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Full Length Research Paper

Evaluation of soybean [*Glycine max*(L) Merrill] genotypes for adaptability to a southern Guinea savanna environment with and without P fertilizer application in north central Nigeria.

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Cultivar evaluation is essential to ascertain the superiority of the newly developed genotypes over the established cultivars in terms of yield and adaptation to an ecology. Field experiments were conducted to evaluate some of the recently developed soybean genotypes with and without P fertilizer application for adaptability to southern Guinea savanna ecology of Nigeria. The study was carried out at the experimental field of the Teaching and Research Farm, University of Ilorin, Nigeria, during the 2003 and 2004 cropping seasons. Application of 30 kg P ha^{-1} resulted in significantly higher growth and grain yield parameters compared to no P application. Grain yield was consistently significantly higher for TGX 1448-2E than for other genotypes including the established cultivar, TGX 923-2E over the two cropping seasons. Significant year x genotype effect indicated that grain yields were significantly different between the two cropping seasons for TGX 1830-20E, TGX 1740-2F and TGX 1871-12E in 2004, while there was no significant variation for grain yield for TGX 1448-2E, TGX 1844-18E and TGX 1869-31E for the two years. This suggests stable grain yields in the latter genotypes and hence good adaptability, while the former ones showed unstable productivity under adverse soil moisture condition resulting from lower rainfall in 2003, and thus were deemed unsuitable for the southern Guinea savanna ecology which is highly prone to drought conditions. Simple linear regression analysis revealed that number of pods per plant was the most important factor influencing grain yield in this study. In conclusion, TGX 1448-2E was the genotype best adapted genotype to the southern Guinea savanna ecology and thus it can successfully replace TGX 923-2E the existing cultivar. Nevertheless, TGX 1844-18E and TGX 1869-31E are promising as drought tolerant genotypes.

Key words: Adaptability, southern Guinea savanna ecology, new soybean genotype, P fertilizer application.

INTRODUCTION

Soybean [*Glycine max* (L) Merrill] is one of the most important oil seed crops in the world. The crop has gained popularity in Nigeria, outranking cowpea [*Vigna unguiculata* (L) Walp], because of its potential to supply high quality protein (Akande et al., 2007). In spite of its great potential, soybean production is still inadequate in Nigeria owing to various limitations which result in low yield per unit area. Grain yields of soybean cultivars are generally low in Nigeria compared to other places in the world. Yield on growers' farms is often lower than 1000 kg ha^{-1} compared to yields > 2500 kg ha^{-1} in the USA (Modali, 2004), 3000 kg ha^{-1} in Brazil and >3500 kg ha^{-1} in Turkey (FAO/ STAT, 2004). There is therefore a wide gap between what is currently being produced and what is needed.

Increasing soybean production to meet the required quantities can best be achieved through an increase in yield per unit area, which can partly be achieved by the cultivation of high-yielding improved varieties. Consequently, new genotypes are being developed through breeding and selection (IITA, 1993). The objective of any

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Table 1. Total monthly rainfall at the experimental site during the growth periods of 2003 and 2004.

Month	Monthly Rainfall (mm)	
	2003	2004
July	123.2	211.4
August	130.9	145.4
September	176.2	243.5
October	133.4	98.1
November	46.7	31.6
Total for growing period	610.4	730.0
Annual total	1215.94	1272.0
20 years mean annual rainfall	1223.63	

breeding programme is the development of improved varieties and genetic stocks that are adapted to a wide range of environments and capable of providing high and sustainable yields. Such newly-developed genotypes are expected to be better than the existing cultivars and therefore capable of replacing them.

