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Full Length Research Paper

Yield parameters and stabilty of soybean [*Glycine max.* (L.) merril] as influenced by phosphorus fertilizer rates in two ultisols

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A field study was conducted for two years to assess the spatial and temporal effect of Phosphorus fertilizer on the yield, yield components and yield stability of five soybean genotypes in Umudike and Amakama in eastern Nigeria. The study was laid out as a split-plot in a randomized complete block with three replications. P rates of 0, 10, 20, 30 and 40 kg P/ha as triple superphosphate (TSP, 20% P) was randomly allocated to sub-plots and five soybean varieties (TGX 1440-1E, TGX 1448-2E, TGX 1485-1D, TGX 1835-10E and TGX 1910-14F) to main plots. Phosphorus rate, year and location were considered as environmental factors in a genotype x environment analysis. Genotype, P rate, year, location and some interactions were significant for most of the traits studied. The Genotypes performed differently across the environments and a high positive and significant association existed between seed yield and number of pods per plant as well as the number of seeds per plant. Hence, these traits can be selected for in the improvement of soybean in this agro ecology. Genotype x environment interactions (GEI) played a significant role in this study and should be given considerable attention in soybean breeding program for development of genetic materials adapted to a wide range of environments. TGX 1910-14F and TGX1440-1E were stable under different P rates.

Key words: Soybean *(Glycine max* L.) genotypes, yield stability, grain yield, genotype x environment interaction (GEI).

INTRODUCTION

Soybean [*Glycine max* (L.) Merrill] is the world's leading source of oil and protein. It has the highest protein content of all food crops and is second only to groundnut in terms of oil content among food legumes (Fekadu et al., 2009; Alghamdi, 2004). The spread of soybean from its native land of origin has been mainly due to its adaptability and predominant use as a food crop for human nutrition, source of protein for animals, medicinal plant and lately as an industrial crop (Yusuf and Idowu, 2001). Traditionally, soybean is widely grown in the middle belt or the savannah zone of Nigeria (Okpara and Ibiam, 2000) but, its production has presently expanded beyond the traditional production areas of the middle belt to cover other Northern and Southern parts of the country that were otherwise considered unsuitable or marginal for soybean production (Asiegbu and Okpara, 2002). However, there are highlighted constraints in the current attempts for the successful incorporation of the crop into the cropping system of these zones most of which are soil related constraints such as low pH, nutrient deficiencies (phosphorus, potassium, molybdenum and sulphur), and toxic levels of some metals like aluminum, iron, and manganese (Rubaihayo et al., 2000). These factors have the potentials to reduce the yield of the crop (Singh et al., 1987; IITA, 1989). Some studies on the adaptability of soybean cultivars to the humid tropical conditions of the southeastern Nigeria have been carried out (Ikeorgu et al., 1990; Solomon and Uwah, 1996; Dada, 1998; Onyegbule, 1999, Okpara and Ibiam, 2000; Osodeke, 2001) and some varieties recommended.

Soybean responds both to P-fertilization and soil P level as well as soil location (Ogoke et al., 2003). Notable responses to phosphorus have been recorded from different ecological zones. Pal et al. (1989) observed that grain yield of soybean responded to P fertilizer in 10 of 11 trials in northern Nigeria. Taiwari (1965), in the derived savanna zone of Nsukka (Southeastern Nigeria) obtained significant response of soybean to 20 kg N and 20 kg P_2O_5/ha. Ochulor (1999) however, obtained no response due to the high level of phosphorus in the experimental site. Onuka and Ugbaja (1995), reported that the application of liming material (cement flue dust) at the rate of 1000 kg/ha and phosphorus at the rate of 15 kg P/ha increased the soil pH and grain yield of soybean in South-eastern Nigeria. Osodeke (2001) recorded a significant response to P-fertilizer application and recommended an application of 50 kg/ha P depending on the soil available P.

Soybean yield has been characterized with high instability within and between species at different sites and among seasons (Radi et al., 1993; Moot and McNeil, 1995; Ma et al., 1998; Ambrose and Hedley, 1984) and the use of stable genotypes for high seed yield is an important objective for sustainable soybean production (Alghamdi, 1991; Carpenter and Board, 1997). The knowledge of the genetic variability in plant improvement programs and the adequate evaluation of breeding materials under different environments are very important (Comstock and Moll, 1963). Stable genotypes are less dependent upon good environments to perform well, and this makes their yield more predictable (Crossa, 1990; Dashiell et al., 1994; Baiyeri and Nwokocha, 2001). Beaver and Johnson (1981) noted that soybean breeders have traditionally emphasized wide adaptation rather than specific adaptation in their breeding programs and selected genotypes that perform well over a wide range of climatic conditions. Broad adaptation provides stability against the variability inherent in an ecosystem, but specific adaptations may provide a significant yield advantage in particular environments (Wade et al., 1999). Multi-environment testing makes it possible to identify cultivars that perform consistently from year to year (temporal variability) and those that perform consistently from location to location (spatial variability). Temporal stability is desired by and beneficial to growers, whereas spatial stability is beneficial to seed companies and breeders (Kang, 2002). Denis and Gower (1996) suggested that plant breeders should consider genotype x environment interaction (GEI) to avoid missing varieties that, on average, perform poorly but do well when grown in specific environments or those that, on average, perform well but do poorly when grown in a particular environment.

