 40 kg P/ha were also significant. In Miringa (2006), the grain yields in the 40 kg P/ha treatment was significantly higher than in the 0 kg P/ha treatment but the grain yields in the 0 and 20 kg P/ha and 20 and 40 kg P/ha treatments were not significantly different from each other. In general, total dry matter was higher in Miringa than in Azir in 2005 but the reverse was the case in 2006.

Although P application to soybean did not increase residual P status of the soil, grain yield of maize increased with increasing P rate. In most instances, application of P to soybean at 20 and 40 kg P/ha (Miringa, 2006), significantly increased dry matter and grain yield of maize. In a related study, Carksy et al. (2000) reported that application of P to soybean did not significantly increase grain yield of succeeding maize in the following year. However, when the experiment was conducted on soils with uniform properties, P application to soybean significantly increased the grain yield of maize. The grain yield increases in this study could not be explained by the residual soil P and P uptake by maize since residual soil P level was very low and P uptake by maize was not significant. However, the possible effects of P on soybean growth particularly root growth may have improved maize yield. Carsky et al. (2000) reported that P application significantly increased soybean root dry matter and root length density. Increase in soybean root dry matter and root length density may improve soil structure (Papastylianou and Puckridge, 1983) and consequently enhance water and nutrient utilization by maize for higher grain yield. In Miringa (2006), the significant grain yield between 0 and 40 kg P/ha only cannot be explained by differences in the P sorption characteristics of the soils in the two sites.

The influence of soybean cultivar on dry matter of succeeding maize in 2005 was significant only in Miringa. In 2006, there were no significant differences in maize dry matter between the two locations. However, grain yield was significantly influenced by soybean cultivar in both locations in the two years despite the fact that soybean did not improve soil chemical properties. In 2005, grain yield of maize following late-maturing cultivars (TGX 1448-2E and TGX 1904-6F) were significantly higher than those following the early-maturing ones (TGX 1830-2E and TGX 1485-1D). The percentage increase over the early maturing varieties in both locations ranged from 8% for TGX1904-6F and TGX1830-20E to 21% for TGX1448-2E and TGX 1485-1D.

However, the late maturing soybean cultivar, TGX 1448-2E did not produce significantly different yield of succeeding maize than TGX1485-1D in 2006 at both locations. Also, the grain yield of maize following the late maturing cultivar, TGX 1904-6F, was significantly lower than those following (TGX 1485-1D) and (TGX1448-2E). This could not be explained by the rainfall received (Figure 1). The crops were planted earlier in 2005 than in 2006 and this might have affected their performance.

Similar results were obtained by Carsky et al. (1997) when medium maturing soybean variety TGX 1660-19F recorded significant grain yield increases of maize equivalent to the application of 40 kg N/ha. The increase following early-maturing soybean cultivars was smaller. The increases involving the late maturing soybean cultivars were reported to be due to positive N balances. Similarly, Singh et al. (2003), reported positive N balance for late and medium-maturing soybean varieties and suggested that these varieties could improve cereal yields when grown in rotation. Sanginga et al. (2002) reported 1.2 to 2-fold increase in yield of maize growing after soybean compared to maize growing after maize. The results in this study did not, however, confirm any N benefit to the succeeding maize although significant grain yield increases were obtained. In this study, the residual N before maize was planted and the N accumulated by the maize crop could not explain the yield increases recorded. This corroborates findings of Sanginga et al. (2003), who reported that the total N contributed by the soybean to the succeeding maize could not explain the yield increases recorded by the maize. The 50 kg N/ha applied at mid-silking stage could not also explain yield recorded by the maize crop. Indeed the N applied might have obscured the differences in the effect of N fixed by the different soybean maturity classes.

In 2005, dry matter and grain yield were higher in Miringa than in Azir because Miringa recorded higher rainfall than Azir (Figure 1). In 2006, grain yield and dry matter of maize were higher in Azir than in Miringa because of the higher N uptake by maize. Possible reasons for the higher N uptake by maize in Azir were given earlier.

Although P application to soybean significantly increased the yield of succeeding maize, the magnitude of yield increase was not very large. This may be due to some unknown limitations on the preceding soybean or on the maize crop itself thereby constraining their growth and yield since crop yields is a function of the interactions between weather, nutrients and soil moisture. Soil test P levels were still low after applying P fertilizer to preceding soybean because soybean itself requires a high amount of P for its nodulation. Moreover P-sorption may have limited release of P to succeeding maize. These coupled with low rainfall in the savanna ecology may reduce the benefit of applying P to soybean on maize.

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