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Genetic and Environmental Variation of Seed Yield and Yield Components in African Yam Bean (Sphenostylis stenocarpa (Hochst. Ex. A. Rich.))

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Abstract
Fourteen genotypes of African Yam Bean were grown in three locations Abakaliki, Enugu and Ibadan in 2012 planting season and were analysed for genotype, environment and genotype × environment variability in yield and yield components. There was significant environmental as well as genetic effect on parameters measured. Genetic effect accounted more for the variability observed in 100 seeds weight (61%) and pod width (56%), but less effect on seed per pod (34%), pod length (40%), peduncle per plant (22%), pod per peduncle (17%), peduncle with pod (36%), peduncle without pod (37%), pods per plant (33%) and seeds per plant (29%). Genotype also largely accounted for variability noticed in days to 50% flowering (50%). G × E interaction significantly affected all the yield components except number of seeds per plant. Ibadan location had good textural and structural characteristics (pH = 6.13, organic matter = 2.88, k = 0.73, p = 8.89, % N = 0.68) than the other locations; Abakaliki (pH = 6.54, organic matter = 1.16, k = 0.32, p = 4.88, % N = 0.09) and Enugu (pH = 6.29, organic matter = 1.48, k = 0.37, p = 5.21, % N = 0.11). Abakaliki and Enugu showed highest maximum temperature, lowest minimum temperature, highest rainfall but lower relative humidity than Ibadan. Ibadan location performed averagely higher for all the parameters measured. The correlation coefficient from the three locations indicated relationship among the parameters. The GGEbiplot result showed that most genotypes are more adapted to Ibadan site while Abakaliki and Enugu similar in adaptation. Hence, AYB adaptation is dependent on genotype, environment and G × E interaction.
Keywords: *Sphenostylis stenocarpa*; genotype, environment, yield component, interaction, yield

1. Introduction

African Yam Bean (AYB) (*Sphenostylis stenocarpa*) is an under-utilized tropical food legume crop that is not as popular as other major food legumes like soybean (Azeke *et al*., 2005; Moyib, *et al*., 2008). It produces nutritious pods, highly proteinous seeds and is capable of growth in marginal areas where other pulses fail to thrive (Okpara and Omaliko, 1997). The crop thus has the potential to meet the ever increasing protein demands of the people in the sub-Sahara Africa if grown on a large scale. Presently, low quantities are offered for sale in the markets compared to other pulses. This leguminous plant is highly adaptable and can thrive in acidic and highly leached sandy soil in the humid lowlands of the tropics (Okigbo, 1973; Aletor and Aladetimi, 1989). Nutritionally, the seeds are known to possess 21% to 29% crude protein and approximately 50% carbohydrate (Okigbo, 1973; Eromosele *et al*., 2008)

Few reports are available on AYB diversity with respect to presence of nutritive and anti-nutritional factors (Ajibade *et al.,* 2005), Protein content (Uguru and Madukaife, 2001), Seed colour and colour pattern (Oshodi *et al.,* 1995), chromosome size and number (Adesoye and Nnadi, 2011). Ene-Obong and Okoye (1992) studied the relationship between seed yield and yield components in four collections of African yam bean in Enugu south eastern Nigeria.

The study of character association provides information about the estimates of interrelationship of various yield components in manifestation of yield. Efficiency of selection for higher yield depends upon the knowledge of the trait components and their interaction with grain yield. This requires information about nature of magnitude of variability in base population and association of yield component with grain yield (Dhaual *et al.,* 2002). Association between any two traits or among various traits is of immense importance in order to make desired selection of combination of characters. Correlation analysis provides information about the correlated response of plant characters to selection (Ahmad *et al.,* 2003). The correlation coefficient between yield and yield components generally demonstrate a compound sequence of interacting association.

Majority of African yam bean accessions at the Genetic Resources Centre of the International Institute for Tropical Agriculture (IITA), Nigeria originated from SouthEastern part of the country (Machuka, 2001). And it might be assumed that the crop is most adapted that locality. Several studies on genetic diversity were conducted within either south east or south western part of Nigeria. It is clear that variation in phenotype arises from the joint action of the genotype and environment and there is need to know which environments best support which genotype. Hence this paper reports on the response of African Yam Bean genotypes to three different environments (one in the south west and two in the south east) in Southern Nigeria with respect to seed yield and its components.

Materials and Methods

Seeds of 14 genotypes of AYB were obtained from the Gene bank of the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria (see Table 6 below). These genotypes were grown at experimental sites in three locations - Ibadan (Southwest Nigeria characteristics (pH = 6.13, organic matter = 2.88, k = 0.73, p = 8.89, % N = 0.68)), Enugu and Abakaliki (pH = 6.54, organic matter = 1.16, k = 0.32, p = 4.88, % N = 0.09 (Southeast Nigeria) in 2012. The genotypes were evaluated on the field in a completely randomized design with three replicates. Seeds were sown in nurseries bags and later transferred to field. The gross plot size was 15 m × 12 m. Treatment plots consisted of ridges with 1 m between rows and 1.5 m within rows. The plants were staked two weeks after transplanting. Weeds were controlled by manual weeding at four weeks intervals. Monocrotophous (Attacke) was applied monthly at the rate of 170ml of insecticide per 20 litres of water beginning from 8 weeks after sowing until harvest to control various categories of insect pests. Experimental sites were weeded manually using hoes or by hands. The average rainfall during the experiment in Ibadan, Abakaliki and Enugu are as shown in Table 2. Seeds were collected on plants in the centre rows per genotype for use in analysis.