The objective of the study was to determine the yields and yield components of five soybean genotypes, genotype x environment interaction (GEI) and evaluate the stability of these genotypes in response to P-fertilization.

MATERIALS AND METHODS

The experiment was conducted at the Michael Okpara University of Agriculture Teaching and Research Farm at Umudike (latitude 05° 29' N; longitude 07° 33' E; altitude 122 m) in 2009 and 2010. In 2010 cropping seasons, an additional location, Amakama was added to study the effect of environmental variability. Amakama is located at latitude 05° 28'N, longitude 07° 29'E; altitude 154.25 m. The soil is classified as sandy acidic soil and a pH of 4.55. Umudike is in the humid tropics and has a total rainfall of about 2177 mm per annum, annual average temperature of about 26°C. The soil has been classified as a sandy loam Ultisol (Agboola, 1979). The rainfall pattern is bimodal.

Two early and three medium maturing genotypes of soybean obtained from the germplasm of International Institute of Tropical Agriculture (IITA) were used (Table 1). The experiment was laid out as a split-plot in a randomized complete block design with the genotypes as main plot and the P rates as the subplot in three replications. The P rates of 0, 10, 20, 30 and 40 kg P ha^{-1} as triple superphosphate (TSP, 20 % P) were randomly allocated to sub-plots. The plot size in 2009 was 3 m × 2 m plots with 50 cm furrow between the plots and 1 m^2 between replications. In 2010, the plot size was 2 m × 2 m, with same spacing between plots and replications as in 2009 in both locations.

Agronomic practices

Planting was done on July 9, 2009 and July 30, 2010 in Umudike and on August 13, 2010 at Amakama. The land was ploughed and harrowed before planting seeds on flat. Seeds were sown at a plant spacing of 50 cm × 10 cm, inter and intra row spacing respectively (200,000 plants/ha). Two seeds were sown per stand and later thinned to one plant at three (3) weeks after planting (WAP). The different P fertilizer dosages were drilled 1 WAP. Weed control was achieved by hoeing carried out twice at 3 and 6 WAP.

Soil analysis

Soil samples were obtained with a steel auger into a plastic bucket and properly mixed. It was air dried at room temperature and passed through 2 mm sieve before it was taken to the laboratory for analysis. The soil pH was measured in a soil/water ratio of 1:2 with glass electrode and pH meter (Maclean, 1965). Soil physical properties were determined by thee hydrometer (Juo, 1979). Total soil N was determined by the Kjeldahl method (Bremner, 1965), available P by the Bray 1 method (Bray and Kurtz, 1945), exchangeable K by the use of a flame photometer.

Data collection

At physiological maturity, net plots were harvested for assessment (0.9 m^{-2}). Data were collected on the seed yield (kg/ha), seed size (100 seed weight in grams), number of pods per plant and

Table 1. Soybean genotypes and their maturity class.

Genotype	Maturity class
TGX 1440-1E	Medium
TGX 1448-2E	Medium
TGX 1485-1D	Early
TGX 1835-10E	Early
TGX 1910-14F	Medium

Table 2. Soil physico-chemical properties of the study areas.

Parameter	UMUDIKE		AMAKAMA
	2009	2010	2010
Texture	Sandy loam	Sandy loam	Sandy loam
Sand (%)	66.4	79.20	75.20
Silt (%)	18.80	7.40	11.40
Clay (%)	14.80	13.40	13.40
pH (H_2O)	5.06	5.04	4.89
Phosphorus (Mg/kg)	16.09	14.40	16.30
Nitrogen (%)	0.280	0.07	0.056
Organic carbon (%)	0.10	0.68	0.75
Organic matter (%)	0.17	1.17	1.30
Calcium (C mol kg^{-1})	3.60	3.20	2.40
Magnesium (C mol kg^{-1})	2.00	2.00	1.20
Potassium (C mol kg^{-1})	0.251	0.317	0.077
Sodium (C mol kg^{-1})	0.113	0.244	0.270
TEA (C mol kg^{-1})	1.96	2.16	2.56
ECEC (C mol kg^{-1})	7.924	7.921	6.507

TEA, Total exchangeable anions; ECEC, effective cation exchange capacity.

number of seeds per plant.

Statistical analysis

Data collected were subjected to Analysis of Variance (ANOVA) using the mixed model procedures (PROCMIXED) in SAS (Little et al., 1996). The analysis estimated the genotype, phosphorus, year and location effects as well as their interactions. The stability pattern of the genotype x P rates was examined across year and location using Genotype and Genotype-by-Environment interaction (GGE) biplot model (Yan, 2001).

