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Growth and yield response of selected improved soybean (*Glycine max* [L.] Merrill) varieties to varying weeding regimes under a tropical condition

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Abstract

The field trial was conducted at the Teaching and Research Farm, Abia State University, Umuahia Campus, Umudike to study the performance of three highly improved soybean varieties (‘TGX 1835-10E’, ‘TGX 1987-62F’ and ‘TGX 1448-2E’) to different weeding regimes (weed free, inweeded, weeded once, weeded twice and weeded three times) and to estimate character association and contribution toward seed yield per hectare. The experiment was a factorial combination of variety and weeding regimes in randomized complete block design with three replications. Vegetative data which included plant height, number of branches and number of leaves were taken at 10 weeks after planting (WAP) while at harvest, the following yield data: pod length, pod width, number of pods per plant, number of seeds per plant, pod weight per plant, 100 seed weight and seed yield per hectare were taken. The only phenological trait taken was number of days to 50% flowering. The competing weeds were also identified, sampled, counted, dried, weighed and recorded at 9 WAP and at harvest. Data were analyzed using the procedure outlined for ANOVA and means separated by LSD ($P=0.05$). Correlation and Path coefficients analyses were also carried out. The results showed a highly significant difference ($P<0.01$) among the varieties in all the traits studied. ‘TGX 1835-10E’ variety gave the highest seed yield/ha while weed regimes like weed free, weeded twice and three times showed non-significantly the best performance in all aspect. The results also showed that plots left inweeded and weeded once inevitably had the highest yield reduction in all the varieties. Plant height, number of branches, number of leaves at 10 WAP, number of seeds and pod weight per plant, 100 seed weight as well as soybean dry weight at 9 WAP showed high positive magnitude and significant ($P<0.01$) correlations with seed yield per hectare. The highest positive direct effect on yield was recorded in plant height at 10 WAP.

Keywords: correlation, path coefficient, seed yield, soybean, weeding regime

Introduction

Soybean is an annual leguminous crop which belongs to the family *Fabaceae*, subfamily *Faboideae*, genus *Glycine* and subgenus *Soja* (Asiegbu and Okpara, 2002; Singh et al., 2003). Although it did not originate in Nigeria, it has however, become popular in the country perhaps because of its numerous potentials that rank it even better than cowpea. It supplies high quality protein (over 40%) for man and livestock consumption as well as oil (about 20%) on a dry matter basis which is 85% unsaturated and cholesterol-free (Dugje et al., 2009). These traits have earned it the title “The miracle Bean” (IITA, 1990; Anyim, 2002). Onochie (1965) and Iwe (2003) found protein content of this crop to have better balance of amino acids when compared to any other crop protein source.

Due to its rapidly rising popularity in Nigeria, annual production rose from about 73,000 to 146,000 metric tons (Wudiri, 1990; Odeleye et al., 2007) from 1979-1989, and has since then risen to about 510,000 metric tons in 2012 (USDA Foreign Agricultural Service, 2016). However, the projected 1.6 million metric tons needed per annum to meet both industrial and domestic demands (Mamman, 1990) are yet unrealizable. This could therefore be a result of a great competition by weeds coupled with other latent and pronounced factors. The performance of any crop, no doubt is linked to its gene make up and environmental variation (Gatti et al., 2005). Consequently, in order to obtain the required increase in soybean production, both biotic and abiotic agents must be considered strongly. Soil moisture, temperature, planting depth and other non-living factors should be optimum. Similarly, pathogens, diseases, and pests which may include weeds should be adequately controlled for soybean optimum yield (IITA, 1990; Akande et al., 2007).

Correlation among soybean and weed traits with yield is necessary in indirect selection of treatment combinations for the best possible yield in soybeans (Machikowa and Laosuwan, 2011). Significant and positive correlation between two traits shows that simultaneous improvement in those traits is possible and selection for one will imply selection and improvement of the other (Fayeun et al., 2012). However, choice of selection based only on correlation may give a deceptive output as it exclusively measured the degree of mutual association between two traits without respect to cause and effect analysis. This is because there is the risk of excluding some vital traits whose contributions through other traits might not be easily valued (Ene et al., 2016).

Weed problems are generally greater in the tropics than in the temperate zone owing to higher densities and more vigorous growth of varying weed species in the tropics (Odeleye et al., 2007). The average recorded yield losses of cowpeas and soybeans in Nigeria and India due to weed competition were about 50% (Moody and Whitney, 1974; Akobundu and Poku, 1987), whereas in the United States the average yield losses of soybeans were about 17% (Vega et al., 1970). Ayeni et al. (1992) reported a lengthy number of days to soybean flower appearance as a result of weed competition with the crop. Also, but negatively affected attributes in soybeans by uncontrolled weed are stem height and number of leaves per plant which however, are not significant 2 WAP (Hagood et al., 1980). Hand weeding has remained the most widely practiced cultural weed control technique in the tropics perhaps because of the prohibitive cost of herbicides, fear of toxic residues and lack of knowledge about their use. It is unethical to cultivate soybean without weeding operation carried out from the time of sowing to harvest, or engage in daily weeding. Some farmers weed twice before crop maturity, considering the cost of labour, others, three times, all to ensure optimum yield. However, the frequency and sequence of such weeding are usually at the farmer's discretion and may not be economical (Iremiren, 1988).

The objective of the study, therefore, was to evaluate the performance of three improved varieties of soybean cultivated under different weeding regimes to know which treatment and treatment combination that would suppress weed in this agro ecology as well as estimate soybean and weed traits association and contribution towards total seed yield/ha.

Materials and methods

The experiment was carried out in the Department of Crop Production and Protection Teaching and Research farm, Faculty of Agriculture, Abia State University, Umuahia Campus, Umudike. Umudike is located on latitude 5°29'N, and longitude 7°33'E with an elevation of 122 m above sea level, characterized by high annual rainfall distribution with over 2,000 mm most of which fall between April and October, soil texture in the plot is sandy loam with pH 5.5, a mean annual temperature 30^{o}C and relative humidity that ranges from 65% to 80% (Anyim, 2002). Three varieties of soybean seeds obtained from International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria were used in this study. The varieties included: 'TGX 1835-10E', 'TGX 1987-62F' and 'TGX 1448-2E' with their features (Table 1).

Table 1. IITA soybean varieties used in the experiment and their common features in Nigeria

Varieties	Ecology	Characteristics	Striga control
TGX 1835-10E	Guinea savanna	Early maturing, rust resistant, pustule resistant, high yield	Not known
TGX 1987-62F	Guinea savanna	Early maturing, pustule resistant, rust susceptible	Not known
TGX 1448-2E	Southern and Northern Guinea Savanna	Medium maturing, high yield, low shattering, high oil content, excellent grain colour	Good

IITA: International Institute of Tropical Agriculture – Ibadan, Nigeria.

Five varying weeding regimes, 'Weed free (WF)', 'Inweeded (IW)', 'Weeded once (W1x)', 'Weeded twice (W2x)' and 'Weeded three times (W3x)' were applied. Monthly rainfall distribution, relative humidity and temperature were recorded during the period of the experiment (Table 2).

Table 2. Mean monthly rainfall (mm), temperature (°C) and relative humidity (%) during the experiment

Month	Rainfall (mm)	Temperature (°C)		Relative Humidity (%)	
		Min	Max	10am	4pm
June	273.61	21.42	28.97	72.14	72
July	198.05	21.02	28.62	72.19	71.62
August	135.72	20.92	26.94	73.21	72.98
September	365.02	21.72	28.03	73.13	73
October	226.82	22.24	29.41	72.63	71.32
November	84.63	20.98	31.01	73.97	72.61
December	9.72	19.03	31.75	70.72	70.23

Source: Meteorological Station, National Root Crops Research Institute, Umudike, Abia State, Nigeria.