It has been suggested that under low P status, P fertilizer application to soybean is important in attaining high yield (Martin, 2005). Klinkinberg and Higgins (1968) characterized the savanna soil as highly-leached ferruginous, low in organic matter, N and P. There are inconsistent reports on the response of soybean to P application on savanna soils. Chiezey et al. (1991, 1992) and Chiezey (2001) reported significant yield increase in soybean with P application on savanna soils. Similar reports were made elsewhere by other workers on soybean (Alpha et al., 2006; Anzaku and Azanaku, 2002). However, Chiezey (1999), Erhabor et al. (1999) and Slaton et al. (1999) reported that grain yield in soybean was not significantly influenced by P application. In spite of these inconsistencies, the importance of P in soybean cultivation has been determined by many workers (Mclaughlin et al., 1991; Vance, 2001).

The bulk of soybean production in Nigeria is in the southern Guinea savanna agro-ecology, even though production has extended to the northern Guinea savanna and rain forest ecologies (Okpara and Ibiam, 2000; Chiezey et al., 2001). Cultivar evaluation is essential to ascertain the superiority of the new lines over the established cultivars in terms of yield and adaptation to a wide ecological zone as well as acceptability to the farmers. Akande et al. (2007) has therefore emphasised the importance of evaluating the newly developed soybean genotypes in the southern Guinea savanna agro-ecology where the bulk of its commercial production takes place. It is therefore pertinent to evaluate the newly developed varieties for their productivity and adaptability to the southern Guinea savanna zone characterized by scanty rainfall (Chiezey et al., 2001). The objective of this study was to evaluate the growth and grain yield of six newly developed soybean genotypes and their responses to P fertilizer application in the southern Guinea savanna ecology of Nigeria.

MATERIALS AND METHODS

A field study was conducted during the 2003 and 2004 copping seasons at the Unilorin Teaching and Research Farm, Bolorunduro, Nigeria (Latitude 8^o 29'N, Longitude 4^o 35'E). The experiment was designed to evaluate the adaptability of six newly developed soybean genotypes to the southern Guinea savanna ecology of the country with and without P fertilizer application. The experiment in each year was designed as a 7 x 2 factorial in RCBD, laid out in split-plots arrangement, with seven soybean genotypes (six newly developed and one existing genotypes) as the main plots, and two phosphorus levels (0 and 30 kg P_2O_5 ha^{-1}) as the sub-plots. In each year, the land was mechanically ploughed, harrowed and ridged after which plots of 20 m^2 consisting of five ridges 1 m apart and 5 m long were marked out. The seven soybean genotypes were one old cultivar TGX 923-2E, and six newly developed genotypes TGX 1830-20E, TGX 1740-2F, TGX 1871-12E, 1448-2E, TGX 1844-18E and TGX 1869-31E, obtained from the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria. The genotypes were planted on the 16 and 18 August in 2003 and 2004 respectively at an intra-row spacing of 10 cm. Phosphorus application was made as a single dose at 2 weeks after planting (WAP) using single super phosphate (18% P_2O_5). Weed control was achieved by pre-emergence application of stomp (Pendimenthalin 500) immediately after planting and supplemented with one hand weeding at five WAP.

The morphological growth parameters plant height, number of branches and leaf area index (LAI) were measured at full bloom. Physiological growth indices including crop growth rate (CGR), relative growth rate (RGR) and net assimilation rate (NAR) also were determined according to (Hunt, 1978), using leaf area data determined by leaf area meter (Model AT Area Meter MK_2, AT Delta T Devices Ltd) and dry matter collected at 4 and 6 WAP. Number of pods per plant and grain yield per plot were recorded at harvest. Data for the two years were pooled and analysed following the split-split-plots model using Genstat 5.32 statistical package and significant means were separated by the Least Significant Difference ($LSD_{0.05}$) at 5% probability level.

RESULTS

The total monthly rainfall during the growth periods, the corresponding annual rainfall as well as 20 years mean annual rainfall are presented on Table 1. It shows that the amount of rainfall was lower in 2003 than in 2004 especially during the active growing period. More importantly, the annual rainfall in 2003 was lower than the 20 years mean annual rainfall, while that of 2004 was higher.