Data Collection

Yield data were collected on days to 50% flowering, number of peduncles per plant, number of peduncles with pods, number of peduncles without pods, pod length per plant, pod width per plant, number of pod per peduncle, number of seeds per pod, 100 seeds weight, pods per plant and seeds per plant. During the cropping season, the maximum temperature, minimum temperature, relative humidity and rainfall were recorded on a monthly basis from the nearest meteorological station at each location. Soil samples were collected from each location and labelled properly for analysis on soil characteristics.

Data Analysis

Data on yield trait were subjected to SAS Windows 9.0 analysis in which analysis of variance, least significance difference and means were derived. Correlation analysis was done of data of parameters of each location were also done. GGEbiplot Software was used to get visual statistical analysis called what-won-where biplot [Yan and Kang, 2003]. This gives graphical illustration of the performance of the genotypes on the locations.

Results and Discussion

Table 1 gives the soil characteristics of the three locations. Abakaliki soil is salty and clayey, Enugu and Ibadan soil is acidic but Ibadan soil is more acidic. The presence and concentration of salt in Abakaliki location would have had adverse effect on soil function and management by affecting the structure, porosity and plant/water relations that can ultimately lead to decreased productivity. This can phenotypically cause chlorosis, plant wilting and reduced seed germination (Rsamson, 2013). Seedlings avoid toxicity by deep rooting (Agrawal, 2007). The fine textured soil of Abakaliki and perhaps Enugu prevented the deep rooting of the plant, hence exposing it to allelopathic effect of the plants of both similar and dissimilar species.

Table 1: Edaphic characteristics of the three environments

Parameters	Abakaliki	Enugu	Ibadan
pH	6.54	6.29	6.13
% sand	92.6	93.8	91.6
% clay	3.8	3.4	2.5
% silt	3.6	2.8	5.9
% organic carbon	0.67	0.86	1.67
% organic matter	1.16	1.48	2.88
K (Cmol/kg)	0.32	0.37	0.73
Ca(Cmol/kg)	2.37	2.76	2.84
Mg(Cmol/kg)	0.66	0.83	0.95
Cu(ppm)	0.25	0.28	0.43
Mn(ppm)	8.21	8.54	11.85
Zn(ppm)	1.65	1.71	1.84
Fe(ppm)	1.26	1.18	1.35
P(ppm)	4.88	5.21	8.89
% N	0.09	0.11	0.68
Exch. Acidity(Cmol/kg)	0.06	0.09	0.11
Na(Cmol/kg)	0.27	0.32	0.44

The fine texture of Abakaliki and Enugu soils make them poorly aerated and has mainly micropores which hold water tightly and dont release it under gravity, hence being prone to anaerobic condition. Ibadan site is well-aggregated soil which is capable of supplying plant with enough water holding capacity, water conducting ability and good chemical soil property because it has enough macropores to provide drainage and aeration, this is in accordance with the Heta (2000) and Jacobsen *et al*., (2005). Enugu soil had highest percentage of sand while Ibadan had the least. High soil organic carbon (SOG) and soil organic matter (SOM) was observed in Ibadan soil, followed by Enugu soil with much variation and must have contributed to the superior soil quality and growth performance in Ibadan. SOM aggregates have been shown to increase walter holding capacity, infiltration, porosity and also reduce compactibility (Carter (2002). .According to Brevik (2013) SOM affects soil chemical properties by releasing other essential plants nutrient during its decay. This explains why for K, Ca, Mg, Cu, Mn, Zn, Fe, P, Exchangeable Acidity and Na, Ibadan soil recorded higher values than other locations. Therefore SOM acted as a natural fertilizer in Ibadan. Table 2 shows monthly temperatures, rainfall and % relative humidity in the three locations. Ebonyi and Enugu site had high temperature for most of the year. This high temperature could cause the ovaries to shrivel, hence producing few number of seeds per pod. Steele *et al*., (1985) reported a reduction in seed yield due to hot temperature conduction. Marfo and Hall (1992) suggested that the combination of high temperatures and long days can slow down or inhibit floral bud development, thus resulting in production of few flower. These locations had averagely lower minimum temperature than Ibadan (Table 2). It is known that the most demanding climatic conditions are those where the plant needs to tolerate extreme temperatures Valconen (2013).

Table 2: Monthly temperatures, rainfall and % relative humidity in the three locations.