The experiment lasted between July and November. Land preparation was done by working the existing vegetation mechanically into the soil using a tractor implement plough followed by two times harrowing to achieve a good soil tilth. The experiment was a factorial combination of variety and weeding regimes in a randomized complete block design (RCBD) with three replications. The experimental area measured 26 m x 14 m containing three blocks of 8 m x 14 m. Each block contained 15 plots (2 m x 2 m) with 1 m alley. Poultry droppings at the rate of 8 metric tons per hectare were worked into the soil within each block. The fifteen treatment combinations were randomly allotted to the plots within each block using the table of random numbers. Seeds were planted at the spacing of 50 cm inter and 10 cm intra rows. Two soybean seeds were sown at the depth of 3 – 5 cm and were thinned down to a seedling 3 weeks after emergence (WAE). NPK fertilizer in the ratio of 15:15:15 was applied at 3 and 6 WAE at the rate of 250 kg/ha. Insecticide (Cypermethrin 110% EC sprayed at the rate of 125 ml in 15 litres of water) and fungicide (Maneb Mancozeb and zoxamide at the rate of 75 ml in 15 litres of water) were applied twice (2 and 4 WAE) to curtail insect attack and disease incidence on young plants. Wormforce® (carbofuran), an insecticide/nematicide was also applied at 3 WAE by scooping a bit soil near each soybean stand and placing about 4 – 6 pellets. The weeds encountered on the experimental plot included grasses such as *Imperata cylindrica* (Sword grass), *Cynodon dactylon* (Bahama grass), *Panicum maximum* (Guinea grass), *Chrysopogon aciculatus*, *Acroceras zizanoides, Brachiaria lata* (Schumach), *Eleusine indica* Gaerth (Goose grass), *Eragrostis tenella* Roem and Schutt (Love grass), *Digiteria horizontalis* wild (Digit grass). Broadleaf weeds included *Emilia practermissa* Milne – Redhead, *Centrosema pubescens*, *Calopogonium mucunoides* Desv, *Acalypha ciliate* Forest (Coper – leaf plant), *Euphorbia hirta* (Snake weed), *Talinum triangulare* (Water leaf), *Ageratum conyzoides* (Goat weed), *Euphorbia heterophylla* (Spurge weed), *Cleome ciliate*

Schum and Thonn, *Phyllanthus amarus* and sedges weed were *Cyperus haspan and Kyllinga spp.* The weeding regimes were as follows: Weed Free (WF), which were plots weeded on a daily basis throughout the field operation from soybean seed emergence to harvest. Inweeded (IW), were unattended to throughout the experiment duration in the field. Weeded once (W1x), were weeded only at 3 WAP. Weeded twice (W2x), were the plots weeded at both 3 WAP and 6 WAP and finally Weeded three times (W3x), were weeded at 3 WAP, 6 WAP and 9 WAP. However, prior to the weeding operations carried out at 6 and 9 WAP, weeds were collected and counted from each of the plots in order to determine the dry weight of the weeds. Weeds were taken from two quadrants which measured 50 cm x 50 cm along a diagonal transect in each plot. They were clipped at ground level and bulked for each plot to form a sample which was oven dried at 80 °C for 48 hours. The dried parts were weighed using mettler balance 1210. The weed dry weight (WDW) was calculated and recorded as well as the number of weeds. This was also repeated at harvest. At 9 WAP the soybean samples were separated into leaves, stem and roots and oven dried at 80 °C for 48 hours. The dried parts were weighed using mettler balance 1210 and the soybean dry weight (SDW) calculated also. After the application of the weeding treatments, five samples of soybean plants were selected from each plot at 10 WAP and data were taken on the following traits: plant height (cm), number of branches and number of leaves per plant. At harvest, data were also taken on pod length (cm), pod width (cm), number of pods per plant, number of seeds per plant, pod weight per plant (g), 100 seed weight (g) and seed yield per hectare (t/ha). The only phenological trait taken was number of days to 50% flowering.

Statistical analysis

Collected data, both soybean and weed, were subjected to ANOVA for RCBD using GenStat Release 10.3 Discovery Edition (PC/Windows; VSN International, Hemel Hempstead, Hertfordshire, UK). Pearson correlation coefficient analysis was done using the computer statistical software package, SPSS version 16. The sets of correlation coefficients were subjected to path coefficient analysis and the direct and indirect effects were estimated according to the method of Dewey and Lu (1959) to show the relationships between traits and contribution towards seed yield/ha.

Results and discussion

The result of the meteorological data (Table 2) showed that the highest rainfall (mm) was recorded in September while November had the least within the soybean growing period. However, the table showed an uneven distribution of rainfall within the period. Temperature (°C) and relative humidity (%) showed relatively uniform distribution during the growing seasons.

Effect of variety on vegetative, yield and weed traits under different weeding regimes

The performance of soybean varieties under varying weeding regimes with respect to some agronomic as well as weed traits is presented in Tables 3 and 4. The result showed a highly significant (P<0.01) variation among the varieties for all the traits studied except for plant height that was non-significant, and number of leaves together with soybean dry weight that were marginally significant (P<0.05). In this understanding, the number of branches, number of days to 50% flowering, pod length and width, number of pods, number of seeds, pod weight, 100 seed weight, soybean dry weight, number of weeds, weed dry weight and seed yield were significantly different at 1% level of significance. Likewise, the number of leaves and soybean dry weights were significant (P<0.05). The significant differences found among the three soybean varieties under varying weeding regimes for all the traits analyzed showed that the varieties responded differently to the weeding regimes. This differential performance of the varieties can be attributed to the inherent genotypic variation (Aduloju et al., 2009; Mudibu et al., 2011) among them as well as their specific responses to environmental factor like soil nutrients as witnessed in cowpea and soybean (Sanginga et al., 2000; Osodeke, 2001). However, plant height was highly non-significant. This implied that all the varieties responded equally in height under the various weeding regimes. This is in agreement with the work done by Odeleye et al. (2007) where the two soybean used did not vary in stem height under varying weeding regimes. 'TGX 1835-10E' showed better performance in all the traits including seed yield/ha except in number of days to 50% flowering and number of weeds at 6 WAP where 'TGX 1987-62F' took the lead. From an earlier soybean evaluation study in this agro ecology, Okpara and Ibiam (2000) identified and recommended 'TGX 1835-10E' to be more adaptable and high yielding and hoped it maintained its performance anywhere in the world with similar agro ecological attribute.

Table 3. Performance of soybean varieties with respect to some vegetative and yield traits

Varietal Effect	PH 10WAP[a]	NoB 10WAP[b]	NoL 10WAP[c]	D50% F[d]	PL H[e]	PW H[f]	NoP PP[g]	NoS PP[h]	PW PP[i]
V1[j]	41.8	5.88	35.32	40.21	10.25	4.62	65.54	106.4	7.43
V2[k]	41.63	4.39	34.71	35.03	5.5	2.55	63.63	73.99	4.89
V3[l]	41.91	5.23	34.67	43.12	7.33	3.26	62.78	98.56	6.25
Sig.	ns	**	*	**	**	**	**	**	**
F-LSD$_{0.05}$	-	0.12	0.46	1.54	0.19	0.21	1.02	1.11	0.19

PH10WAP[a] = Plant Height at 10 Week After Planting (cm), NoB10WAP[b] = Number of Branches at 10 Week After Planting, NoL10WAP[c] = Number of Leaves at 10 Week After Planting, D50%F[d] = Number of Days to 50% Flowering, PLH[e] = Pod Length at Harvest (cm), PWH[f] = Pod Width at Harvest (cm), NoPPP[g] = Number of Pods Per Plant, NoSPP[h]= Number of Seeds Per Plant, PWPP[i] = Pod Weight Per Plant (g), V1[j]= TGX 1835-10E, V2[k]= TGX 1987-62F, V3[l]= TGX 1448-2E