Plant growth parameters

Plant height

Plant height was not significantly different for the two years of the study, while it was significantly influenced by both genotype and P fertilizer application (Table 2). There was no significant interaction effect on the parameter. Plant height was slightly higher in 2004 than in 2003,

Table 2. Significance level of the effects of year, genotype and phosphorus application and their interactions growth and yield parameters of soybean.

Source of Variation	df	Significance Level									
		LA	LAI	LAR	CGR	RGR	NAR	Branch	PHT	PODS	GYLD
Year (Y)	1	*	*	ns	**	*	ns	*	ns	ns	ns
Genotype (G)	6	*	ns	ns	ns	ns	*	***	***	***	***
Y x G	6	*	**	ns	**	*	**	ns	ns	**	***
Phosphorus (P)	1	***	***	ns	***	***	***	***	***	***	*
Y x P	1	ns	ns	ns	**	ns	ns	ns	ns	**	ns
G x P	6	**	*	*	ns	ns	ns	ns	ns	ns	ns
Y x G x P	6	**	**	ns	ns	ns	ns	ns	ns	ns	ns

*, **, *** denote effects significant at 5, 1 and 0.1 percent probability level respectively: ns denotes effect not significant

LA=leaf area, LAI= leaf area index, LAR= leaf area ratio, CGR= crop growth rate, RGR= relative growth rate, NAR= net assimilation rate, PHT= plant height.

Table 3. Effects of year, genotype and phosphorus application on growth parameters and grain yield of soybean

Treatment	LA (cm^2)	LAI	LAR	CGR (gd^{-1})	RGR ($gg^{-1}d^{-1}$)	NAR ($gm^{-2}d^{-1}$)	Branch (no)	Plant height (cm)	Pods (no)	GYLD (kg/ha)
Year										
2003	5679	2.84	87.3	0.45	0.086	10.34	4.4	50.98	93.9	1396
2004	7726	5.06	96.6	0.70	0.107	11.50	4.6	52.86	85.0	1541
s.e.d	472.3	0.556	5.35	0.039	0.0056	0.671	0.03	0.720	7.84	145.2
$L.S.D_{(0.05)}$	1503.2	1.770	ns	0.124	0.0179	ns	0.11	2.291	ns	ns
CV(%)	10.0	19.9	8.2	9.5	8.2	8.7	1.1	2.0	12.4	14.0
Genotype										
TGX 923-2E	6754	3.57	103.1	0.52	0.083	8.,50	5.5	63.13	98.6	1534
TGX 1830-20E	6208	3.19	90.6	0.69	0.114	13.88	3.4	40.31	79.2	1409
TGX 1740-2F	5939	3.24	85.1	0.54	0.093	11.06	3.9	55.63	74.7	1374
TGX 1871-12E	6221	4.58	88.8	0.49	0.079	9.44	5.1	50.63	65.6	1153
TGX 1448-2E	8259	5.15	94.6	0.72	0.114	12.06	4.6	57.81	110.0	1985
TGX 1844-18E	8027	4.13	89.9	0.64	0.101	11.44	5.5	55.31	98.1	1593
TGX 1869-31E	5509	3.79	91.7	0.47	0.092	10.06	3.5	40.63	99.8	1233
s.e.d	931.0	0.737	7.94	0.095	0.0146	1.600	0.31	2.564	99.8	159.3
$L.S.D_{(0.05)}$	1888.2	ns	ns	ns	ns	3.244	0.62	5.199	18.55	323.0
CV(%)	27.8	37.3	17.3	32.8	30.2	29.3	13.6	9.9	20.5	21.7
Phosphorus Level(kg P_2O_5 ha^1)										
0	5516	3.48	90.4	0.45	0.080	9.27	4.2	48.39	82.1	1374
30	7889	4.42	93.5	0.71	0.113	12.57	4.8	55.45	96.7	1563
s.e.d	433.5	0.253	4.26	0.052	0.0078	0.929	0.10	1.181	5.36	93.5
$L.S.D_{(0.05)}$	874.0	0.511	ns	0.105	0.0157	1.876	0.21	2.384	10.82	188.7
CV(%)	34.2	33.9	24.5	47.6	42.6	45.0	12.3	12.0	31.7	33.7

