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Field Performance of Soybean (*Glycine max* (L.) *Merill*) with Farmyard Manure and Inorganic P Fertilizers in the Sub-Humid Savanna of Nigeria

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Abstract

Field trials were conducted during the rainy seasons of 2009, 2010 and 2011 in Samaru in the northern Guinea Savanna zone of Nigeria to evaluate the response of soybean to separate and combined applications of farmyard manure (FYM) and mineral phosphorus fertilizers levels. Soybean varieties TGx 1448-2E and TGx 1019-2E were grown with three levels of FYM (0, 1 and 2 t/ha) and four levels of P (0, 13.2, 26.4 and 39.6 kg P/ha) in all possible factorial combinations laid out as a randomised complete block design, replicated four times. Leaf area index, number of days to 50% bloom stage nodule dry weight per plant, number and weight of pods per plant and 100-seed weight were similar for both varieties. TGx 1448-2E was shorter but produced more total dry matter (TDM) than TGx 1019-2E. Although TGx 1448-2E produced higher grain yield than TGx 1019-2E, the difference was not significant. Application of FYM increased plant height nodule dry weight, TDM, 100-seed weight and grain yield per hectare. Application of 1 t/ha of FYM increased grain yield by 16.7% compared with plots without FYM but there was no difference by increasing FYM to 2 t/ha. Phosphorus application increased grain yield significantly and application of 26.4 kg P/ha increased grain yield by 46.6% and 16.0% compared with plots without P and with 13.2 kg P/ha respectively when averaged over the three years. There were no interactions between FYM and inorganic P on grain yield in any of the years. The result showed that both varieties were similar in grain yield and 1 t/ha of FYM or 26.4 kg P/ha produced similar grain yields above 2 t/ha. Regression equation across the years showed soybean responded optimally to P rates ranging from 15.9 to 39.7 kg P/ha for grain yields of 1950.2 to 2665.4 kg/ha depending on the fertility status of the soil.

1. Introduction

Soybean (*Glycine max* (L.) *Merill*) production was initially centred in the southern Guinea Savanna zone of Nigeria where the annual rainfall of 150cm per annum, spread between March and October could support the crop growth (Kassam & Kowal, 1978). Production gradually expanded into the northern Guinea Savanna with annual rainfall of 112cm distributed between April/May to September/October. Increase in production was stimulated by local demand for vegetable oil for domestic and industrial purposes and the cake used in compounding livestock feed. The initial variety introduced was the ‘Malayan’ from Indonesia which was characterised by lodging and pod shattering; two undesirable characteristics. Breeding programme of the Institute for Agricultural Research (IAR) Samaru, Zaria, Nigeria culminated in the release of two lodging-resistant and non-shattering varieties. These were SAMSOY-1 and SAMSOY-2. These varieties proved susceptible to frog eye leaf spot-a devastating disease. The International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria subsequently developed some non-shattering and frog eye leaf spot resistant varieties. These were TGx 1448 -2E and TGx 1019-2E. Both were adaptable to the northern Guinea savanna and adoptable by farmers.

The major constraint to crop production in the savanna is the low nutrient content of the soils (Jones & Wild, 1975, Klinkinberg & Higgins, 1968). Farmers in the savanna rarely use fertilizers for soybean except for high valued crops such as maize (*Zea mays L.*) and vegetables. Fertilizer consumption is low rarely exceeding 15 kg/ha on the average because of scarcity and the high cost.

Field trials in the savanna have confirmed that grain yield of soybean could be doubled or trippled (1750-2000 kg/ha) with the use single super phosphate. Rates ranging between 20-30 kg P/ha have been recommended (Pal et al., 1989, Chiezey et al., 1992). Most Tropical soils contain adequate strains of Rhizobia that nodulate soybean, particularly, promiscuous varieties, hence N application rarely increased grain yield of soybean (Pulver et al., 1985, Radley, 1968).