Table 4. Performance of soybean varieties with respect to some yield and weed traits

Varietal Effect	100 SW[m]	SDW 9WAP[n]	NW 6WAP[o]	NW 9WAP[p]	NW H[q]	WDW 6WAP[r]	WDW 9WAP[s]	WDW H[t]	SY/ Ha[u]
V1[j]	10.75	63.61	26.33	8.93	9.67	9.7	3.59	4.41	1.87
V2[k]	13.06	62.86	23.76	11.27	13.6	10.01	4.53	5.98	1.44
V3[l]	11.76	58.15	24.06	12.59	13.9	8.08	4.76	5.88	1.71
Sig.	**	*	**	**	**	**	**	**	**
F-LSD$_{0.05}$	0.11	4.97	0.48	0.5	0.61	0.55	0.03	0.03	0.15

100SW[m] = 100 Seed Weight (g), SDW9WAP[n] = Soybean Dry Weight at 9 Week After Planting (g), NW6WAP[o] = Number of Weeds at 6 Week After Planting, NW9WAP[p] = Number of Weeds at 9 Week After Planting, NWH[q] = Number of Weeds at Harvest, WDW6WAP[r] = Weed Dry Weight at 6 Week After Planting (g), WDW9WAP[s] = Weed Dry Weight at 9 Week After Planting (g), WDWH[t] = Weed Dry Weight at Harvest (g), SY/Ha[u] = Seed Yield Per Hectare (t/ha), V1[j]= TGX 1835-10E, V2[k] = TGX 1987-62F, V3[l] = TGX 1448-2E

Effect of weeding regimes on vegetative, yield and weed traits of soybean

The results of this study (Tables 5 and 6) showed highly significant difference (P<0.01) in all the agronomic traits of soybean plants as well as the weed traits subjected to different weeding regimes. Similarly, weed free plot, plot weeded twice and three times showed better performance and were statistically the same in most of the soybean traits as well as the weed traits studied. However, these varied significantly when compared to plots weeded once and inweeded plots. This suggests that with prudent management of weeds, cost of production would be reduced. Since, it is unethical and uneconomical to carry out weeding operation on a daily basis and, also, plots weeded twice and three times showed similarity in performance, hence, the adoption of two weeding regimes for soybean production at 3 and 6 WAP for cost efficiency would be more appropriate. This falls in line with the findings of Odeyele et al. (2007) which also suggested similar weeding regimes, though, at 2 and 6 WAP. The plots with better weed control also resulted into higher fruit yield. The plots weeded once and inweeded plots showed non-significant differences in all traits studied except number of weed and weed dry weight at 6 WAP. This suggests that a single weeding operation at 3 WAP as well as leaving the field unattended to from the time of sowing to harvest is useless, as they both produced similar poor results. This disagrees with the report of Iyagba et al. (2012) in Okra which revealed that weeding operation carried out only at 3 weeks after sowing (WAS) is better for the growth and yield of okra in South-Eastern Nigeria. This probably could be because of the variation in vegetative growth and duration between the two crops. The shortest soybean plants, least number of branches and leaves, number of pods, seeds and pod weight per plant, soybean dry weight and seed yield per hectare were produced from the inweeded soybean plots which showed similarity to the plots weeded only at 3 WAP. This is in line with the findings of Iyagba et al. (2013) where the shortest plants, smallest leaf size and number of flowers were produced from the inweeded okra plots. It is a known fact that weed competition with crops more than necessary has always led to yield reduction in crops. All the weed traits including: number of weeds and weed dry weight at 6, 9 WAP and at harvest showed zero values in the plots with weed free conditions. This suggests that, though seemingly impossible and unnecessary, engaging a crop farm on a daily weeding operation shall mean total absence of weed in such farm. The highest number of weeds and weed dry weight at 6 and 9 WAP were shown in the inweeded plots while the highest number of weeds and weed dry weight at harvest were shared between the plots weeded at 3 WAP and inweeded plots, respectively, which adversely affected yield. This is probably because it has been observed that higher weed competition brings about intense competition for light which lowers the photosynthetic strength as well as number of stomata of the crop and hence, the yield (Fabro and Rhodes, 1980; Iyagba et al., 2013). Weed free plots significantly ($P<0.05$) produced the highest seed yield/ha which was similar to the plots weeded twice and three times statistically. This is possibly because nutrients were readily obtainable by the crop during the vegetative periods with little or no weed competition at these weeding regimes. This further suggests that the weeding regimes perhaps could have concurred with the time when nutrients needed for metabolic processes are made readily available and utilizable to manufacture photosynthates (Dada and Fayinminnu, 2010; Iyagba et al., 2012). This therefore showed that adequate absorption and use of nutrients for soybean vegetative growth and yield is a function of the timing of weed competition, control and type of soybean variety.

Table 5. Effect of weeding regimes on some selected vegetative and yield traits

Weeding Regime Effect	PH 10WAP[a]	NoB 10WAP[b]	NoL 10WAP[c]	D50%F[d]	PL H[e]	PW H[f]	NoPPP[g]	NoS PP[h]	PWPP[i]
W1[v]	50.96	6.17	41.02	41.19	8.15	3.7	89.31	139.3	7.14
W2[w]	28.68	3.04	26.4	48.97	7.73	3.59	24.87	36.63	3.69
W3[x]	28.39	4	26.17	49.14	7.39	3.17	26.64	49.62	4.1
W4[y]	50.53	6.27	40.4	40.03	7.73	3.7	89.03	105.57	8.01
W5[z]	50.33	6.34	40.52	39.25	7.46	3.22	90.08	133.7	8
Sig.	**	**	**	**	**	**	**	**	**
$F\text{-}LSD_{0.05}$	2.39	1.15	1.6	4.03	1.25	1.28	2.31	15.43	2.24

PH10WAP[a] = Plant Height at 10 Week After Planting (cm), NoB10WAP[b] = Number of Branches at 10 Week After Planting, NoL10WAP[c] = Number of Leaves at 10 Week After Planting, D50%F[d] = Number of Days to 50% Flowering, PLH[e] = Pod Length at Harvest (cm), PWH[f] = Pod Width at Harvest (cm), NoPPP[g] = Number of Pods Per Plant, NoSPP[h]= Number of Seeds Per Plant, PWPP[i] = Pod Weight Per Plant (g), W1[v] = Weed Free, W2[w] = Inweeded, W3[x] = Weeded Once, W4[y] = Weeded Twice, W5[z] = Weeded Three times

Table 6. Effect of weeding regimes on some selected yield and weed traits

Weeding Regime Effect	100 SW[m]	SDW 9WAP[n]	NW 6WAP[o]	NW 9WAP[p]	NW H[q]	WDW 6WAP[r]	WDW 9WAP[s]	WDWH[t]	SY/Ha[u]
W1[v]	9.11	77.15	0	0	0	0	0	0	2.13
W2[w]	15.93	35.87	80.8	15.44	15.17	26.88	6.47	7.3	1.08
W3[x]	13.93	36.4	17.78	15.22	17.56	7.53	5.82	6.98	0.99
W4[y]	9.79	80.36	12.78	12.22	14.22	6.17	4.44	6.29	2.07
W5[z]	10.51	77.93	12.22	11.78	15	5.74	4.75	6.53	2.1
Sig.	**	**	**	**	**	**	**	**	**
F-LSD$_{0.05}$	2.14	6.42	2.62	1.65	3.79	7.71	2.03	2.04	0.19