Months	Locations	max temp	min temp	rain fall	% R. Humidity
May-12	Enugu/Abakaliki	31.9	21.7	181.5	79
	Ibadan	31.4	23.1	215.9	81
Jun-12	Enugu/Abakaliki	30.6	21.5	282.5	87
	Ibadan	30	22.5	215	83
Jul-12	Enugu/Abakaliki	29.6	21.4	288.2	87
	Ibadan	28.3	22.1	218.2	87
Aug-12	Enugu/Abakaliki	28.9	21.5	312.5	83
	Ibadan	27.4	21.4	93.3	88
Sep-12	Enugu/Abakaliki	29.9	21.7	393.2	86
	Ibadan	29.2	22	218.2	86
Oct-12	Enugu/Abakaliki	30.9	21.5	210.6	83
	Ibadan	30.7	22.3	141.2	83
Nov-12	Enugu/Abakaliki	32.6	22.1	73.9	79
	Ibadan	32.6	23.4	54.9	82
Dec-12	Enugu/Abakaliki	33.7	19.4	0	59
	Ibadan	34.2	23.1	0	71
Jan-13	Enugu/Abakaliki	34.4	21.2	23.4	56
	Ibadan	34.8	23	3.3	101
Feb-13	Enugu/Abakaliki	35	23.1	0	62
	Ibadan	35.1	22.8	64.4	73
Mar-13	Enugu/Abakaliki	35.5	23.2	31.7	69
	Ibadan	34.1	23.7	139	80
Sum	Enugu/Abakaliki	353	238.3	1797.5	830
	Ibadan	347.8	249.4	1363.4	915
Mean	Enugu/Abakaliki	32.1	21.7	163.4	75.5
	Ibadan	31.6	22.7	123.9	83.2

More rainfall was observed in Enugu and Abakaliki location, the combination of high temperature and abundant rainfall fosters high rate of chemical weathering and production of leached clay soil of low inherent fertility (Barrios *et al*., 2004). Normal range of rainfall was recorded at the germination and growing season of the plant. The rain increased during the development and maturity season of the plant. In Ibadan, there was noticeable increase of relative humidity at the development and maturity stage of the plant. Table 3 shows means and ranges of AYB yield and yield component in the three locations. The averagely high data recorded in Ibadan site over Abakaliki and Enugu (except in pod per peduncle) showed that the genotypes generally have high adaptation to Ibadan than other locations. The similarity observed in performance of Enugu and Abakaliki locations show that those AYB genotypes have similar adaptability towards the locations (Table 3 & 7), and could be due to similarity in their environmental and edaphic factors. Table 4 gives components of variation for yield and yield components across the three locations. Genotype contributed more to 100 seeds weight and seed width than environment, but had equal influence as environment on days to 50% flowering..

Table 5 gives the analysis of variance of seed yield and yield components in the three locations. To significant difference shown in replicates across the locations over the parameters could be attributed to no observable change in the micro-environment of the plants. Environment recorded high significant difference across the parameters and this indicates high phenotypic plasticity or environmental sensitivity (Falconer & mackay, 1996), hence suggesting that synergistic selection was employed in selecting the genotypes for experiment (Walsh, 2012; Falconer, 1990). Genotype by environment interaction (G×E) was significant in most parameters except pod per peduncle and seeds per plant. This agrees with Berker and Leon (1988), which stated that the existence of G×E interaction and their effects on selection process are widely recognized. Under genotype, significant difference were observed in most parameters except in seed per pod, pod per peduncle, peduncle with pod, pod per plant and seeds per plant, this could be attributed to their allelic differences.

Table 6 shows means and least significance difference of the genotypes across the three locations. Under seed per pod, TSs 52, TSs 86 and TSs 131 are not significantly different. TSs 10, TSs 57, TSs 96, TSs 101, TSs 163 and TSs 368 are not significantly different from each other, while TSs 45 is significantly different from other genotypes, same with TSs 58, TSs 61, TSs 306 and TSs 373. Although the performance of some genotypes did not show any significant difference, it does not mean that their genes are the same. This is because a single genotype may produce different phenotypes depending on environment in which organism develop, the same phenotype may be produced by different genotypes depending on the environment (Griffiths *et al*., 2005). This is also described by Via *et al*., (1995), stating that gene regulation may change depending on the environment or joint action of genotype and environment. So it is pertinent to recall that no two organisms of the same species have the same genotype except for asexually reproduced organisms. The genotypes that had different performance as witnessed in TSs 101 and TSs 131 under peduncle per plant could be as a result of the difference in allelic constitution of the organism, which is the hereditary underpinning of the phenotype (Griffiths *et al*., 2005).

Table 7 shows Least Squares Means of genotypes for seed yield and yield component in three locations. In Ibadan location, almost all the genotypes scored very high but TSs 306 had highest number of seeds per pod while TSs 61 had least. Under 100 seeds weight, TSs 96 recorded highest value whereas TSs 368 recorded least. In Abakaliki location, poor performance was recorded , TSs 61 had the highest number of seeds per pod while TSs 96 had the least. TSs 52 recorded highest value under 100 seeds weight while TSs 96 had least value. Very poor performance was recorded in Enugu location, TSs 306 scored highest while TSs 58 performed very poor on number of seeds per pod. While TSs 52 recorded highest value on 100 seeds weight, TSs 10 had the least value. TSs 52 had highest pod length in all the three locations. Ibadan site had more days to 50% flowering while Enugu and Abakaliki had similar days range, this could be due to temperature differences among the three locations. Enugu and Ebonyi had similar metrological value and this could be the reason for the similar days range. Temperature is undoubtedly the dominant factor that affect flowering and maturity (Wallace *et al*., 1995). This has also been reported in navy bean (Husain *et al*., 1988) and in field bean (Wallace *et al*., 1988). The authors observed that the rate of development of beans was largely controled by temperature accounting for 80% of the variation. Their results were also supported by Wien and Summerfield (1984), they proposed that warmer temterature hastens the appearance of flowers in day-length sensitive genotype.