The current emphases are on organic agriculture in order to mitigate climate change and increase carbon sequestration. Yields have increased with the application of organic matter (OM) in both cereal and horticultural crops (Abdullahi & Lombin, 1978; Ezeakunne, 1985; Aliyu, 2009). Trials with organic matter on the performance of legumes, particularly on soybean are few. Chiezey and Odunze (2009) found that the application of 1 t/ha of poultry manure significantly increased the grain yield of soybean. Most recommended rates of OM range between 3-15 t/ha which is quite high and may not be easily generated by small-scale farmers. Similarly, alternative uses of OM for fencing, tatching, livestock feed and fuel may preclude their uses for soil amendment. Rather, the emphasis should be on the complementary roles of organic matter with inorganic fertilizers for crop use. Inorganic fertilizers have also been indicted in environment polution particularly, the aquifer. This study was undertaken to investigate the response of two soybean varieties (TGx 1448 2E and TGx 1019-2E) to various levels of farm yard manure and inorganic fertilizers using single super phosphate.

2. Materials and Methods

Field experiments were conducted for three years (2009, 2010, and 2011) in the Research Farm of the Institute for Agricultural Research (IAR), Ahmadu Bello University, Samaru, Zaria (II^{o}II′N, 7^o 38′E), 686m above sea level. Samaru is located in the northern Guinea Savanna with annual rainfall of 112cm. The objective of these experiments was to evaluate the responses of two soybean varieties (TGx 1448-2E and TGx 1019-2E) to four levels of P (0, 13.2, 26.4 and 39.6 kg P/ha) and three levels of farmyard manure (FYM) (0, 1 and 2 t/ha) in all possible factorial combinations using a randomised complete block design with four replications. The gross plot size was 4.5 m x 4.5 m (20.25 m^2) and the net plot was 3 m x 4.5 m (13.5 m^2). Soybean seeds were drilled 4cm apart on 75cm row ridges to achieve a plant density of 333,333 plants per hectare. Dates of planting were 11th of July, 4th July and 6t July in 2009, 2010 and 2011 respectively after a good rain. The FYM were obtained from the Samaru College of Agriculture, Ahmadu Bello University, Zaria and were incorporated into the ridges one week before planting. The inorganic fertilizer was applied at planting by side-banding, 7.5cm beside and below the seed.

Prior to land preparation, glyphosate at 4 L/ha was applied to the field to burn off the vegetation. Subsequently, butachlor at 4 L/ha was applied pre-emergence at planting which was two weeks after the application of glyphosate. One hoe weeding was carried out at six weeks after sowing (WAS) to remove weeds that emerged later. Concurrently done was moulding up to shore up plants that lodged.

Soil samples were collected 30cm deep randomly before land preparation for physico-chemical analyses (Tel & Hagarty, 1984). Rainfall data for the duration of the experiments were collected from the IAR meteorological station. The FYM was also analysed for physico-chemical properties. Five plants per plot were sampled to determine treatment effects on leaf area index (LAI), number of days to 50% flowering, nodule dry weight, plant height at harvesting, total dry matter (TDM) at harvesting, grain yield per hectare and 100-grain weight.

All the data collected were analysed for each year and the three years combined using analysis of variance as described by Snedecor and Cochran (1982). Means were compared using the Duncan Multiple Range Test (DMRT) as described by Duncan (1955) at 5% level of probability. Regression of grain yield on phosphorus was also as described by Snedecor and Cochran (1982) using the equation $Y = a + bx-cx^2$.

3. Results

Table 1 shows the rainfall total and distribution during the three years of the study. Rainfall was highest in 2009 but the distribution was evenly spread throughout the years to support crop growth. Rainfall was heaviest in August in the three years, particularly in 2009 which caused water logging problem probably responsible for the least yield among the years. Grain yield was highest in 2010 probably as a result of better rainfall distribution during the critical grain filling period. The soils were characteristically sandy loam to loam, typical of savanna soils, low in pH, organic carbon and available nitrogen (Table 2). The farmyard manure in each of the years had high contents of N, P, K and organic carbon reflecting the good management during the production and storage (Table 3) and subsequent positive effect on grain yield.