100SW[m] = 100 Seed Weight (g), SDW9WAP[n] = Soybean Dry Weight at 9 Week After Planting (g), NW6WAP[o] = Number of Weeds at 6 Week After Planting, NW9WAP[p] = Number of Weeds at 9 Week After Planting, NWH[q] = Number of Weeds at Harvest, WDW6WAP[r] = Weed Dry Weight at 6 Week After Planting (g), WDW9WAP[s] = Weed Dry Weight at 9 Week After Planting (g), WDWH[t] = Weed Dry Weight at Harvest (g), SY/Ha[u] = Seed Yield Per Hectare (t/ha), W1[v] = Weed Free, W2[w] = Inweeded, W3[x] = Weeded Once, W4[y] = Weeded Twice, W5[z] = Weeded Three times

Variety and weeding regimes interaction effect on vegetative, yield and weed traits

The interactions between variety and weeding regimes were highly significantly (P<0.01) different for all traits except plant height, number of leaves, number of days to 50% flowering, pod length and width, number of pods, soybean dry weight and seed yield/ha (tables 7 and 8). This indicates that the three soybean varieties responded similarly as well as differently to the weeding regimes in traits that showed non-significant and significant variation, respectively. However, Odeyele et al. (2007) found the interactions between variety and weeding regimes not significantly different for all parameters studied. Although non-significant, plant height at 10 WAP varied from 28.11 cm for ‘TGX 1987-62F x Weeded once’ to 51.12 cm for ‘TGX 1835-10E x Weed free’. This showed that the weeding regimes affected the varieties similarly but varied among themselves. However, it was observed that the interactions between varieties and plots weeded once and inweeded showed the least but similar values which differed from the higher but related values in plots weeded twice, three times and with weed free condition. Ayeni and Oyenka (1992) and Lamptey et al. (2015), had earlier reported that the longer the period of weed infestation the stronger the suppressive influence on the stem height of soybean. This could be likened to the pressure caused by weeds and their competition for nutrients, photosynthetic light, space and water. This is because weeds have the strength to cause a depressive effect on soybean plant height relatively. The highest number of branches at 10 WAP was observed in ‘TGX 1835-10E x Weeded twice’ which showed significant (P<0.05) variation among other interactions except ‘TGX 1835-10E x Weed free’. This could be because of the assumption that low weed density reduces the depressive and suppressive activity of weeds for nutrients on some vegetative traits of soybean like production of soybean with larger leaf area, higher proliferation of branches in number as reported by Harder et al. (2007). However, but significantly, the least number of branches was recorded in ‘TGX 1987-62F x Inweeded’. Plants on the inweeded plots recorded the minimum growth traits such as leaf area, number of branches etc., due to high weed density. Similar effect of weed-crop competition has also been reported by Dzomeku et al. (2009). Leaf is a very important plant organ for photosynthesis. ‘TGX 1835-10E x Weed free’ gave the highest number of leaves at 10 WAP, followed by ‘TGX 1835-10E x Weeded three times’ and ‘TGX 1835-10E x Weeded twice’ while the least number of leaves occurred in ‘TGX 1987-62F x Weeded once’ followed by ‘TGX 1448-2E x Inweeded’ though statistically similar. The result corroborates with the findings of Labrada et al. (1994) who noted the likelihood of weeding to reduce the space available to weeds. Hence, an increase in the number of leaves in plots with weed free conditions, plots weeded twice and three times. On the other hand, the soybean plants of the inweeded plots and weeded once had the least number of leaves which might be likened to the competition posed by weeds in terms of nutrients and other growth factors. This agrees with the findings of Halford et al. (2001) who reported the depressive activity of weeds on soybean vegetative traits such as the number of leaves. The least number of days to 50% flowering was observed in ‘TGX 1987-62F x Weed free’ joined by ‘TGX 1835-10E x Weed free’ which were statistically the same with the recorded highest value in ‘TGX 1987-62F x Inweeded’. Early flowering could be said to be caused by less weed competition for nutrients which leads to early vegetative growth and development. The highest number of days to 50% flowering was recorded in the inweeded plots irrespective of the variety interaction. This is in line with the study carried out by Tijani and Akinnifesi (1998) and Odeleye et al. (2007) that flowering of soybean usually stayed longer significantly on fields with high weed density as a result of high weed competition with the growth and development of soybean. Pod length, pod width and number of pods per plant showed non-significant differences, however, ‘TGX 1835-10E x Weed free’, ‘TGX 1835-10E x Weeded twice’, and ‘TGX 1835-10E x Weeded three times’ maintained the highest, respectively. This could be as a result of regular and sufficient weeding practice which agreed with the findings of Dugje et al. (2009) who noted that weeding reduced the growth, development and competitive ability of weeds by that improving optimum pod formation and development. Lamptey et al. (2015) quoted that weeding of soybean field would make some nutrients such as phosphorus, nitrogen, potassium and other micro-nutrients readily available which of course would promote fast and prolific pod formation. The soybean plants on the inweeded plots and plots weeded once recorded the least number of pods, lesser pod length and width as a result of high competition by weeds for nutrients stated above as well as light, space, moisture and other growth factors over the soybean plants, which lead to less pod formation, development and number. This is consistent also with the study carried out by Lavabre (1991). ‘TGX 1835-10E x Weed free’ significantly produced the highest number of seeds per plant, while the same was applicable to ‘TGX 1835-10E x Weeded three times’ in pod weight per plant though non-significant with ‘TGX 1835-10E x Weed free’. Significantly, ‘TGX 1448-2E x Weed free’ had the least 100 seed weight, followed by ‘TGX 1835-10E x Weed free’, which is similar statistically to ‘TGX 1835-10E x Weeded twice’. The results obtained were not in support of the study conducted by Hagood et al. (1980) and Halford et al. (2001), who reported of decreased 100 seed weight on plots with high weed density. Plots with low weed density as seen in plots weeded twice, three times and plots with weed free conditions produced the lowest weight for 100 seeds. This could be ascribed to the fact that though weed competition was insignificant, the upper leaves of soybean plants in these plots could have covered the lower and basal leaves, which reduced the amount of photosynthates produced for the food sink (Mudibu et al., 2011). The highest soybean dry weight at 9 WAP was recorded in 'TGX 1987-62F x Weeded three times' which was statistically the same when compared to rest interactions. Number of weeds at 6, 9 WAP and harvest showed significant level of increase among the treatment interactions with all the variety x weed free interactions having zero values across the traits. However, 'TGX 1835-10E x Inweeded', 'TGX 1448-2E x Weeded once' and 'TGX 1987-62F x Weeded once' possessed the highest number of weeds at 6, 9 WAP and at harvest, respectively. This showed that a constant weeding operation would definitely result to little or no biomass of any weed species in a soybean field when compared to the inweeded plots. Hence, the highest number of weeds in plots inweeded or weeded once, irrespective of the varietal interaction. This is in agreement with Odeyele et al. (2007) that the inweeded plots had significantly the highest level of weed biomass when compared to weeded plots. Significantly ($P<0.05$), 'TGX 1987-62F x Inweeded' constantly maintained the highest values in weed dry weight at 6, 9 WAP and harvest. This showed a weak competitive ability of this particular variety with the weed species for nutrients, water and space when compared to the rest varieties exposed under the same weeding regime. 'TGX 1835-10E x Weed free' showed non-significantly ($P>0.05$) the highest soybean seed yield per hectare, followed by 'TGX 1835-10E x Weeded three times', and 'TGX 1835-10E x Weeded twice' with the least shared between 'TGX 1448-2E x Weeded once' and 'TGX 1987-62F x Inweeded'. Pedersen and Lauer (2004) stated that adequate and constant weeding operation to ensure weed free condition increased sufficient flower appearance in the soybean plant by the quality and length of light intensity required to produce high seed yield. Furthermore, the presence of sufficient soil macro and micro nutrients, water and other growth agents as a result of low weed competition as observed in plots with weed free condition, weeded twice and three times also contributed to the best possible yield of soybean. This supported the findings of Reddy (2002). The soybean plants, irrespective of the variety, on the inweeded plots and plots weeded just once produced the least grain yield due to high density, growth and infestation by weeds on the crops. However, 'TGX 1835-10E' competed favorably with weeds based on yield and other traits when compared to the performance of the other varieties. This still supports the claim by Okpara and Ibiam (2000) that it is the preferred variety in terms of yield in this agro ecology. Nathanael et al. (2013) stated that weed is a major pest of soybean which is mostly neglected and capable of reducing yield by 5% depending on their density and soybean variety.