Table 3: Means and ranges of African Yam Bean yield and yield components in the three locations

Locations	Statistics	Seeds per pod	100 seeds Weight(g)	Pod width (cm)	Pod length (cm)	Peduncle per plant	Pod per peduncle	Days to 50% flowering	Peduncle with pod	Peduncle without pod	Pods per plant	Seeds per plant
Abakaliki	X	10	20.17	0.89	20.76	14	2	100	4	10	6	66
	SD	1.66	1.75	0.08	1.15	3.08	0.28	0.66	1.13	2.93	4.74	60.03
Enugu	X	10	20.67	0.90	22.58	11	1	95	5	6	6	60
	SD	2.36	1.65	0.04	1.15	2.74	0.19	1.03	1.64	1.40	5.23	54.25
Ibadan	X	14	24.05	0.96	25.08	25	2	107	10	15	24	337
	SD	1.43	1.78	0.03	1.07	6.32	0.33	2.14	4.47	3.48	24.88	372.50

Table 4: Components of variation for African Yam Bean yield and yield components across the three locations

Parameters	Vg	Vm	Vi	Vt	Hb (bs)
Seed per pod	217.15	413.83	483.06	1114.04	0.34
100 seeds Weight(g)	581.11	374.03	660.35	1615.49	0.61
Pod width(cm)	0.14	0.11	0.20	0.45	0.56
Pod length(cm)	267.71	395.58	175.73	839.09	0.40
Peduncle per plant	1462.83	5132.71	3598.84	10194.38	0.22
Pod per peduncle	4.76	23.06	6.71	34.53	0.17
Days to 50% flowering	3298.93	3262.97	6804.14	13366.04	0.50
Peduncle with pod	498.36	881.63	1030.14	2410.13	0.36
Peduncle without pod	1160.98	1948.78	3156.11	6265.87	0.37
Pods per plant	4265.56	8763.87	8225.02	21254.45	0.33
Seeds per plant	842156.99	2104184.33	1784587.89	4730932.21	0.29

Vg, genetic variance ; Vm, environmental variance ; Vi, interaction variance ; Vt, total variance ; Hb (bs), broad sense heritability

The high significant positive correlation shown between peduncle per plant and both peduncle with and without pod (Table 8, 9 & 10) showed that increase in peduncle per plant led to significant increase in both peduncle with and without pod. Pod per peduncle increased significantly as peduncle with pod increased (Table 8). Seed per pod strongly and significantly increased as pod length and seeds per plant increased and a high significant positive correlation existed between 100 seeds weight and pod per peduncle (Table 9). Table 10 showed that increase in 100 seeds weight strongly increased pod width which also significantly increased with increase in days to 50% flowering.

A polygon was formed by connecting the vertex genotypes which include TSs 61, TSs 306, TSs 96, TSs 101 and TSs 58 (Figure 1) and the rest of the genotypes were placed within the polygon. The partitioning of G×E interaction through GGE biplot analysis showed that PC1 and PC2 accounted for 51.7% and 42.2% of GGE sum of squares respectively, explaining a total of 93.9% variation. The genotypes fell into three mega-environments;

Ibadan, Abakaliki and Enugu. Greater percentage of genotypes performed better in Ibadan site with no much variation in their performance, if number of seeds per pod is used to determine yield. According to Thompson and Taylor (1981), seed number had proved to be the most consistent component of yield. Experimental results by Duarte and Adams (1972), Krarup and Davis (1970) indicated that number of seeds per pod is usually considered to be related to yield in a positive manner. very few genotypes did well in Abakaliki and Enugu location. TSs 373 had the same performance in Abakaliki and Enugu location. Also in Enugu and Ibadan location, TSs 86 had the same performance.

Table 5: Analysis of variance of seed yield and yield components of African Yam Bean in the three locations.

Source of Variation	Seed per pod	100 seeds Weight(g)	Pod width(cm)	Pod length(cm)	Peduncle per plant	Pod per peduncle	Days to 50% flowering	Peduncle with pod	Peduncle without pod	Pods per plant	Seeds per plant
Genotype(G)	16.70	44.70***	0.01***	20.59***	112.53*	0.37	253.76***	38.34	89.31***	328.12	64781.31
Environment(E)	206.91***	187.01***	0.06***	197.79***	2566.36***	11.53***	1631.48***	440.82***	974.39***	4381.94***	1052092.17***
Replicates	11.35	11.06	0.01	2.88	19.17	0.44	0.46	4.90	12.72	34.98	4112.83
G*E	18.58*	25.10***	0.01***	6.76*	138.42**	0.26	261.70***	39.62*	121.39***	316.35*	68637.10
Error	10.37	8.95	0.00	3.80	57.00	0.22	6.06	23.91	22.65	188.80	42386.12

$*0.05 > p > 0.01$; $** p < 0.01$; $*p<0.001$

Table 6: Means and least significance difference of AYB genotypes across the three locations.