Table 1. Rainfall data for Samaru, Zaria, Nigeria at 10 days interval: 2009-2011

Month	Rainfall (mm)		
April	2009	2010	2011
1-10	-	-	-
11-20	8.3	3.3	4.3
21-30	12.0	49.1	9.6
May			
1-10	47.3	55.1	33.0
11-20	13.3	13.1	18.6
21-31	24.5	24.8	71.7
June			
1-10	39.5	82.5	74.7
11-20	15.6	26.6	57.9
21-30	34.4	49.2	29.9
July			
1-10	80.4	140.4	83.1
11-20	43.1	47.0	
101.8			
21-31	161.5	30.5	39.0
August			
1-10	79.7	76.2	50.2
11-20	232.9	138.4	177.9
21-31	127.1	91.5	11.8
September			
1-10	98.2	59.7	33.2
11-20	92.8	112.9	68.4
21-31	15.7	45.9	11.3
October			
1-10	12.8	40.9	38.8
11-20	121.7	9.4	15.2
21-31	17.2	32.0	
November			
1-10			
11-20			
21-30			
Total	**1278.0**	**1128.5**	**930.4**

Table 2. Physical and chemical properties of the experimental soil of the Institute for Agricultural Research Farm, Samaru

Physical composition	30cm depth		
	2009	2010	2011
Sand (g/kg)	480	480	520
Silt (g/kg)	460	320	340
Clay (g/kg)	160	200	140
Textural class	loam	sandy loam	sandy loam
Chemical composition			
PH in H_20	5.20	5.4	5.3
PH in $CaCL_2$	5.04	5.0	4.9
Organic carbon (g/kg)	2.5	2.4	2.3
Available P (mg/kg)	7.5	10.0	9.6
Total N (g/kg)	0.3	0.3	0.2
Exchangeable bases			
Ca (Cmol/kg soil)	0.09	1.3	1.1
Mg“	0.4	0.5	0.4
K“	0.22	0.12	0.2
CEC“	5.3	1.1	4.3

Table 3. Chemical composition of farmyard manure samples used in 2009, 2010 and 2011 experiments

Farmyard manure	Chemical composition (%)		
	2009	2010	2011
N	2.1	2.0	1.8
P	0.8	1.0	1.1
K	1.2	1.1	0.9
Ca	1.5	1.2	1.1
Mg	0.2	0.3	0.2
OC	23.5	28.0	30.1

Leaf area index (LAI) did not significantly differ between the two varieties tested in each of the years and when averaged over the three years (Table 4). Application of farmyard manure (FYM) increased LAI in 2009 only when the plots with FYM increased LAI compared with plots without FYM. Averaged over the three years, application of FYM increased LAI but not significantly. Similarly, application of P increased LAI in 2009 only when plots with P had higher LAI than plots without P. When averaged over the three years, P application had no significant influence on LAI.

Table 4. Leaf area index of two soybean varieties as influenced by different rates of farmyard manure and inorganic P fertilizers in Samaru (2009-2011)

Treatment	LAI			
	2009	2010	2011	Mean
TGx 1448-2E	2.9	3.6	-	3.2
TGx 1019-2E	2.9	3.1		3.0
Mean	2.9	3.4		3.1
SED	NS	NS		NS
FYM (t/ha)				
0	2.7b	2.8		2.7
1	2.9a	4.1		3.5
2	3.0a	3.2		3.1
SE+	0.07	NS		NS
P rate (kg/ha)				
0	2.7b	4.3		3.4
13.2	3.0a	2.9		2.9
26.4	2.9a	3.2		3.0
39.6	3.0a	3.1		3.0
SE+	0.08	NS		0.38

Means within same column and treatment group followed by similar letter(s) are not significantly different at 5% level of probability, using DMRT.