Table 7. Effect of soybean and weeding regime interaction with respect to some vegetative and yield traits

Treatment combinations	PH 10WAP[a]	NoB 10WAP[b]	NoL 10WAP[c]	D50% F[d]	PL H[e]	PW H[f]	NoP PP[g]	NoS PP[h]	PW PP[i]
V1W2[a]	29.04	3.84	26.57	48.87	10.35	4.76	25.77	44.11	3.77
V3W1[b]	50.95	6.04	40.71	40.29	7.86	3.58	88.25	141.67	6.04
V1W5[c]	50.09	6.86	41.25	40.49	9.95	4.38	92.19	139.6	9.99
V3W5[d]	50.74	6.45	40.25	41.97	7.03	3.23	88.31	136.01	8.11
V3W2[e]	28.69	2.98	26.12	47.99	7.29	3.07	22.83	35.3	4.24
V2W3[f]	28.11	3.13	25.99	46.18	5.18	2.36	25.97	40.41	3.91
V1W4[g]	50.17	7.17	41.05	40.23	10.38	4.96	91.54	141.42	9.05
V3W3[h]	28.39	4.52	26.16	47.98	7.05	3.05	26.52	48.79	3.74
V2W2[i]	28.41	2.29	26.5	49.06	5.55	2.94	26.02	30.49	3.07
V3W4[j]	50.79	6.14	40.1	40.35	7.42	3.35	88.02	131.05	9.13
V2W1[k]	50.82	5.3	40.97	34.11	5.97	2.62	88.88	129.3	5.68
V1W1[l]	51.12	7.16	41.38	38.18	10.62	4.9	90.8	146.94	9.7
V2W5[m]	50.16	5.72	40.05	39.28	5.39	2.05	89.76	125.49	5.91
V1W3[n]	28.68	4.34	26.36	48.27	9.95	4.09	27.43	59.67	4.65
V2W4[o]	50.65	5.5	40.04	37.52	5.41	2.8	87.55	44.26	5.86
Sig.	ns	**	ns	ns	ns	ns	ns	**	**
F-LSD$_{0.05}$	-	0.26	-	-	-	-	-	2.47	0.42

PH10WAP[a] = Plant Height at 10 Week After Planting (cm), NoB10WAP[b] = Number of Branches at 10 Week After Planting, NoL10WAP[c] = Number of Leaves at 10 Week After Planting, D50%F[d] = Number of Days to 50% Flowering, PLH[e] = Pod Length at Harvest (cm), PWH[f] = Pod Width at Harvest (cm), NoPPP[g] = Number of Pods Per Plant, NoSPP[h]= Number of Seeds Per Plant, PWPP[i] = Pod Weight Per Plant (g), V1W2[a] = TGX 1835-10E x Inweeded, V3W1[b] = TGX 1448-2E x Weed Free, V1W5[c] = TGX 1835-10E x Weeded Three times, V3W5[d] = TGX 1448-2E x Weeded Three times, V3W2[e] = TGX 1448-2E x Inweeded, V2W3[f] = TGX 1987-62F x Weeded Once, V1W4[g] = TGX 1835-10E x Weeded Twice, V3W3[h] = TGX 1448-2E x Weeded Once, V2W2[i] = TGX 1987-62F x Inweeded, V3W4[j] = TGX 1448-2E x Weeded Twice, V2W1[k] = TGX 1987-62F x Weed Free, V1W1[l] = TGX 1835-10E x Weed Free, V2W5[m] = TGX 1987-62F x Weeded Three times, V1W3[n] = TGX 1835-10E x Weeded Once, V2W4[o] = TGX 1987-62F x Weeded Twice

Table 8. Effect of soybean and weeding regime interaction with respect to some yield and weed traits

Treatment combinations	100 SW[m]	SDW 9WAP[n]	NW 6WAP[o]	NW 9WAP[p]	NW H[q]	WDW 6WAP[r]	WDW 9WAP[s]	WDWH[t]	SY/Ha[u]
V1W2[a]	14.97	36.42	87.32	12.34	12	28.57	4.85	5.86	2.13
V3W1[b]	8.5	69.63	0	0	0	0	0	0	2.15
V1W5[c]	10.09	81.48	11.33	12	11.67	5.64	5.16	5.68	2.32
V3W5[d]	9.57	69.96	13.67	11.67	16	6.58	5.27	6.35	2.12
V3W2[e]	16.02	35.57	76.78	17.97	18.17	23.2	6.64	7.94	1.36
V2W3[f]	15.94	36.82	18	15.33	22	8.83	6.17	8.84	0.83
V1W4[g]	8.9	81.68	15.33	11.33	12	7.81	5.11	5.66	2.23
V3W3[h]	14.91	35.34	17.67	21.33	18	7.27	7.45	7.27	0.79
V2W2[i]	16.81	35.61	78.31	16	15.33	28.87	7.93	8.09	0.79
V3W4[j]	9.78	80.27	10.67	12	17.33	3.34	3.45	7.81	2.13
V2W1[k]	10.01	80.39	0	0	0	0	0	0	1.88
V1W1[l]	8.82	81.42	0	0	0	0	0	0	2.35
V2W5[m]	11.86	82.36	11.67	11.67	17.33	5	3.81	7.55	1.86
V1W3[n]	10.95	37.03	17.67	9	12.67	6.48	2.83	4.83	1.36
V2W4[o]	10.69	79.13	12.33	13.33	13.33	7.37	4.75	5.41	1.85
Sig.	**	ns	**	**	**	**	**	**	ns
F-LSD$_{0.05}$	0.24	-	1.07	1.13	1.36	1.23	0.06	0.07	-

100SW[m] = 100 Seed Weight (g), SDW9WAP[n] = Soybean Dry Weight at 9 Week After Planting (g), NW6WAP[o] = Number of Weeds at 6 Week After Planting, NW9WAP[p] = Number of Weeds at 9 Week After Planting, NWH[q] = Number of Weeds at Harvest, WDW6WAP[r] = Weed Dry Weight at 6 Week After Planting (g), WDW9WAP[s] = Weed Dry Weight at 9 Week After Planting (g), WDWH[t] = Weed Dry Weight at Harvest (g), SY/Ha[u] = Seed Yield Per Hectare (t/ha), V1W2[a] = TGX 1835-10E x Inweeded, V3W1[b] = TGX 1448-2E x Weed Free, V1W5[c] = TGX 1835-10E x Weeded Three times, V3W5[d] = TGX 1448-2E x Weeded Three times, V3W2[e] = TGX 1448-2E x Inweeded, V2W3[f] = TGX 1987-62F x Weeded Once, V1W4[g] = TGX 1835-10E x Weeded Twice, V3W3[h] = TGX 1448-2E x Weeded Once, V2W2[i] = TGX 1987-62F x Inweeded, V3W4[j] = TGX 1448-2E x Weeded Twice, V2W1[k] = TGX 1987-62F x Weed Free, V1W1[l] = TGX 1835-10E x Weed Free, V2W5[m] = TGX 1987-62F x Weeded Three times, V1W3[n] = TGX 1835-10E x Weeded Once, V2W4[o] = TGX 1987-62F x Weeded Twice