S/N	genotype	Seed/pod	100 seeds weight(g)	pod width(cm)	pod length(cm)	Peduncle/plant	Pod/peduncle	Days to 50% flowering	Peduncle with pod	Peduncle without pod	Pods per plant	Seeds per plant
1	TSs 10	10 ^{bcd}	20.94 ^{bc}	0.85 ^{b}	21.43 ^{def}	19 ^{ab}	2 ^{abc}	97 ^{e}	8 ^{abc}	11^{bc}	17^{abc}	198^{abc}
2	TSs 101	10 ^{bcd}	21.92 ^{b}	0.94 ^{b}	22.84 ^{bcd}	25 ^{a}	2 ^{ab}	103^{c}	7^{abc}	19^{a}	14^{bc}	152^{bc}
3	TSs 131	12 ^{abcd}	21.79 ^{bc}	0.94 ^{b}	22.09 ^{cdef}	15 ^{bc}	2 ^{abcd}	104^{bc}	5^{bc}	10^{bcd}	9^{c}	110^{c}
4	TSs 163	11 ^{bcd}	21.94 ^{b}	0.90 ^{b}	20.77 ^{f}	19 ^{ab}	2 ^{ab}	93^{f}	11^{a}	8^{cd}	27^{a}	362^{a}
5	TSs 306	14 ^{a}	19.05 ^{cd}	0.92 ^{b}	22.68 ^{bcde}	13 ^{bc}	1 ^{cd}	91^{f}	6^{bc}	7^{cd}	11^{bc}	154^{bc}
6	TSs 368	11 ^{bcd}	18.12 ^{d}	0.85 ^{b}	24.33 ^{ab}	12 ^{c}	1 ^{abcd}	96^{e}	5^{bc}	7^{d}	10^{bc}	108^{c}
7	TSs 373	13 ^{abc}	20.22 ^{bcd}	0.90 ^{a}	24.11 ^{ab}	20 ^{ab}	1 ^{d}	106^{ab}	4^{c}	16^{b}	6^{c}	70^{c}
8	TSs 45	10 ^{cd}	21.20 ^{bc}	0.97 ^{b}	21.07 ^{def}	15 ^{bc}	2 ^{abcd}	106^{ab}	5^{bc}	10^{bcd}	11^{bc}	155^{bc}
9	TSs 52	12 ^{abcd}	27.78 ^{a}	0.92 ^{b}	25.76 ^{a}	14 ^{bc}	2 ^{ab}	100^{d}	5^{bc}	9^{bcd}	8^{c}	99^{c}
10	TSs 57	11 ^{bcd}	20.22 ^{bcd}	0.91 ^{b}	22.06 ^{cdef}	18 ^{bc}	2 ^{a}	104^{bc}	9^{ab}	9^{cd}	22^{ab}	306^{ab}
11	TSs 58	9 ^{d}	22.14 ^{b}	0.93 ^{b}	23.80 ^{bc}	14 ^{bc}	2 ^{bcd}	107^{a}	3^{c}	11^{bcd}	6^{c}	57^{c}
12	TSs 61	13 ^{ab}	22.40 ^{b}	0.90 ^{b}	24.15 ^{ab}	13 ^{bc}	2 ^{ab}	98^{e}	5b^{c}	8^{cd}	10^{bc}	128^{bc}
13	TSs 86	12 ^{abcd}	22.12 ^{b}	0.93 ^{b}	20.87 ^{ef}	19 ^{ab}	2 ^{abcd}	107^{a}	6^{bc}	13^{b}	9^{c}	125^{bc}
14	TSs 96	11 ^{bcd}	22.98 ^{b}	0.92 ^{b}	23.36 ^{bc}	18 ^{bc}	1 ^{cd}	98^{e}	7^{bc}	11^{b}	10^{bc}	140^{bc}
15	L.S.D	3	2.81	0.09	1.83	7.09	0.44	2.31	4.59	4.47	12.90	193.22

Note: **Genotypes with the same letter in the same column are not significantly different at p=0.05**

Table 7: Least Squares Means of African Yam Bean genotypes for seed yield and yield component in three locations