RESULTS AND DISCUSSION

Soil and weather characteristics of study area

Table 2 shows the soil properties of the experimental sites. The results show that the soil texture is sandy loam. The soil pH ranged from 4.9 to 5.1 with the Amakama soil being more acidic than the Umudike soil. Soil phosphorus was high in Amakama but low at the Umudike in 2010. The soil nitrogen content was higher in Umudike than Amakama. Organic carbon was higher at Amakama than Umudike but Umudike had low ECEC and the basic cations – calcium, magnesium and potassium than Amakama-compared to the latter.

Figure 1 shows the monthly rainfall (mm) distribution at Umudike. The average monthly rainfall was 177.16 and 194.16 mm in 2009 and 2010, respectively. The rainfall pattern showed a bimodal rainfall distribution in 2009 with peaks in April and September. Annual rainfall was higher in 2010 than in 2009 with no distinct break.

Effect of genotype on soybean yield and yield parameters at different P fertilizer rates

Soybean genotypes showed high variability in yield and yield associated traits. Genotype effect was highly significant ($P<0.01$) on seed yield (kg/ha), seed size, number of pods/plant and number of seeds/plant in Umudike and Amakama (Tables 3 to 6). The genotypes - TGX 1910-14F had the highest mean performance for seed yield and number of seeds/plant while TGX 1835-10E had the lowest mean values for seed yield, the

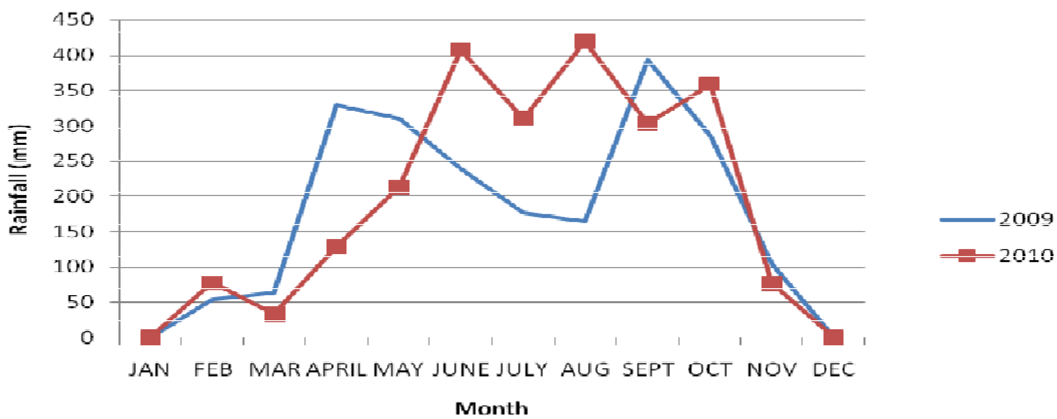

Figure 1. Monthly rainfall (mm) distribution of Umudike in 2009 and 2010. Source: National Root Crops Research Institute's (NRCRI) Agro-meteorological Unit, Umudike.

Table 3. Effect of phosphorus rates and soybean genotypes, year, location and their interactions on seed yield (kg/ha).

Treatment	Location				
	Umudike			Amakama	#Mean
	2009	2010	Mean	2010	
Genotype					
TGX1440-1E	1407.05	861.76	1134.41	833.07	847.42
TGX1448-2E	1518.68	866	1192.34	565.3	715.65
TGX1485-1D	1435.06	568.87	1001.97	749.79	659.33
TGX1835-10E	1128.35	461.25	794.8	597.01	529.13
TGX1910-14F	1880.97	992.59	1436.78	843.32	917.96
P Rates (kg/ha)					
0	1507.83	604.55	1056.19	668.74	636.65
10	1559.22	727.56	1143.39	860	793.78
20	1339.19	781.94	1060.57	720.28	751.11
30	1556.39	761.55	1158.97	645.89	703.72
40	1407.48	874.88	1141.18	693.58	784.23
Mean	1474.03	750.1	1112.07	717.7	733.9
LSD 0.05	Genotype: 154.35***; P-rates: ns; Genotype × P-rates: 354.6***; Year: 97.62***; Year × Genotype: ns; Year × P-rates: ns; Year × Genotype × P-rates: 838.7*			Genotype: 130.32***;P-rates: ns; Genotype × P-rates: 313.6**; Location: ns; Location × Genotype: 248.3**; Location × P-rates: ns; Location x Genotype × P-rates: ns	

#Mean: 2010 mean in Umudike and Amakama.

number of seeds/plant and number of pods/plant in both years and locations. Soybean seed size was smallest on TGX 1440-1E in both the year and location trials. TGX 1910-14F and TGX 1448-2E had the highest seed size and the number of pods/plant in year trials, while TGX 1485-1D and TGX 1440-1E gave the least seed size and the number of pods/plant in the location, respectively. The observed differential genotypic responses can be traceable to differences in inherent genetic composition and specific tolerance to P. Such responses had been recorded by Pulver et al. (1985), Nwoko and Sanginga (1999), Sanginga et al. (2000) and Osodeke (2001).