while the application of 30 kg P ha^{-1} significantly increased plant height compared to no P application. The old cultivar, TGX 923-2E showed the greatest height and was significantly taller than all the newly developed genotypes (Table 3). Plant height was lowest for TGX1830-20E, but the value was not significantly less than that of TG X 1869-31E.

Number of branches per plant

Number of branches per plant was significantly affected by year, genotype and P application (Table 2). Nevertheless, there was no significant interaction effect on the parameter. Number of branches per plant was significantly lower in 2003 than in 2004, while the application of

Table 4. Year x genotype interaction effects on growth parameters and grain yield of soybean.

Year	Genotype	LA (cm^2)	LAI	CGR (gd-1)	RGR (gg-1d-1)	NAR (gm-2d-1)	Pods (no)	Grain yield (kg/ha)
2003	TGX 923-2E	6750	3.38	0.35	0.076	7.38	125.9	1892
	TGX 1830-20E	6271	3.14	0.35	0.138	17.87	73.0	1019
	TGX 1740-2F	4679	2.34	0.36	0.088	11.75	65.7	1086
	TGX 1871-12E	4822	2.41	0.46	0.051	6.88	58.0	756
	TGX 1448-2E	5667	2.84	0.67	0.088	9.88	117.7	2032
	TGX 1844-18E	7906	3.96	0.47	0.095	11.25	101.7	1749
	TGX 1869-31E	3657	1.83	0.56	0.068	7.38	115.2	1241
	Mean	5679	2.84	0.46	0.086	10.34	93.9	1396
2004	TGX 923-2E	6757	3.77	0.69	0.089	9.63	71.2	1175
	TGX 1830-20E	6145	3.25	1.03	0.091	9.88	85.5	1800
	TGX 1740-2F	7199	4.15	0.72	0.099	10.38	83.6	1663
	TGX 1871-12E	7619	6.74	0.52	0.108	12.00	73.3	1550
	TGX 1448-2E	10850	7.47	0.77	0.140	14.25	102.3	1938
	TGX 1844-18E	8148	4.30	0.91	0.106	11.63	94.5	1438
	TGX 1869-31E	7361	5.75	0.39	0.116	12.75	84.4	1225
	Mean	7726	5.06	0.70	0.107	11.50	85.0	1541
	s.e.d	1307.3	1.113	0.131	0.0199	2..199	14.31	254.1
	$L.S.D_{(0.05)}$	2647.7	2.282	0.264	0.0402	4.449	29.61	528.8

LA= leaf area; LAI= leaf area index; CGR= crop growth rate; RGR= relative growth rate, NAR= net assimilation rate.

30 kg P ha^{-1} significantly increased number of branches per plant (Table 3). The highest numbers of branches (5.5 and 4.6) were found on TGX 923-2E (old) and TGX 1448-2E (new), respectively. Their values were significantly higher than those of the other new geno-types, except TGX 1871-12E. As with plant height, the lowest number of branches was found on TGX 1830-20E, although the value was not significantly lower than those of TGX 1740-2F and TGX 1869-31E.

Leaf area index

Leaf area index was significantly affected by year and P application, but not significantly different among genotypes (Table 2). In addition, all the primary and secondary interaction effects were significant for the parameter with the exception of year x P effect which was not significant. Leaf area index was significantly higher in 2004 than in 2003, while the application of 30 kg P ha^{-1} resulted in significantly higher LAI than with no P application (Table 3). Leaf area index was highest and lowest with TGX 1448-2E and TGX 1830-20E respectively, even though there were no significant differences among the new genotypes and the old cultivar. Significant year x genotype interaction effect showed that LAI was significantly higher in 2004 than in 2003 in TGX 1448-2E and TGX 1869-31E, while there were no significant changes in LAI for the two years in the other genotypes including the old cultivar (Table 4).