Genotype	Locations	Seed per pod	100 seeds weight(g)	Pod width (cm)	Pod length (cm)	Peduncle per plant	Pod per peduncle	Days to 50% flowering	Peduncle with pod	Peduncle without pod	Pods per plant	Seeds per plant
TSs 10	Ibadan	14	25.01	0.82	23.45	26	2	106	11	15	30	437
	Enugu	10	16.65	0.82	22.86	11	1	91	5	6	6	57
	Abakaliki	7	21.14	0.89	17.99	21	2	93	9	12	14	100
TSs 101	Ibadan	14	25.03	0.97	24.49	46	2	107	10	36	22	316
	Enugu	7	19.65	0.99	23.39	15	2	111	8	7	15	107
	Abakaliki	8	21.09	0.88	20.63	13	2	91	3	10	4	33
TSs 131	Ibadan	14	19.83	1.01	23.46	17	2	106	8	9	15	197
	Enugu	8	23.03	0.88	21.12	7	1	110	4	3	4	31
	Abakaliki	13	22.52	0.93	21.68	20	2	96	4	16	8	101
TSs 163	Ibadan	14	24.17	0.99	23.43	35	3	105	25	10	68	967
	Enugu	9	18.88	0.84	19.16	12	1	65	6	6	6	52
	Abakaliki		22.77	0.87	19.71	10	2	110	3	7	7	67
TSs 306	Ibadan	16	20.68	0.99	25.38	17	2	107	8	9	16	264
	Enugu	14	17.81	0.86	24.13	14	1	71	6	8	9	127
	Abakaliki	11	18.66	0.91	18.52	10	1	96	5	5	7	71
TSs 368	Ibadan	12	18.88	0.91	28.86	17	2	106	10	7	22	262
	Enugu	9	16.66	0.82	21.90	9	1	88	3	6	3	29
	Abakaliki	10	18.82	0.82	22.22	9	2	95	2	7	3	33
TSs 373	Ibadan	13	24.81	1.01	24.52	42	1	107	11	31	6	74
	Enugu	12	19.06	0.83	24.95	7	1	101	3	4	3	30
	Abakaliki	12	16.80	0.87	22.85	9	2	110	5	4	9	105
TSs 45	Ibadan	12	20.98	0.96	21.31	24	2	109	10	14	27	398
	Enugu	7	22.01	0.94	21.35	7	1	97	3	4	3	20
	Abakaliki	10	20.62	1.02	20.54	16	2	111	4	12	4	47
TSs 52	Ibadan	15	29.11	0.92	27.97	16	2	102	5	11	13	191
	Enugu	10	26.33	0.98	25.64	12	1	92	7	5	7	74
	Abakaliki	9	27.90	0.87	23.68	13	2	107	2	11	3	31
TSs 57	Ibadan	14	22.88	0.95	26.91	28	3	109	19	9	54	788
	Enugu	11	20.62	0.92	20.01	12	2	111	6	6	9	104
	Abakaliki	7	17.15	0.85	19.25	13	2	94	2	11	4	25
TSs 58	Ibadan	12	28.75	0.97	26.92	26	2	111	6	20	12	123
	Enugu	3	19.02	0.95	23.13	6	1	102	2	4	2	7
	Abakaliki	12	18.65	0.88	21.34	11	1	108	3	8	4	42
TSs 61	Ibadan	11	22.03	0.96	24.91	12	3	111	5	7	14	154
	Enugu	11	24.01	0.84	24.78	9	1	89	4	5	4	31
	Abakaliki	16	21.17	0.89	22.76	17	2	92	6	11	12	198
TSs 86	Ibadan	15	23.05	0.93	23.42	31	2	108	8	23	15	223
	Enugu	10	23.46	0.99	20.21	13	1	105	7	6	8	98
	Abakaliki	10	19.84	0.61	18.98	14	2	109	4	10	5	53
TSs 96	Ibadan	14	31.50	0.99	26.13	20	2	106	11	9	21	326
	Enugu	11	22.17	0.93	23.45	13	1	91	6	7	6	68
	Abakaliki	6	15.29	0.85	20.51	19	1	95	3	16	4	25

Table 8: Correlation coefficient among yield components in Ibadan.

Parameters	Seed per pod	100 seeds weight	Pod width	Pod length	Peduncle per plant	Pod per peduncle	Days to 50% flowering	Peduncle with pod	Peduncle without pod	Pods per plant
100 seeds weight	0.19									
Pod width	0.02	-0.00								
Pod length	0.27	0.29	-0.12							
Peduncle per plant	0.06	0.17	0.16	-0.14						
Pod per peduncle	-0.02	0.01	-0.28	0.18	0.09					
Days To 50% flowering	-0.29	-0.13	0.06	-0.24	0.06	0.01				
Peduncle with pod	0.20	-0.03	-0.06	-0.03	0.51***	0.45**	-0.07			
Peduncle without pod	-0.07	0.20	0.20	-0.16	0.78***	-0.159	0.12	-0.11		
Pods per plant	0.17	0.01	-0.13	-0.01	0.48**	0.58***	-0.04	0.98***	-0.13	
Seeds per plant	0.27	0.04	-0.13	-0.01	0.47**	0.56***	-0.06	0.97***	-0.14	0.99***

*0.05 > p > 0.01; ** p < 0.01; *p<0.001

Table 9: Correlation coefficient among yield components in Abakaliki.

parameters	Seed per pod	100 seeds weight	Pod width	Pod length	Peduncle per plant	Pod per peduncle	Days to 50% flowering	Peduncle with pod	Peduncle without pod	Pods per plant
100 seeds weigth	0.13									
Pod width	0.03	-0.08								
Pod length	0.39**	0.20	0.22							
Peduncle per plant	-0.05	0.10	-0.08	-0.01						
Pod per peduncle	0.06	0.52***	0.09	0.14	-0.01					
Days to 50% flowering	0.13	0.12	0.17	0.14	-0.24	0.06				
Peduncle with pod	0.10	-0.07	0.21	-0.30	0.35*	-0.06	-0.22			
Peduncle without pod	-0.12	0.09	-0.18	0.10	0.91***	-0.01	-0.18	-0.05		
Pods per plant	0.10	0.07	0.02	-0.23	0.34*	0.32*	-0.22	0.90***	-0.03	
Seeds per plant	0.51***	0.08	0.07	0.05	0.24	0.27	-0.13	0.76***	-0.08	0.84***

*0.05 > p > 0.01; ** p < 0.01; *p<0.001

Table 10: Correlation coefficient among yield components in Enugu.