Effect of Phosphorus rates on soybean yield and yield parameters

P at different rates significantly influenced only the number of pods/plant (P<0.01) in year and number of seeds/plant (P<0.05) in the location trials. However, the mean yield and yield components revealed a relative P rate -trait responses. P rates at 30 kg/ha gave the highest seed yield in year but highest at 10 kg/ha in location trial (Table 3). At 40 kg/ha P, the highest mean number of pods/plant and the number of seeds/plant were obtained in the year and at 10 kg/ha P in the location trial

Table 4. Effect of Phosphorus rates and soybean genotypes, year, location and their interactions on seed size (g).

Treatment	Location				
	Umudike			Amakama	#Mean
	2009	2010	Mean	2010	
Genotype					
TGX1440-1E	8.95	9.73	9.34	11.27	10.5
TGX1448-2E	8.92	10.6	9.76	10.47	10.54
TGX1485-1D	8.83	11.47	10.15	11.6	11.54
TGX1835-10E	9.66	10.13	9.9	11.53	10.83
TGX1910-14F	9.68	11	10.34	11.53	11.27
P Rates (kg/ha)					
0	9.49	10.47	9.98	11.33	10.9
10	9.35	10.47	9.91	11.27	10.87
20	9.29	10.93	10.11	11.33	11.13
30	9.52	10.4	9.96	11.2	10.8
40	8.39	10.67	9.53	11.27	10.97
Mean	9.21	10.59	9.9	11.28	10.94
LSD 0.05	Genotype: 0.52**; P-rates: ns; Genotype × P-rates: ns; Year: 0.33***; Year × Genotype: 0.89***; Year × P-rates: 0.71*; Year × Genotype × P-rates: ns			Genotype:0.42 ***; P-rates: ns; Genotype × P-rates: ns; Location: ns; Location × Genotype: 1.19***; Location × P-rates: ns; Location × Genotype × P-rates: 1.70*	

#Mean: 2010 mean in Umudike and Amakama.

Table 5. Effect of phosphorus rates and soybean genotypes, year, location and their interactions on the number of pods per plant.

Treatment	Location				
	Umudike			Amakama	#Mean
	2009	2010	Mean	2010	
Genotype					
TGX1440-1E	50.95	23.98	37.47	14.85	19.42
TGX1448-2E	60.04	21.04	40.54	14.89	17.97
TGX1485-1D	49.98	12.73	31.36	16.13	14.43
TGX1835-10E	31.53	11.21	21.37	11.68	11.45
TGX1910-14F	55.21	21.35	38.28	16.62	18.99
P Rates (kg/ha)					
0	46.69	14.48	30.72	15.34	14.91
10	50.09	18.31	34.2	17.47	17.89
20	44.69	19.11	31.9	14.83	16.97
30	53.99	17.53	35.76	12.26	14.9
40	51.98	20.89	36.44	14.28	17.59
Mean	49.55	18.07	33.81	14.84	16.46
LSD 0.05	Genotype: 3.13***; P-rates: 3.13**; Genotype × P-rates: 7.60***; Year: 1.99***; Year × Genotype: 6.47***; Year × P-rates: 5.36*; Year × Genotype × P-rates: 12.41***			Genotype: 2.89***; P-rates: ns; Genotype × P-rates: 7.70**; Location: 1.83***; Location × Genotype: 5.64***; Location × P-rates: ns; Location × Genotype × P-rates: ns	

#Mean: 2010 mean in Umudike and Amakama.

(Tables 5 and 6). Maximum soybean seed size was obtained at 20 kg/ha P in both year and location trials (Table 4). At 0 kg/ha P, seed yield (kg/ha) (Table 3) and number of seeds/plant (Table 6) in both years and locations were lowest. Number of pods/plant had the lowest mean performance at 0 kg/ha P in year and

Table 6. Effect of phosphorus rates and soybean genotypes, year, location and their interactions on the number of seeds per plant.

Treatment	Location				
	Umudike			Amakama	#Mean
	2009	2010	Mean	2010	
Genotype					
TGX1440-1E	78.79	43.69	61.24	36.78	40.24
TGX1448-2E	84.85	40.4	62.63	27.48	33.94
TGX1485-1D	82.35	25.19	53.77	32.6	28.9
TGX1835-10E	58.12	22.64	40.38	25.99	24.32
TGX1910-14F	95.85	45.06	70.46	35.5	40.28
P rates (kg/ha)					
0	78	28.72	53.36	29.45	29.09
10	83.48	34.64	59.06	38.47	36.56
20	72.84	35.97	54.41	30.54	33.26
30	81.05	36.64	58.85	28.93	32.79
40	84.6	41.02	62.81	30.96	35.99
Mean	80	35.4	57.7	31.67	33.54
LSD $_{0.05}$	Genotype: 6.73***; P-rates: 6.73*; Genotype × P-rates: 16.66***; Year: 4.26****; Year × Genotype: 13.94**; Year × P-rates: ns; Year × Genotype × P-rates: 24.50**			Genotype: 5.42***; P-rates: ns; Genotype × P-rates: 13.51**; Location: 3.43*; Location × Genotype: 10.66***; Location × P-rates: ns; Location × Genotype × P-rates: ns	

#Mean: 2010 mean in Umudike and Amakama.