Physiological growth indices

The effect of year was significant for the crop growth rate (CGR) and relative growth rate (RGR), but not for net assimilation rate (NAR), while the effect of genotype was significant for the NAR, but not for CGR and RGR (Table 2). However, all of these parameters were significantly affected by the P fertilizer application, while there was no significant interaction effect on any of them. All the physiological growth indices were higher in 2004 than in 2003, although the difference was significant only for NAR (Table 3). Application of 30 kg P ha^{-1} resulted in significantly higher CGR, RGR and NAR values than in the no P application. TGX 1448-2E showed the highest values for CGR and RGR, which were however not significantly higher than those of the other genotypes including the old cultivar. NAR was highest with TGX 1830-20E, but the value was not significantly higher than those of TGX 1448-2E and TGX 1844-18E. The lowest NAR value was obtained by the old cultivar, TGX 923-2E, but the value was significantly lower than those of TGX 1830-20E and TGX 1448-2E only.

Significant year x genotype effect observed for CGR revealed that CGR was significantly higher in 2004 than in 2003 in TGX 923-2E, TGX 1830-10E, TGX 1740-2F and TGX 1844-18E, while there were no significant differences between years in TGX 1871-12E, TGX 1445-2E and TGX 1869-31E. Similar significant year x genotype for RGR showed that TGX 1830-20E, TGX 1871-12E, TGX 1448-2E and TGX 1869-31E had

Table 5. Estimate of regression coefficient of grain yield (GYLD) on plant height (PHT) and number of pods per plant (PODS)

	Estimate	S.E.	t (109)	t probability
Constant	-3.6	202	-0.18	0.859
PHT	8.31	3.75	2.22	0.029*
PODS	12.00	1.18	10.14	<0.001***
GYLD = -3.6 + 8.31 PHT +12.00 PODS, R^2 = 52.7* **				
Constant	562	268	2.10	0.038*
PHT	17.46	5.06	3.45	<0.001***
GYLD = 562 + 17.46 PHT, R^2 = 9.0 **				
Constant	339	112	3.03	0.003**
PODS	12.63	1.17	10.81	<0.001***

GYLD = 339 + 12.63 PODS, R^2 = 51.1***
GYLD = grain yield; PODS = number of pods per plant; PHT = plant height

significantly higher RGR in 2004 than in 2003, while there were no significant changes due to year in RGR values of TGX 923-2E, TGX 1740-2F and TGX 1844-18E. In the same vein NAR was significantly higher in 2004 than in 2003 in TGX 1871-12E and TGX 1869-31E, but significantly lower in 2004 than in 2003 in TGX 1830-20E, while there were no significant differences between years in TGX 923-2E, TGX 1740-2F, TGX 1448-2E and TGX 1844-18E.

Yield component and grain yield

Table 2 shows that the effect of year was not significant for number of pods per plant and grain yield. The soybean genotypes varied significantly for number of pods and grain yield and the application of P fertilizer significantly affected both number of pods and grain yield. Year x genotype interaction effects were significant for both number of pods and grain yield, while year x P effect was significant for number of pods only.

Across the two years of the study, number of pods per plant was highest with TGX 1448-2E (Table 3). However, the value was not significantly higher than in TGX 923-2E (old cultivar), TGX 1844-18E and TGX 1869-31E. Number of pods was lowest with TGX 1871-12E and the value was significantly lower than in the control (TGX 923-2E), but not significantly lower than those of TGX 1830-20E and TGX 1740-2F. The significant year x genotype interaction (Table 4) showed that the control (TGX 923-2E) and TGX 1869-31E had significantly lower number of pods in 2004 than in 2003, while other genotypes showed no significant differences in their pod production for the two years of the study.