Table 5 shows the influence of the treatments on 50% bloom stage. Both varieties significantly differed on the number of days to 50% bloom stage with TGx 1448-2E having a slightly longer period. Application of FYM and P also increased the number of days to 50% bloom stage slightly.

Table 5. Number of days to 50% bloom stage of two soybean varieties with various levels of farmyard manure and inorganic P in Samaru (2009 and 2011)

Treatment Variety	No of days to 50% flowering			
	2009	2010	2011	Mean
TGx 1448-2E	51.9	Na	51.9	51.9
TGx 1019-2E	51.2	Na	51.4	51.3
Mean	51.6	Na	51.7	51.6
SED	NS	Na	NS	NS
FYM (t/ha)				
0	51.3	Na	51.5	51.4b
1	51.2	Na	51.3	51.3b
2	52.2	Na	52.2	52.2a
SE+	NS	Na	NS	NS
P rate (kg/ha)				
0	50.6b	Na	50.8c	50.7c
13.2	52.5a	Na	52.6a	52.5a
26.4	51.7ab	Na	51.6ab	51.6b
39.6	51.6ab	Na	51.8ab	51.26
SE+	0.36	Na	0.39	0.28

Means within same column and treatment group followed by similar letter(s) are not significantly different at 5% level of probability using DMRT.

Nodule dry weights were similar for both varieties (Table 6). Nodule dry weight was significantly influenced by FYM. Application of 1 t/ha FYM increased nodule dry weight by 23%. Increasing FYM from 1 t/ha to 2 t/ha did not significantly influence nodule dry weight. Phosphorus application similarly increased nodule dry weight by same magnitude by applying 13.2 kg compared with zero P. Increasing P rate above 13.2 kg did not confer any significant benefit on nodule dry weight.

Table 6. Nodule dry weight of two soybean varieties as influenced by different rates of farmyard manure and inorganic P in Samaru (2009 and 2011)

Treatment Variety	Nodule dry weight (g)		
	2009	2010	Mean
TGx1448-2E	1.4	1.5	1.5
TGx1019-2E	1.5	1.5	1.5
Mean	1.5	1.5	1.5
SED	NS	NS	NS
FYM (t/ha)			
0	1.3b	1.2b	1.3b
1	1.5a	1.7a	1.6a
2	1.6a	1.7a	1.7a
SE+	0.04	0.11	0.06
Prate (kg/ha)			
0	1.3b	1.36	1.3b
13.2	1.3b	1.8a	1.6a
26.4	1.6a	1.6ab	1.6a
39.6	1.5a	1.4ab	1.5ab
SE+	0.04	0.13	0.07

Means within same column and treatment group followed by same letter(s) are not significantly different at 5% level of probability using DMRT.

Plant height at harvesting significantly differed between the two varieties (Table 7). Averaged over both years, TGx 1019-2E was 15.5% taller than TGx 1448-2E. Each increase in the level of FYM significantly increased plant height. Tallest plant were obtained with the highest level of FYM. Application of phosphorus increased plant height and 13.2 kg P/ha increased plant height compared with plots without P but no significant increase in height was observed by increasing P rate to 26.4 or 39.6 kg P/ha.

Table 7. Plant height at harvest of two soybean varieties with different levels of farmyard manure and inorganic P fertilizer in Samaru (2009-2011)

Treatment Variety	Plant height (cm)			
	2009	2010	2011	Mean
TGx1448-2E	54.26	57.9b	Na	56.0b
TGx1019-2E	61.8a	67.6a	Na	64.7a
Mean	58.0b	62.8a	Na	60.4
SED	1.60	1.87	Na	1.29
FYM (t/ha)				
0	53.6b	49.6b	Na	51.6c
1	55.7b	67.1a	Na	61.4b
2	64.7a	71.5a	Na	68.1a
SE+	1.9b	2.29	Na	1.58
Prate (kg/ha)				
0	53.7	53.6b	Na	53.6b
13.2	59.2	64.6a	Na	61.9a
26.4	59.2	65.4a	Na	62.3a
39.6	59.8	67.4a	Na	63.6a
SE+	2.26	2.64	Na	1.83

Means within same column and treatment group followed by similar letter(s) are not significantly different at 5% levels of probability using DMRT.