Parameters	Seed per pod	100 seeds weight	Pod width	Pod length	Peduncle per plant	Pod Per peduncle	Days to 50% flowering	Peduncle with pod	Peduncle without pod	Pods per plant
100 seeds weigth	0.12									
Pod width	-0.29	0.45**								
Pod length	0.30	0.13	-0.04							
Peduncle per plant	0.13	0.08	0.18	0.16						
Pod per peduncle	0.16	-0.16	0.14	0.02	0.32*					
Days to 50% flowering	-0.28	0.21	0.42**	-0.04	-0.13	0.22				
Peduncle with pod	0.06	0.18	0.21	0.16	0.93***	0.30	-0.03			
Peduncle withoutpod	0.19	-0.06	0.10	0.12	0.89***	0.29	-0.23	0.66***		
Pods per plant	0.08	0.03	0.19	0.15	0.83***	0.66***	0.10	0.87***	0.62***	
Seeds per plant	0.40**	0.04	0.05	0.16	0.77***	0.69***	-0.05	0.77***	0.62***	0.87***

*0.05 > p > 0.01; ** p < 0.01; *p<0.001

TSs 61 won in Abakaliki location, TSs 306 won in Enugu location while in Ibadan location, TSs 96 won. Ibadan location showed a closer relationship with Enugu location than to Abakaliki location. TSs 58 and TSs 101 did not win in any of the environments. The high performance observed in Ibadan site could be as a result of good environmental factors associated with the environment. Judging from Figure 2 in which seed weigth is used as yield determinant, a polygon was formed by connecting the vertex genotypes which include TSs 96, TSs 52, TSs 131, TSs 368 and TSs 373.

The partitioning of G×E interaction through GGE biplot analysis showed that PC1 and PC2 accounted for 47.7% and 38.1% of GGE sum of squares respectively, explaining a total of 85.8% variation. It is shown that Enugu location and Abakaliki location are similar in performance; this is supported by the winning of TSs 52 in both locations. TSs 96 won in Ibadan environment while TSs 131, TSs 368 and TSs 373 did not win in any environment.

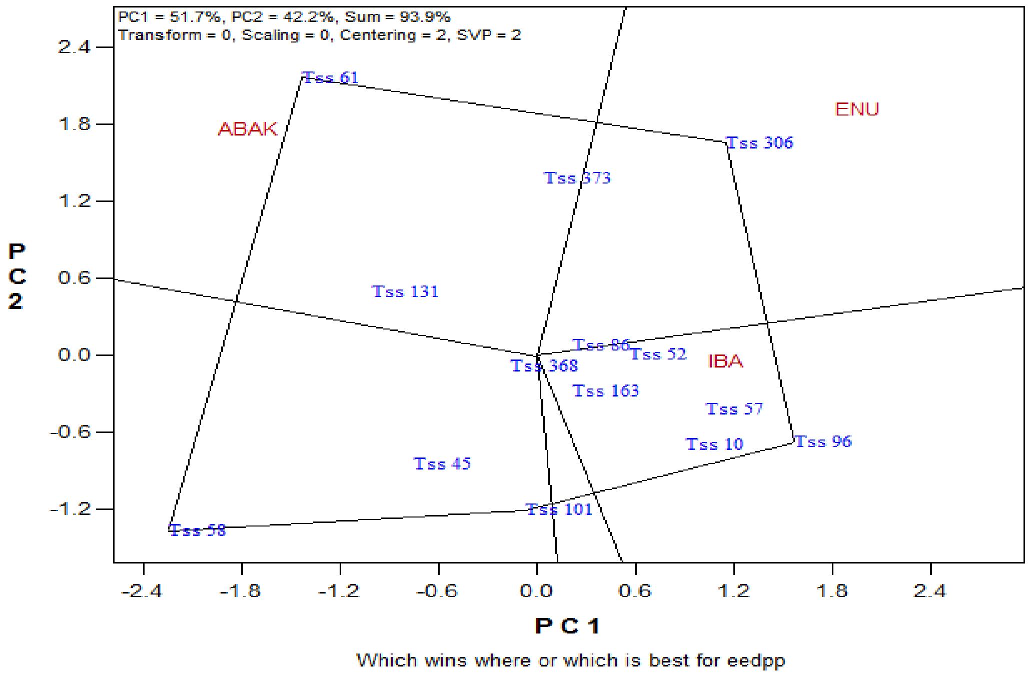

Figure 1. showing which wins where or which is best for number of seed per pod
ABAK = Abakaliki site ; ENU = Enugu site ; IBA = Ibadan site