30 kg/ha in location; seed size at 40 kg/ha P in year trial and 30 kg/ha in location. Significant P responses have also been reported by Ogoke et al. (2003) and Pal et al. (1989) in the northern Nigeria. In the south east agro-ecology, Osodeke (2001) recommended 50 kg/ha P for soybean production. The non response of traits to P rates might be obviously due to high level of phosphorus above the critical level of 8 to 12 ppm recommended by Wade et al. (1999), Aune and Lal (1997), and Singh et al. (2000) for this agro ecology.

Effect of year on soybean yield and yield parameters

Significantly year effect (P<0.001) was recorded for all the yield and yield components in this study. Number of pods/plant, number of seeds/plant and seed yield/ha were higher in 2009 than in 2010 (Tables 3, 5 and 6), while seed size had better performance in 2010 (Table 4) than in 2009. The variations in soybean yield and yield parameters as occasioned by year can be attributed to changes in both soil and weather environments across the years (Tenkouano and Baiyeri, 2007).

Effect of location on soybean yield and yield parameters

Location effect was significant (P<0.5) on the number of pods/plant (P<0.001) and the number of seeds/plant but not seed yield and seed size. Mean performance of the measured attributes were higher at Umudike except for seed size which was higher at Amakama. Location effect had been attributed to differences in soil type and climatic factors as reported by Pulver et al. (1985) and Singh et al. (2000). It has also been reported that soybean perform differently across locations even within the same agro-ecology (Finlay and Wilkinson, 1963; Comstock and Moll, 1963; Saeed and Francis, 1983; Romagosa and Fox, 1993; Lin and Lin, 1994; Cooper et al., 1995; Baiyeri and Nwokocha, 2001; Moltaldo, 2001).

Genotype × environment interactions (GEI) and yield components

Some notable significant interactions existed in this study. Genotype x P rate interaction was highly significant (P<0.001) on yield, pods/plant and seeds/plant in year and location. Genotype x year interaction was significant (P<0.01) for all the other yield parameters except for seed yield/ha. Also, genotype x location interaction was highly significant (P<0.001) for all the attributes while P rate x year interaction was only significant (P<0.5) on the number of pods/plant and seed size. Year x genotype x location interaction was significant for all the attributes except for seed size. These reported significant interaction effects confirm the presence of GEI and emphasis the need for the development of genotypes that are stable across diverse