Pearson correlation matrix on vegetative, yield and weed traits of soybean

The result of the correlation coefficient among some agronomic and weed traits of soybean varieties under varying weeding regimes is presented in Table 9. Finding the relationship between growth traits and yield of a crop is vital in indirect selection of variety for yield increase (Machikowa and Laosuwan, 2011). Significant and positive relationship between two traits shows that these traits can be improved simultaneously in a crop improvement programme. This is because it shows common relationship among traits and selection for one will result to selection and improvement of the other (Fayeun et al., 2012). From the correlation matrix, plant height, number of branches, number of leaves at 10 WAP, number of seeds and pod weight per plant, 100 seed weight as well as soybean dry weight at 9 WAP showed high positive magnitude and significant ($P<0.01$) correlations with seed yield per hectare. This implies that in a selection process, the choice of such traits would result to higher soybean seed yield per hectare, but in the case of plant height, this did not agree with Antalikova et al. (2008) which described negative correlations between plant height and soybean grain yield. Furthermore, the positive correlation between 100 seed weight and seed yield per hectare recorded as well as the negative correlations between 100 seed weight and all the vegetative and yield traits measured agree with the findings of Mudibu et al. (2011) in their work on morphovariability and agronomic characteristics of soybean accessions. The negative correlation value estimated between number of leaves and 100 seed weight showed that the soybean varieties with a high number of leaves per plant produced the lowest weight for 100 seeds. This can be ascribed to the fact that upper leaves cover lower and basal leaves, which affect the amount of photosynthates that translocate to the sink (Mudibu et al., 2011). Pearson correlation analysis among seed yield and its contributing weed traits showed that correlation of seed yield per hectare was found to be highly significant ($P<0.01$) and negative for number of weeds at 9 WAP and harvest as well as weed dry weight at both 9 WAP and harvest, though lower in magnitude when compared to the vegetative and yield traits. This showed that an increase in the weed dry matter and weed density which of course was found in most of the inweeded plots or plots weeded once implied a decrease in the seed yield of soybean in such plots. This is perhaps as a result of the intense competition for the available resources with the soybean crop in the plots. This is in agreement with the findings of Lamptey et al. (2015) that the longer the time of weed competition, the stronger the depressive influence on the yield of soybean and Odeleye et al. (2007) that the inweeded plots had significantly the highest level of weed biomass compared to weeded plots.

Table 9. Correlation coefficient for 12 selected vegetative, yield and weed traits in soybean and weeding regime interaction

Traits	PH10 WAP[a]	NoB10 WAP[b]	NoL10 WAP[c]	NoSPP[d]	PW PP[e]	100 SW[f]	SDW9 WAP[g]	NW9 WAP[h]	NW H[i]	WDW9 WAP[j]	WDW H[k]	SY/Ha[l]
PH10WAP[a]	1	0.88**	0.996**	0.863**	0.801**	-0.874**	0.954**	-0.592**	-0.492**	-0.598**	-0.496**	0.896**
NoB10WAP[b]		1	0.888**	0.889**	0.899**	-0.914**	0.848**	-0.512**	-0.453**	-0.524**	-0.479**	0.878**
NoL10WAP[c]			1	0.875**	0.811**	-0.876**	0.953**	-0.6**	-0.509**	-0.597**	-0.509**	0.898**
NoSPP[d]				1	0.84**	-0.862**	0.814**	-0.657**	-0.535**	-0.637**	-0.534**	0.856**
PWPP[e]					1	-0.8**	0.791**	-0.404**	-0.316*	-0.404**	-0.306*	0.868**
100SW[f]						1	-0.809**	-0.707**	-0.604**	-0.726**	-0.644**	0.884**
SDW9WAP[g]							1	-0.533**	-0.432**	-0.548**	-0.43**	0.847**
NW9WAP[h]								1	0.904**	0.962**	0.916**	-0.605**
NWH[i]									1	0.834**	0.976**	-0.505**
WDW9WAP[j]										1	0.869**	-0.61**
WDWH[k]											1	-0.504**
SY/Ha[l]												1

** Correlation is significant at the 0.01 level. * Correlation is significant at the 0.05 level.
PH10WAP[a] = Plant Height at 10 Week After Planting (cm), NoB10WAP[b] = Number of Branches at 10 Week After Planting , NoL10WAP[c] = Number of Leaves at 10 Week After Planting, NoSPP[d] = Number of Seeds Per Plant, PWPP[e] = Pod Weight Per Plant (g), 100SW[f] = 100 Seed Weight (g), SDW9WAP[g] = Soybean Dry Weight at 9 Week After Planting (g), NW9WAP[h] = Number of Weeds at 9 Week After Planting, NWH[i] = Number of Weeds at Harvest, WDW9WAP[j] = Weed Dry Weight at 9 Week After Planting (g), WDWH[k] = Weed Dry Weight at Harvest (g), SY/Ha[l] = Seed Yield Per Hectare (t/ha)

Cause and effect analysis showing direct and indirect effects of vegetative, yield and weed traits on seed yield of soybean

Cause and effect analysis means partitioning of Pearson correlation coefficients into direct and indirect effects. Agrama (1996) had earlier described path analysis to also require causal relationships among the traits. The result is presented in table 10. Relying any selection choice on the coefficient of correlation only may give a deceptive idea as it tends to quantify the degree of relationship that exist between two traits which goes with no respect to causation. This is however, because, there is the danger of excluding some vital traits whose contributions through other traits might easily lose value. Hassan et al. (2013) suggested that it is relevant to quantify the mutual association between different plants traits and ascertain definitely the component traits, on which any selection process can be based for direct and indirect improvement of crop yield. From the present study, plant height at 10 WAP gave the highest positive direct effect on seed yield per hectare, followed by pod weight per plant while the highest negative direct effect was obtained from weed dry weight at harvest. It suggests therefore, that, this trait (plant height) appeared to be the most relevant trait that contributed immensely to the performance witnessed in soybean yield. Similar result had been reported by Robinson et al. (2009). The following traits which included; Plant height, number of leaves at 10 WAP and pod weight per plant had positive direct effects on the seed yield per hectare. It shows that increase in yield may depend solely on direct selection of these traits irrespective of weed competition. However, the rest of the soybean traits studied including all the weed traits highly gave negative direct effects on the seed yield per hectare. It gives an indication that direct selection of these traits may not increase yield. Hence, in the case of the soybean traits, selection for these traits must be done indirectly via plant height. Uguru (1996) in vegetable cowpea and Nwofia et al. (2015) in cucumber suggested that it is an indication that the traits have appreciable value despite the negative direct effects recorded. The residual factors which determine the extent to which the casual factors have explained the performance in seed yield were a bit low and observed to be 0.108. This is an indication that 89% of the total performance in seed yield/ha had been sufficiently accounted for by the traits that were used in the path analysis in the investigation. Comparable residual factors had also been reported in cucumber (Nwofia et al., 2015).