Na = Not available.

Total dry matter (TDM) per hectare differed between the two varieties (Table 8). TGx 1448-2E had 6.4% more dry matter than TGx 1019-2E when averaged over the three years. Each increase in FYM was accompanied by significant increase in TDM when averaged over the three years. Application of phosphorus also increased TDM significantly. Highest TDM was obtained with 39.6 kg P/ha, though not significantly different from 26.4 kg P/ha when averaged over the three years. Application of 39.6 kg P/ha increased TDM by 36.5% and 12.2% compared with plots without P and with 13.2 kg P/ha respectively.

Table 8. Total dry matter per hectare of two soybean varieties as influenced by rates of farmyard manure and inorganic P fertilizer in Samaru (2009-2011)

Treatment Variety	Total dry matter (kg/ha)			
	2009	2010	2011	Mean
TGx1448-2E	5850.0	5271.4a	6986.1	6038.5a
TGx1019-2E	5524.6	4771.2b	6730.7	5675.5b
Mean	5691.3	5021.3	6858.4	5857.0
SED	NS	172.3	NS	111.23
FYM(t/ha)				
0	5180.8b	3649.4b	6002.2c	4944.2c
1	5795.2ab	5684.1a	6814.16	6097.8b
2	6097.8a	5730.4a	7758.9a	6529.0a
SE+	272.31	211.40	206.2	136.12
Prate(kg/ha)				
0	4721.8b	3721.5b	6010.3c	4817.9c
13.2	5775.7a	5117.0a	6689.6b	5860.8b
26.4	5862.1a	5508.1a	7150.7ab	6173.6ab
39.6	6405.5a	5738.6a	7583.1a	6575.7a
SE+	275.68	244.30	240.5	157.23

Means within same column and treatment group followed by same letter(s) are not significantly different at 5% level of probability using DMRT

Number of pods did not significantly differ between the two varieties when averaged, over the years (Table 9). Application of manure increased number of pods significantly. Application of 2 t/ha of FYM increased number of pods per plant by 36.9% compared with plots without FYM. Application of P had no significant effect on number of pods per plant when averaged over the years.

Table 9. Number of pods and pod weight per plant of two soybean varieties with varying rates of farmyard manure and inorganic P fertilizer in Samaru (Mean of 2 years 2009 and 2010)

Treatment Variety	No of pods/plant	Pod weight/plant (g)
TGx1448-2E	40.6	26.0
TGX1019-2E	40.0	22.5
Mean	40.3	24.3
SED	NS	NS
FYM(t/ha)		
0	35.2b	23.2
1	37.5b	23.1
2	48.2a	26.5
SE+	3.24	NS
Prate(kg/ha)		
0	36.9	21.3
13.2	45.9	24.4
26.4	39.3	27.5
39.6	39.6	24.0
SE+	NS	NS

Means within same column and treatment group followed by same letter(s) are not significantly different at 5% level of probability using DMRT.

Pod weight per plant was not influenced by any of the treatments when averaged over the three years (Table 10). 100-seeds weight of the two varieties differed significantly only in 2009 but were similar in 2010, 2011 and when averaged over the three years (Table 10). Application of FYM increased 100-seed weight in 2009, 2010 and when averaged over the three years, application of 2 t/ha of FYM increased 100-seed weight by 4.8% compared with plots without FYM. Similarly, application of 13.2 kgP/ha increased 100-seed weight by 7.8% compared with plots without P but not significantly different from plots with 26.4 and 39.6 kg P/ha.