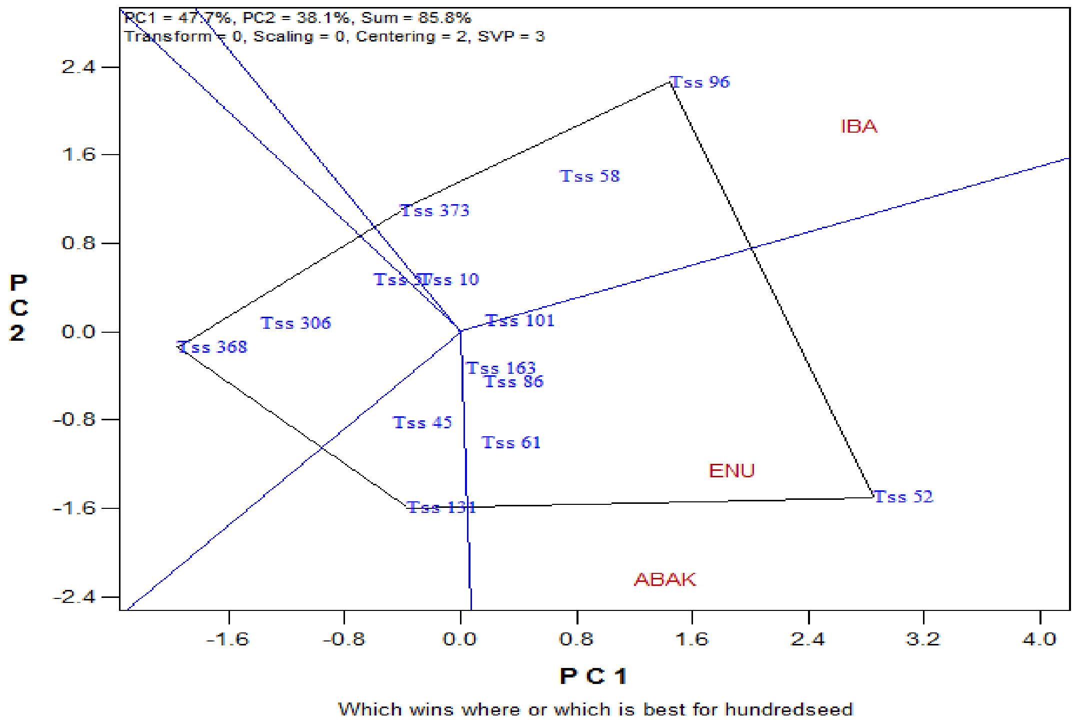

Figure 2. Showing which wins where or which is best for hundred seeds weight
ABAK = Abakaliki site ; ENU = Enugu site ; IBA = Ibadan site

Conclusion

G×E interaction was observed with the example seen in Tss 58 which is consistent in performance but for Enugu site under seed per pod. The genotypes generally performed higher with less variation in Ibadan site than other locations. Although similarity in performance is recorded under pod per peduncle across the three locations, the difference is significant in 100 seeds weight, pod length, peduncle per plant, days to 50% flowering and peduncle without pod. This high variation was aided by the variation in soil properties, metrological data and other biotic components which include organisms of the same or different species. The high yield recorded in

Ibadan environment is as a result of the good property possessed by both the soil and climate, while the similarity in poor performance observed in Abakaliki and Enugu site is ascribed to their similar environment which is less supportive to good agricultural farming. This study shows that Ibadan site edaphic nature is more fertile and productive because it enables deep rooting, provides good aeration, has good Water Holding Capacity, consist of adequate and balance supply of plants nutrient. Abakaliki site holds water more among the locations. This led to water-logging, thereby seizing the easy flow of nutrients and deep rooting of plants. It is also salty and possess least fertility among the three locations. Enugu soil is more fertile than Abakaliki soil but they are of close value in edaphic properties. The climatic condition for Ibadan site supports agriculture more than other sites. Genotypes showed different reaction to different environment. Hence, environment gave very high significant differences across all the parameters. Using seed per pod to judge for yield, and little view from 100 seeds weight, Abakaliki site best favours TSs 61, but other genotypes like TSs 306, TSs 373, TSs 58, TSs 52 and TSs 131 could also be produced from the site. Enugu site best favours TSs 306, TSs 52 and TSs 61, whereas genotypes like TSs 96, TSs 57 and TSs 373 could still be produced from the site. All the genotypes could be produced from Ibadan location with least preference is given to TSs 61. However, Ibadan environment best favours TSs 96, TSs 52 and TSs 306. On the average across the 3 locations, TSs 52 and TSs 306 can be produced in any of the locations, other genotypes like TSs 131, TSs 373, TSs 61 and TSs 86 could also be produced with less chances of maximizing output. Although AYB is described to be highly adaptable and can thrive in acidic and highly leached sandy soil in the humid lowlands of the tropic (Okigbo, 1973; Aletor & Aladetimi, 1989), This work has shown that AYB least adapted to salty and leached environment with high level of variation in response among the genotypes.

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