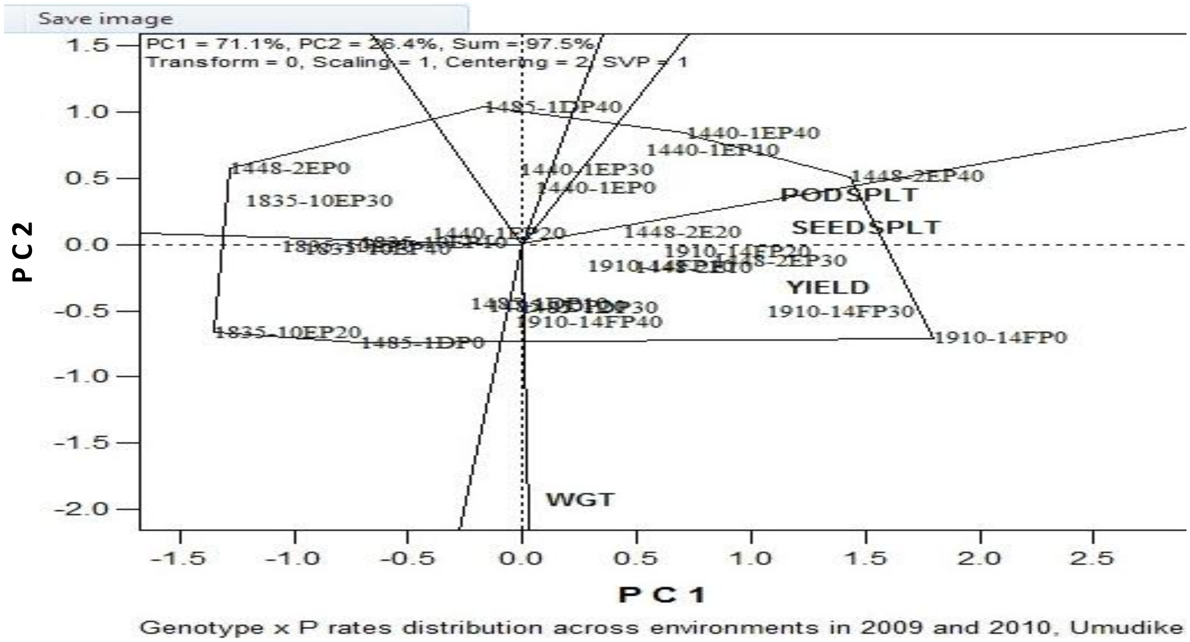

Figure 2. Genotype × P rates distribution to soybean yield and yield components in 2009 and 2010, Umudike. Traits: Grain yield [YIELD], number of seeds/plant [SEEDSPLT], number of pods/plant [PODSPLT], seed size [WGT]; Genotype × P rate interaction: TGX 1440 -1E × 0kg/ha [1440-1EP0], TGX 1440 -1E × 10 kg/ha [1440-1EP10], TGX 1440 -1E × 20 kg/ha [1440-1EP20], TGX 1440 -1E × 30 kg/ha [1440-1EP30], TGX 1440 -1E × 40 kg/ha [1440-1EP40]; TGX 1448-2E × 0 kg/ha [1448-2EP0], TGX 1448-2E × 10 kg/ha [1448-2EP10], TGX 1448-2E × 20 kg/ha [1448-2EP20], TGX 1448-2E × 30 kg/ha [1448-2EP30], TGX 1448-2E × 40 kg/ha [1448-2EP40]; TGX 1485-1D × 0 kg/ha [1485-1DP0], TGX 1485-1D × 10 kg/ha [1485-1DP10], TGX 1485-1D × 20 kg/ha [1485-1DP20], TGX 1485-1D × 30 kg/ha [1485-1DP30], TGX 1485-1D × 40 kg/ha [1485-1DP40]; TGX 1910-14F × 0 kg/ha [1910-14FP0], TGX 1910-14F × 10 kg/ha [1910-14FP10], TGX 1910-14F × 20 kg/ha [1910-14FP20], TGX 1910-14F × 30 kg/ha [1910-14FP30], TGX 1910-14F × 40 kg/ha [1910-14FP40].

environments in the improvement of soybean. The implication of the high environmental influence will lead to low heritability and thus will render yield selection unpredictable (Ene-Obong and Okoye, 1992; Ariyo, 1995; Ofori, 1996). Similar interaction effects have been reported previously (Rao et al., 2002; Osodeke, 2001).

From Figures 2 and 3, major yield factors include number of pods/plant and number of seeds/plant. These traits therefore, can be selected for in the improvement of soybeans in the southeast agro-ecology. Similar associations have been reported in soybean and other grain legumes (Doku, 1970; Walton, 1971; Singh and Malhotra, 1973; Walson, 1987; Okoye and Ene-Obong, 1992; Okeleye et al., 1999; Osodeke, 2001).

Genotype stability as influenced by P rates

The stability analysis (Figures 4 and 5 for Umudike and between Umudike and Amakama respectively) revealed that TGX 1910-14F and TGX 1440-1E genotypes had high mean performances but at different P rates. TGX 1910-14F at 0 kg/ha P had the highest mean yield in the year trial but highly unstable. High mean yield and high stability performance however, was obtained at 30 kg/ha.

Across locations, TGX 1440-1E at 40 kg/ha had the highest mean yield and high (Figure 5). This result tends to support specific than broad adaptation in stability studies and gave evidence for the existence of spatial and temporal variations. Specific adaptation, according to Evans (1993) has a greater significance to the subsistence farmers. Both types of spatial and temporal variations have also, been reported in *Musa* spp. (Baiyeri et al., 2000a, b, 2004). Spatial variations have been attributed to differences in climate (rainfall and temperature), soil quality (biophysical characteristics), and cultural practices. Changes over time cause the same factors to explain temporal variations (Tenkouano and Baiyeri, 2007).

In conclusion, the southeast agro ecology has high potential for soybean production with appreciable grain yield. Umudike showed a higher potential for soybean production than Amakama in this agro ecology. Major contributors of soybean grain yield are the number of pods/plant and number of seeds/plant. Genotype x environment interactions (GEI) played a significant role in this study. The genotypes TGX 1910-14F and TGX 1440-1E had high stable yield performance than the other genotypes but were not necessarily the highest performing genotypes. Genotypes showed differential