Table 10. Direct and indirect effects of vegetative, yield and weed traits on yield in soybean and weeding regime interaction

Traits	PH10 WAP[a]	NoB10 WAP[b]	NoL 10WAP[c]	NoSPP[d]	PW PP[e]	100 SW[f]	SDW9 WAP[g]	NW9 WAP[h]	NW H[i]	WDW9 WAP[j]	WDW H[k]	SY/ Ha[l]	TIE[m]
PH10WAP[a]	0.493	-0.033	0.036	-0.065	0.345	0.197	-0.147	0.026	0.105	0.067	-0.127	0.896**	0.403
NoB10WAP[b]	0.434	-0.037	0.032	-0.067	0.387	0.206	-0.131	0.022	0.097	0.058	-0.123	0.878**	0.915
NoL10WAP[c]	0.491	-0.033	0.036	-0.066	0.35	0.197	-0.147	0.026	0.109	0.067	-0.13	0.898**	0.863
NoSPP[d]	0.426	-0.033	0.031	-0.076	0.362	0.194	-0.125	0.029	0.114	0.071	-0.137	0.856**	0.932
PWPP[e]	0.395	-0.034	0.029	-0.064	0.431	0.18	-0.122	0.018	0.068	0.045	-0.078	0.868**	0.436
100SW[f]	-0.431	0.034	-0.031	0.065	-0.345	-0.225	0.125	-0.031	-0.129	-0.081	0.165	-0.884**	-0.659
SDW9WAP[g]	0.47	-0.032	0.034	-0.062	0.341	0.182	-0.154	0.023	0.092	0.061	-0.11	0.847**	1
NW9WAP[h]	-0.292	0.019	-0.021	0.05	-0.174	-0.159	0.082	-0.043	-0.193	-0.107	0.235	-0.605**	-0.561
NWH[i]	-0.243	0.017	-0.018	0.041	-0.136	-0.136	0.067	-0.039	-0.214	-0.093	0.25	-0.505**	-0.291
WDW9WAP[j]	-0.295	0.02	-0.021	0.048	-0.174	-0.163	0.084	-0.042	-0.178	-0.112	0.223	-0.61**	-0.498
WDWH[k]	-0.245	0.018	-0.018	0.04	-0.132	-0.145	0.066	-0.04	-0.209	-0.097	-0.256	-0.504**	-0.76
		Residuals = 0.108											

PH10WAP[a] = Plant Height at 10 Week After Planting (cm), NoB10WAP[b] = Number of Branches at 10 Week After Planting, NoL10WAP[c] = Number of Leaves @ 10 Week After Planting, NoSPP[d] = Number of Seeds Per Plant, PWPP[e] = Pod Weight Per Plant (g), 100SW[f] = 100 Seed Weight (g), SDW9WAP[g] = Soybean Dry Weight at 9 Week After Planting (g), NW9WAP[h] = Number of Weeds at 9 Week After Planting, NWH[i] = Number of Weeds at Harvest, WDW9WAP[j] = Weed Dry Weight at 9 Week After Planting (g), WDWH[k] = Weed Dry Weight at Harvest (g), SY/Ha[l] = Seed Yield Per Hectare (t/ha), TIE[m] = Total Indirect Effect

Conclusions

Application of different weeding regimes had a significant effect on the traits including yield of soybean varieties studied. The result showed significant differences among the three soybean varieties under varying weeding regimes for all the traits analyzed which showed that the varieties responded differently to the weeding regimes except for plant height. This differential performance of the varieties can be attributed to the inherent genotypic variation. The results obtained also revealed that weed free plots, plots weeded twice and three times did not differ from among themselves, hence, weeding twice at 3 WAP and 6 WAP is recommended for soybean production in order to reduce labour and cost of soybean production. 'TGX 1835-10E x Weed free' showed non-significantly ($P>0.05$) the highest soybean seed yield per hectare, followed by 'TGX 1835-10E x Weeded three times', and 'TGX 1835-10E x Weeded twice' which showed that 'TGX 1835-10E' competed favorably with weeds based on yield and other traits when compared to the performance of the other varieties. Furthermore, 'TGX 1835-10E', considering its growth and yield performance as well as responses to weeding regimes should be recommended for the improvement and production of soybean in this or related agro ecology. Plant height, number of branches, number of leaves at 10 WAP, number of seeds and pod weight per plant, 100 seed weight as well as soybean dry weight at 9 WAP showed high positive magnitude and significant ($P<0.01$) correlations with seed yield per hectare. This implies that in a selection process, the choice of such traits would result to higher soybean seed yield per hectare. Path coefficients analysis revealed that plant height at 10 WAP having the highest positive direct effect on yield is of utmost importance in contributing to yield improvement in soybean and hence, should require major attention.

References

Aduloju, M.O., Mahamood, J., Abayomi, Y.A. (2009) 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. African Journal of Agricultural Research, 4 (6), 556-563.

Agrama, H.A.S. (1996) Sequential path analysis of grain yield and its components in maize. Plant Breeding, 115, 343-346. DOI: https://doi.org/10.1111/j.1439-0523.1996.tb00931.x

Akande, S.R., Owolade, O.F., Ayanwole, J.A. (2007) Field evaluation of soybean varieties at Ilorin in the southern guinea savanna ecology of Nigeria. African Journal of Agricultural Research, 2 (8), 356-359.

Akobundu, I.O., Poku, J.A. (1987) Weed control in soybeans in the tropics. In: Singh, S.R., Rachie, K.O., Dashiell, K.E., eds. Soybean for the tropics. New York: John Wiley & Sons, 69-77.

Antalikova, G., Zakova, M., Benedikova, D. (2008) Characterization of soybean traits variability by cluster analysis. Agriculture, 54 (2), 45-53.

Anyim, A. (2002) Effect of planting dates on the yield and control of major insect pests of soybean (*Glycine max* [L.] Merrill) in southeastern Nigeria. International Journal of Agriculture and Rural Development, 3, 121–126. DOI: https://doi.org/10.4314/ijard.v3i1.2529

Asiegbu, J.E., Okpara, D.A. (2002) Soybean production in marginal soils of southeastern Nigeria. In: Proceedings of 36th Annual conference of the Agricultural Society of Nigeria. Owerri, Nigeria, 20 – 24 October 2002, Federal University of Technology, 104 – 107.

Ayeni, A.O., Oyekan, P.O. (1992) Weed control in soybean (*Glycine max*. [L.] Merrill) in Nigeria. Tropical Oil Seed Journal, 1, 43-52.

Dada, O.A. Fayinminnu, O.O. (2010) Period of weed control in okra (*Abelmoschus esculentus* [L.] Moench) as influenced by varying rates of cattle dung and weeding regimes. NotulaeBotanicaeHortiAgrobotanici Cluj-Napoca, 38 (1), 149-154. DOI: https://doi.org/10.15835/nbha3813676

Dewey, D.R., Lu, K.H. (1959) A correlation and path coefficient analysis of components of crested wheatgrass seed production. Agronomy Journal, 51, 515-518.
DOI: https://doi.org/10.2134/agronj1959.00021962005100090002x

Dugje, I.Y., Omoigui, LO., Ekeleme, F., Bandyopadhyay, R., Lava Kumar, P., Kamara, A.Y. (2009) Farmers' guide to soybean production in northern Nigeria. Ibadan, Nigeria: International Institute of Tropical Agriculture.

Dzomeku, I.K., Abudulai, M., Brandenburg, R.L., Jordan, D.L. (2009) Survey of weeds and management practices in peanut (*Arachis hypogaea* L.) in the savanna ecology of Ghana. Peanut Science, 36 (2), 165-173.
DOI: https://doi.org/10.3146/PS08-009.1

Ene, C.O., Ogbonna, P.E., Agbo, C.U., Chukwudi, U.P. (2016) Evaluation of sixteen cucumber (*Cucumis sativus* L.) genotypes in derived savannah environment using path coefficient analysis. Notulae Scientia Biologicae, 8 (1), 85-92.
DOI: https://doi.org/10.15835/nsb.8.1.9722

Fabro, L.E., Rhodes, R.C. (1980) On farm trials on weed control in legumes. Weed science report. 1979-80. Lagara: Department of Agronomy University of Philippines, 62-66.