Grain yield was significantly higher in TGX 1448-2E than in all other genotypes including the control (TGX 923-2E) over the two years of study. TGX 923-2E had grain yield value similar to those of TGX 1830-20E, TGX 1740-2F and TGX 1844-18E, while TGX 1871-12E had the lowest grain yield which was significantly lower than that of the control. A significant year x genotype interaction for grain yield revealed that grain yield was significantly lower in 2004 than in 2003 in TGX 923-2E, but significantly higher in 2004 than in 2003 in TGX 1830-20E, TGX 1740-2F and TGX 1871-12E. However, grain yields were not significantly different for the two years in TGX 1448-2E, TGX 1844-18E and TGX 1869-31E.

Simple linear regression analysis of grain yield on growth and yield components showed that plant height and number of pods per plant were the two important factors affecting yield in the present study, with the number of pods per plant showing greater impact, contributing 51.1% to grain yield variation (Table 5).

DISCUSSION

Identification of adapted genotypes would help farmers to realize increased grain yield in soybean and thereby increase profitability (Modali, 2004). Consequently, we evaluated seven soybean genotypes consisting of an existing cultivar and six newly developed genotypes for adaptation to the southern Guinea savanna ecology of Nigeria. The results show that growth and grain yield varied significantly among the genotypes. This is in line with reports from earlier workers who showed significant genotypic differences in growth and grain yield of soybean (Haq et al., 2002; Chandrappa et al., 1999; Zhang and Zhang, 2000; Tang et al, 1997).

Plant height, number of branches per plant, LAI and other physiological growth indices varied significantly among genotypes in the study. Significant variation in plant height of soybean genotypes had been reported (Viera and Mandarin, 1999; Ehsanullah and Hatara, 1989). However, Marrison et al. (1999) found no significant differences among genotypes for NAR. Yield of soybean has been observed to be a function of light interception, dry matter (DM) accumulation and partition of DM into the seeds. Shibles and Weber (1966) had earlier reported that optimal crop growth rate is achieved when

when LAI is large (3.5 – 4.0) to intercept 95% of the sun's light. The results of this study show that LAI was lower in 2003 (2.8) than in 2004 (5.06), resulting in significantly lower CGR in 2003 (0.46 g d^{-1}) than in 2004 (0.70 g d^{-1}).

It has been reported that cultural practices increase yield in soybean by affecting the relationship between light interception, CGR, TDM and LAI, which demonstrate a circular cause-and effect relationship (Loomis and Connor, 1992b). Greater light interception stimulates CGR, which in turn increases TDM and LAI. Greater LAI causes higher light interception which further enhances CGR and thus results in higher yield. Results of this study show that TGX 1448-2E has the highest LAI, hence highest CGR resulting in highest grain yield in the genotype. TGX 1844-18E also had higher LAI and CGR than the old cultivar, TGX 923-2E, hence, higher grain yield. Egli and Yu (1991) had also reported a linear relationship between CGR and seed yield in soybean.

Grain yields among the evaluated genotypes varied significantly during the two years of this study. The average of the two years shows that a new genotype, TGX 1448-2E, produced the highest grain yield (1985 kg ha^{-1}) which was significantly higher than all other genotypes including the old cultivar. This was followed by a grain yield of 1593 kg ha^{-1} from another new genotype, TGX 1844-18E, although the value was not significantly better than that of the old cultivar, TGX 923-2E (1534 kg ha^{-1}). Other workers have reported significant yield differences among soybean genotypes (Zhang and Zhang, 2000; Ablett et al., 2000). Across all genotypes and P application, grain yield was higher in 2004 than in 2003, although the difference was not significant.