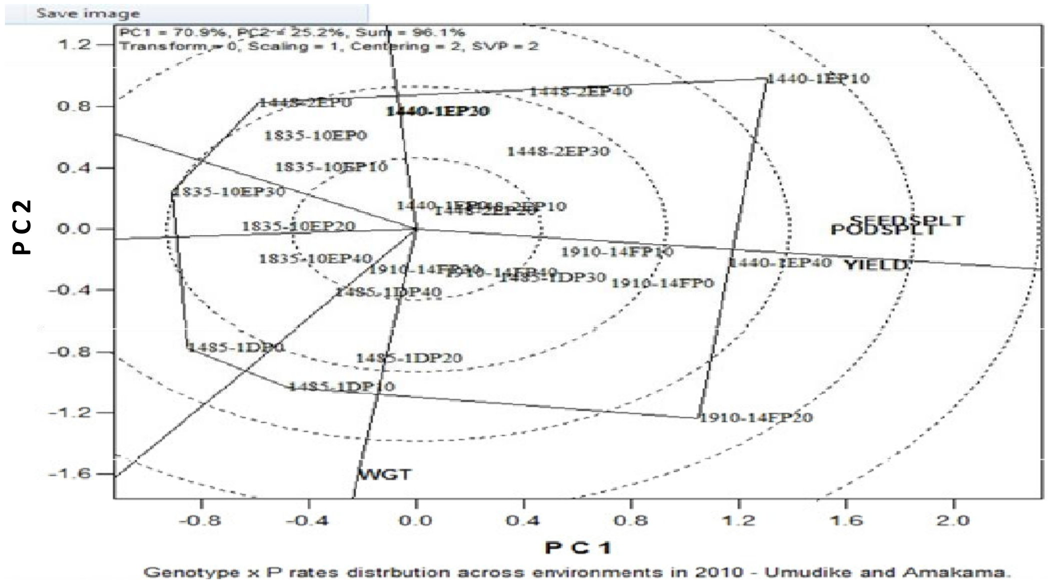

Figure 3. Genotype × P rates distribution to soybean yield and yield components in 2010 between Umudike and Amakama. Traits: Grain yield [YIELD], number of seeds/plant [SEEDSPLT], number of pods/plant [PODSPLT], seed size [WGT]; Genotype × P rate interaction: TGX 1440 -1E × 0 kg/ha [1440-1EP0], TGX 1440 -1E × 10 kg/ha [1440-1EP10], TGX 1440 -1E × 20 kg/ha [1440-1EP20], TGX 1440 -1E × 30 kg/ha [1440-1EP30], TGX 1440 -1E × 40 kg/ha [1440-1EP40]; TGX 1448-2E X 0kg/ha [1448-2EP0], TGX 1448-2E × 10 kg/ha [1448-2EP10], TGX 1448-2E × 20 kg/ha [1448-2EP20], TGX 1448-2E × 30 kg/ha [1448-2EP30], TGX 1448-2E × 40 kg/ha [1448-2EP40]; TGX 1485-1D × 0 kg/ha [1485-1DP0], TGX 1485-1D × 10 kg/ha [1485-1DP10], TGX 1485-1D × 20 kg/ha [1485-1DP20], TGX 1485-1D × 30 kg/ha [1485-1DP30], TGX 1485-1D × 40 kg/ha [1485-1DP40]; TGX 1910-14F × 0 kg/ha [1910-14FP0], TGX 1910-14F × 10 kg/ha [1910-14FP10], TGX 1910-14F × 20 kg/ha [1910-14FP20], TGX 1910-14F × 30 kg/ha [1910-14FP30], TGX 1910-14F × 40 kg/ha [1910-14FP40].