Table 10. 100-seed weight of two soybean varieties as influenced by rates of farmyard manure and inorganic P fertilizer in Samaru (2009 & 2011)

Treatment Variety	100-seed weight (g)			
	2009	2010	2011	Mean
TGx 1488-2E	12.8a	11.6	14.0	12.7
TGx 1019-2E	12.4b	11.6	13.0	12.3
Mean	12.6	11.6	13.5	12.6
SED	0.80	NS	NS	0.22
FYM(t/ha)				
0	12.5b	11.4b	13.2	12.4b
1	12.5b	11.6ab	12.9	12.3b
2	12.8a	11.7a	14.5	13.0a
SE+	0.10	0.11	NS	0.22
Prate(kg/ha)				
0	12.0c	11.2b	12.2	11.8b
13.2	12.6b	11.7a	14.2	12.8a
26.4	12.7b	11.5ab	14.3	12.8a
39.6	13.1a	11.8a	13.4	12.7a
SE+	0.11	0.13	NS	0.25

Means within same column and treatment group followed by same letter(s) are not significantly different at 5% level of probability using DMRT.

Table 11 Grain yield of soybean as influenced by rates of farmyard manure and inorganic P fertilizer in Samaru for three years (2009-2011)

Treatment Variety	Grain yield (kg/ha)			
	2009	2010	2011	Mean
TGx 1448-2E	1998.8	2332.8	2038.4	2124.1
TGx 1019-2E	1721.3	2264.4	2151.6	2044.8
Mean	1860.1	2298.6	2095.0	2084.4
SED	NS	NS	NS	NS
FYM(t/ha)				
0	1830.8	1773.1b	1839.3b	1814.1b
1	1783.3	2516.0a	2049.5b	2116.3a
2	1965.9	2606.7a	2398.1a	2322.5a
SE+	NS	97.57	81.70	76.58
Prate(kg/ha)				
0	1235.9b	1668.5b	1890.7b	1598.4c
13.2	1782.2ab	2350.8a	1895.4b	2009.5b
26.4	2298.5a	2488.1a	2216.7a	2334.4a
39.6	2123.4a	2687.0a	2354.7a	2388.4a
SE+	219.34	112.7b	94.42	88.46

Means within same column and treatment group followed by same letter(s) are not significantly different at 5% level of probability using DMRT.

Table 11 shows treatment effects on grain yield per hectare. The two varieties did not significantly differ in grain yield per hectare although TGx 1448-2E produced 3.9% more grain yield than TGx 1019-2E. Application of 2 t/ha of FYM produced significantly higher grain yield than plots without FYM but there was no difference with grain yield with 1 t/ha. Applying 1 t/ha of FYM increased grain yield by 16.7% compared with plots without FYM. Phosphorus application similarly increased grain yield per hectare. Application of 26.4 kg P/ha increased grain yield by 46.6% and 16.0% in plots without P and with 13.2 kg P/ha respectively. Increasing P level from 26.4 kg P/ha to 39.6 kg P/ha did not significantly increase grain yield. There were no interactions between FYM and inorganic P in any of the years and averaged over years.

4. Discussion

Rainfall was highest in 2009 (Table 1) particularly during the grain formation period. The waterlogging experienced during the period (August) must have affected nutrient uptake and hence adversely affected the grain yield which was lowest among the three years. A more evenly distributed rainfall in 2010 and 2011 ensured adequate nutrient uptake with the attendant high grain yields (above 2 t/ha Table 11). The soils showed the typical characteristics of the savanna, low N and low OM (Table 2) hence the observed positive response to applied FYM and P.