Grain yields were significantly lower in 2003 than in 2004 for TGX 1830-20E, TGX 1740-2F and TGX 1871-12E, while there were no significant changes in grain yields for TGX 1448-2E, TGX 1844-18E and TGX 1869-31E. The significant changes in yields of the former three new genotypes may be attributable to higher rainfall in 2004 than in 2003, thereby suggesting that these newly developed genotypes may be susceptible to water stress conditions. Conversely, the three latter genotypes that showed stability of grain yield over the two cropping seasons suggests better water stress tolerance.

Soybean yields have been related to moisture availability in many earlier reports (de Souza et al., 1997; Gan and Amasino, 1997). Oya et al. 2004 reported that drought stress is one of the main constraints for soybean production in Brazil. Water stress at any stage of soybean development can reduce yield, but the negative effects of water stress are particularly important during flowering, seed set and seed filing (Doss et al., 1974; Sionit and Kramer, 1977).

The occurrence of drought stress is not uncommon for the southern Guinea savanna ecology where most of Nigerian soybean is cultivated. It is therefore pertinent that any genotype(s) introduced to the area be drought tolerant for good sustainable grain yield. The results of this study therefore suggest that TGX 1448-2E, TGX 1844-18E and TGX 1869-31E are better than the existing cultivar, TGX 923-2E and are hence promising as cultivars grown under sporadic drought conditions.

The importance of P in soybean cultivation has been stressed by many workers (Mclaughlin et al., 1991; Vance, 2001). Results of this study show significant positive effects of P application on growth and grain yield of soybean genotypes. This is in line with the reports of earlier workers who showed significant increase in grain yield due to P application (Chiezey et al., 1991, 1992; Chiezey, 2001). Similar reports were made by other workers on soybean (Alpha et al., 2006; Anzaku and Azanaku, 2002). Nevertheless, Chiezey (1999), Erhabor et al. (1999) and Slaton et al. (1999) reported that grain yield in soybean was not significantly influenced by P application. The reports on responses of soybean to P application show inconsistent results. Fageria et al. (1995) suggested that very large quantities of P fertilizer may be required for successful soybean production. However, most recently, Ferguson et al. (2006) reported that soybean can produce maximum yield with relatively low levels of P in the soil and suggested that P application is not likely to increase grain yield at P soil concentration above 12 ppm (Bray-1 test).

The soil of the experimental site of this study is low in available P (3.8 – 4.1 ppm), hence the significant positive responses to P application. The soils of the savanna are low in P and thus are expected to respond to P application. However, the lack of significant responses reported by other workers may be due to P occlusion, as fertilizer P has been noted to be generally fixed into forms unavailable to plants by Fe and Al oxides in the soil (Sample et al. 1980). It has been suggested that under such circumstances, the integration of plant species or genotypes that can make most efficient use of P supplied by the soil represent a key element of a sustainable cropping system (Horst et al., 2001; Lynch, 1998).

Results of the simple linear regression of grain yield on growth and yield components in the present study showed that plant height and number of pods per plant were the most important factors affecting grain yield, individually accounting for 9.0 and 51.1% respectively of the variation in grain yield, and jointly accounting for 52.7% (Table 5). Regression of yield on individual yield components recently has been used to show that the most important yield components in yield formation were number of pods and number of seeds per unit area (Modali, 2004). Other workers have also shown the importance of number of pods/seeds per area in grain yield improvement in soybean (Egli and Yu, 1991; Egli, 1998). Modali (2004) also showed by correlation analysis that number of pods per area was more important in determining number seeds per unit area than was seeds per pod. TGX 1448-2E produced the highest number of pods per plant over the two years of study, and hence the highest grain yield. Grain yield was lowest in TGX 1871-

12E due to lowest number of pods per plant. The reduced number of pods per area has been shown to play a prominent role in decreasing yield (Board and Harville, 1996; Board and Tan, 1995).

In conclusion, TGX 1448-2E and TGX 1844-18E showed better performance than the existing cultivar, TGX 923-2E in this study and therefore can replace the old cultivar. It can also be concluded that application of 30 kg P ha^{-1} is beneficial to soybean growth and grain yield in soils with low available P.

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