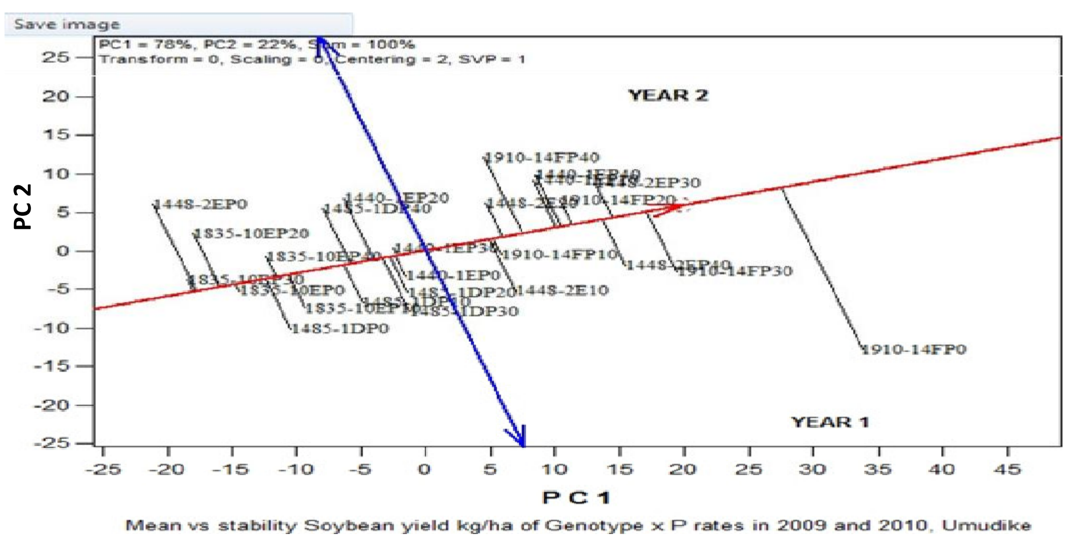

Figure 4. Yield stability of Soybean genotypes × P rates in 2009 and 2010 at Umudike. Year: 2009 [Year 1], 2010 [Year 2]; Genotype × P rate interaction: TGX 1440 -1E × 0 kg/ha [1440-1EP0], TGX 1440 -1E × 10 kg/ha [1440-1EP10], TGX 1440 -1E × 20 kg/ha [1440-1EP20], TGX 1440 -1E× 30 kg/ha [1440-1EP30], TGX 1440 -1E × 40 kg/ha [1440-1EP40]; TGX 1448-2E × 0 kg/ha [1448-2EP0], TGX 1448-2E × 10 kg/ha [1448-2EP10], TGX 1448-2E × 20 kg/ha [1448-2EP20], TGX 1448-2E × 30 kg/ha [1448-2EP30], TGX 1448-2E × 40 kg/ha [1448-2EP40]; TGX 1485-1D × 0 kg/ha [1485-1DP0], TGX 1485-1D × 10 kg/ha [1485-1DP10], TGX 1485-1D × 20 kg/ha [1485-1DP20], TGX 1485-1D × 30 kg/ha [1485-1DP30], TGX 1485-1D × 40 kg/ha [1485-1DP40]; TGX 1910-14F × 0 kg/ha [1910-14FP0], TGX 1910-14F × 10 kg/ha [1910-14FP10], TGX 1910-14F × 20 kg/ha [1910-14FP20], TGX 1910-14F × 30 kg/ha [1910-14FP30], TGX 1910-14F × 40 kg/ha [1910-14FP40].

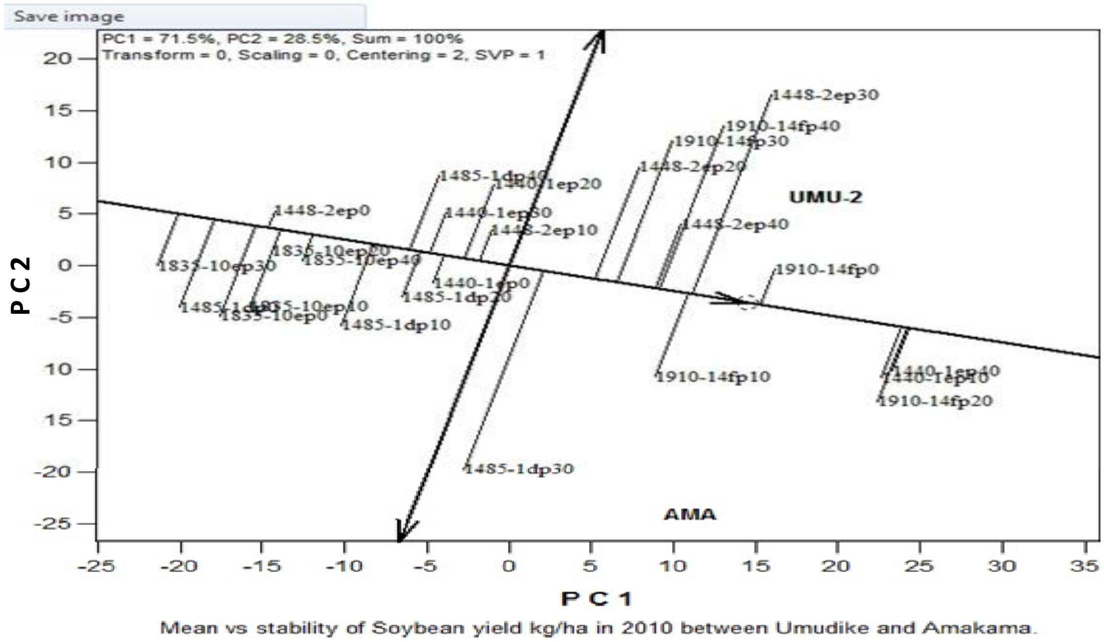

Figure 5. Yield stability of soybean genotypes × P rates in 2010 between Umudike and Amakama. Locations: Amakama [AMA], Umudike [UMU-2]; Genotype × P rate interaction: TGX 1440 -1E × 0 kg/ha [1440-1EP0], TGX 1440 -1E × 10 kg/ha [1440-1EP10], TGX 1440 -1E × 20 kg/ha [1440-1EP20], TGX 1440 -1E × 30 kg/ha [1440-1EP30], TGX 1440 -1E × 40 kg/ha [1440-1EP40]; TGX 1448-2E × 0 kg/ha [1448-2EP0], TGX 1448-2E × 10 kg/ha [1448-2EP10], TGX 1448-2E × 20 kg/ha [1448-2EP20], TGX 1448-2E X 30kg/ha [1448-2EP30], TGX 1448-2E X 40kg/ha [1448-2EP40]; TGX 1485-1D × 0 kg/ha [1485-1DP0], TGX 1485-1D × 10 kg/ha [1485-1DP10], TGX 1485-1D × 20 kg/ha [1485-1DP20], TGX 1485-1D × 30 kg/ha [1485-1DP30], TGX 1485-1D × 40 kg/ha [1485-1DP40]; TGX 1910-14F × 0 kg/ha [1910-14FP0], TGX 1910-14F × 10 kg/ha [1910-14FP10], TGX 1910-14F × 20 kg/ha [1910-14FP20], TGX 1910-14F × 30 kg/ha [1910-14FP30], TGX 1910-14F × 40kg/ha [1910-14FP40].

response to P rate fertilization as well as other environmental factors used in this study and hence, supported narrow than broad stability. The two genotypes - TGX 1910-14F and TGX 1440-1E are therefore, recommended for improvement in the southeast agro ecology.

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