Varietal differences: The two varieties differed significantly in some characteristics but were similar in others. Both had similar LAI, number of days to 50% flowering, nodule dry weight, number and weight of pods per plant, 100-seed weight and grain yield per hectare. These similarities could be due to their common genetic background. The similarity in grain yield was unexpected because in an earlier trial with the two varieties Chiezey and Odunze (2009) observed that TGx 1448-2E out yielded TGx 1019-2E because the former had higher TDM, more pods per plant and heavier 100-seed weight, while the later was taller thereby expending more assimilates for non-productive functions. A more favourable environmental factors might have been responsible for both varieties expressing their optimal yield potential.

Influence of Farmyard Manure: The application of FYM had positive effects on some of the soybean growth and yield characters. Plant height, nodule dry weight, total dry matter, 100-seed weight increased with the application of FYM. The result was increased grain yield. The application of it FYM/ha increased grain yield considerably compared with plots without FYM. Examination of the chemical composition of the FYM showed high levels of N and P, (Table 3), nutrients critical for the growth and productivity of soybean. Higher levels of the FYM had no further significant influence in the yield of the crop because the nutrients in 1 t/ha of the material were enough for the crop. Chiezey and Odunze (2009) similarly observed that 1 t/ha of poultry manure increased the grain yield of soybean significantly. Increasing FYM from 1 t/ha to 2 t/ha increased grain yield by 84 kg/ha only which is not justifiable. Therefore, with 1 t/ha of FYM, high yield of soybean could be obtained. However, the quality of the FYM must be considered. Adequate rainfall in the three years of the study ensured a good decomposition and mineralisation of the FYM, thus releasing the nutrients required by the crop.

Influence of Phosphorus on Growth and Yield Phosphorus application influenced some parameters in some years but not in others, particularly where the P level was low as in 2009 (Table 2). Leaf area index increased with P application in 2009 only because the soil tested low in P but not in other years, Number of days to 50% flowering increased with P application ensuring enough time for nutrient accumulation, increased dry matter accumulation and translocation for grain filling, 100-seed weight and consequently, higher grain yield. Pal et al. (1983), Chiezey et al. (1992) and Chiezey and Odunze (2009) observed similar trends in soybean trials with P. Application of P up to 30 kg P/ha more than doubled the yield of soybean compared with plots testing low in P and without P application indicating the essentiality of P in soybean mineral nutrition. The optimum P rate for each year and the three years combined showed quadratic responses.

Combined-2009, 2010 and 2011

$$- Y = 1584 + 41.3x - 0.52x^2$$

Optimum P rate was 39.7 kg P/ha for a grain yield of 2404.0 kg

$$2010 - Y = 1698.8 + 51.65x - 0.69x^2$$

Optimum P rate = 37.4 for grain yield of 2665.4 kg/ha.

$$2009 - Y = 1202.89 + 65.02x - 1.04x^2$$

Optimum P = 31.9 kg P/ha for grain yield of 2218.6 kg/ha

$$2011 - Y = 1865.0 + 5.73x - 0.18x^2$$

Optimum P = 15.9 kgP/ha for grain yield of 1950.2 kg/ha

From the above equations, grain yields were highest in 2009 and 2010 ranging between 2218.6 to 2665.4 kg/ha which were quite high compared with less than 1000 kg/ha obtained by farmers. Averaged over the three years grain yield of 2404.0 kg/ha with 39.7 kg/ha of P was remarkable and indicates that yields of soybean could be significantly increased with the application of between 32 and 40 kg P/ha. Chiezey and Odunze (2009) obtained an optimum yield of 1.7 t/ha with 23.3 kg P/ha which was quite low compared with the figures obtained in this study. It must be noted that environmental factors particularly soil nutrient status and rainfall total and distribution play important roles in determining the response of crops to fertilizer inputs.

Therefore, the current study shows that any of the two varieties of soybean TGx 1448-2E or TGx 1019-2E with 1 t/ha of FYM or 32-39.7 kg P/ha could give a good yield of soybean above 2 t/ha.

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