Fayeun, L.S., Odiyi, A.C., Makinde, S.C.O., Aiyelari, O.P. (2012) Genetic variability and correlation studies in the fluted pumpkin (*Telfairia occidentalis* Hook F.). Journal of Plant Breeding and Crop Science, 4 (10), 156-160.
DOI: https://doi.org/10.5897/JPBCS12.011

Gatti, I., Anido, F.L., Vanina, C., Asprelli,P., Country, E. (2005) Heritability and expected selection response for yield traits in blanched asparagus. Genetics and Molecular Research, 4 (1), 67-73.

Hagood, E.S.J., Bauman, T.T., Williams, J.L.J., Schreiber, M.M. (1980) Growth analysis of soybean (*Glycine max* [L.] Merrill) in competition with velvet leaf (*Abutilon theophrasti*). Weed Science, 28, 729-734.

Halford, C., Hamill, A.S., Zhang, J., Doucet, C. (2001) Critical period of weed control in no-till soybean and corn. Weed Technology, 15 (4), 737-744. DOI: https://doi.org/10.1614/0890037X(2001)015[0737:CPOWCI]2.0.CO;2

Harder, D.B., Sprague, C.L., Renner, K.A. (2007) Effect of soybean row width and population on weeds, crop yield, and economic return. Weed Technology, 21 (3), 744-752. DOI: https://doi.org/10.1614/WT-06-122.1

Hassan, S.M.F., Muhammad, S.I., Ghulam, R., Naeem-ud-Din, Ghulam, S., Muhammad, R., Ljaz, R.N. (2013) Correlation and path analysis for yield and yield components in sunflower (*Helianthus annus* L.). African Journal of Biotechnology, 12 (16), 1968-1971. DOI: https://doi.org/10.5897/AJB12.817

IITA (1990) Annual report of the International Institute of Tropical Agriculture. Ibadan Nigeria: International Institute of Tropical Agriculture, 45-47.

Iremiren, G.O. (1988) Frequency of weeding okra (*Abelmoschus esculentus* [L.] Moench) for optimum growth and yield. Experimental Agriculture, 24 (2), 247-252. DOI: https://doi.org/10.1017/S0014479700015994

Iwe, M.O. (2003) The science and technology of soybeans: chemistry, nutrition, processing and utilization. Uwani, Enugu, Nigeria: Rejoint Communications services Ltd., 90-94.

Iyagba, A.G., Onuegbu, B.A., Ibe, A.E. (2012) Growth and yield response of okra (*Abelmoschus esculentus* [L.] Moench) varieties to weed interference in South-Eastern Nigeria. Global Journal of Science Frontier Research Agriculture and Veterinary Sciences, 12 (7).

Iyagba, A.G., Onuegbu, B.A., Ibe, A.E. (2013) Growth and yield response of okra (*Abelmoschus esulentus* [L.] Moench) to NPK fertilizer rates and weed interference in South-eastern Nigeria. International Research Journal of Agricultural Science and Soil Science, 3 (9), 328-335. DOI: http://dx.doi.org/10.14303/irjas.2013.098

Labrada, R., Caseley, J.C., Parker, C. (1994) Weed management in developing countries. Italy: Food and Agriculture Organization of United Organization.

Lamptey, S., Yeboah, S., Sakodie, K., Berdjour, A. (2015) Growth and yield response of soybean under different weeding regimes. Asian Journal of Agriculture and Food Sciences, 3 (2), 155-163.

Lavabre, E.M. (1991) Weed control (the tropical agriculturist). London and Basingstoke: Macmillan Education Ltd.

Machikowa, T., Laosuwan, P. (2011) Path coefficient analysis for yield of early maturing soybean. Songklanakarin Journal of Science and Technology, 33 (4), 365-368.

Mamman, I. (1990) Soybean in Nigeria Agriculture. In: 3rd Annual conference of Nigeria Soybean Association. Badeggi, 26-29 March 1990.

Moody, K., Whitney, W.K. (1974) The effect of weed on insect damage and developing cowpea and soybean seeds. In: Proceedingsof4th Nigerian weed science group meeting, Nsukka, 15 – 18 July 1974, University of Nigeria, 16-26.

Mudibu, J., Nkongolo, K.K.C., Kalonji-Mbuyi, A. (2011) Morphovariability and agronomic characteristics of soybean accessions from the Democratic Republic of Congo (DR-Congo) gene pool. Journal of Plant Breeding and Crop Science, 3 (11), 260-268.

Nathanael, D.F., Chris, M.B., David, E.S. (2013) Soybean yield loss potential associated with early-season weed competition across 64 site-years. Weed Science Society of America, 61 (3), 500-507. DOI: https://doi.org/10.1614/WS-D-12-00164.1

Nwofia, G.E., Amajuoyi, A.N., Mbah, E.U. (2015) Response of three cucumber varieties (*Cucumis sativus* L.) to planting season and NPK fertilizer rates in lowland humid tropics: sex expression, yield and inter-relationships between yield and associated traits. International Journal of Agriculture and Forestry, 5 (1), 30-37. DOI: http://doi.org/10.5923/j.ijaf.20150501.05

Odeleye, F.O., Odeleye, O.M.O., Dada, O.A. (2007) The performance of soybean (*Glycine max* [L.] Merrill) under varying weeding regimes in south western Nigeria. NotulaeBotanicaeHortiAgrobotanici Cluj-Napoca, 35 (1), 27-36. DOI: https://doi.org/10.15835/nbha351247

Okpara, D.A., Ibiam, B. (2000) Evaluation of soybean varieties for adaptability to a humid tropical environment in south east Nigeria. Journal of Sustainable Agriculture and Environment, 2, 26-31.

Onochie, B.E. (1965) The potential value of soybean as a protein supplement in the Nigerian diet. In: Proceedings of 3rd annual conference of the Agricultural Society of Nigeria, Ibadan, Nigeria, 7 – 10 July 1965, 43-45.

Osodeke, V.E. (2001) Yield performance, N_2-fixation and fertilizer requirement of soybean (*Glycine max* [L.] Merrill) in some soils of the forest zone of Southeastern Nigeria. Ph.Dthesis. Umudike: Department of Soil Science and Agro climatology, Michael Okpara University of Agriculture.

Pedersen, P., Lauer, J.G. (2004) Soybean growth and development in various management systems and planting dates. Crop Science, 44, 508-515. DOI: https://doi.org/10.2135/cropsci2004.5080

Reddy, K.N. (2002) Weed control and economic comparisons in soybean planting systems. Journal of Sustainable Agriculture, 21 (2), 21-35. DOI: https://doi.org/10.1300/J064v21n02_04

Robinson, A.P., Conley, S.P., Volenec, J.J., Santini, J.B. (2009) Analysis of high yielding, early-planted soybean in Indiana. Agronomy Journal, 101,131-139. DOI: https://doi.org/10.2134/agronj2008.0014x

Sanginga, N., Lyasse, O., Singh, B.B. (2000) Phosphorus use efficiency and nitrogen balance of cowpea breeding lines in a low P soil of the derived savanna zone in West Africa. Plant and Soil, 220 (1/2), 119-128. DOI: https://doi.org/10.1023/A:1004785720047

Singh, C., Singh, P., Singh, R. (2003) Modern techniques of raising field crops. New Delhi: Oxford and IBH publishing Co. PVT Ltd.

Tijani, E.H., Akinnifesi, F.K. (1998) Effect of weeding regimes and crop spacing on the performance of soybean (*Glycine max* [L.] Merrill). Nigeria Journal of Weed Science, 11, 25-30.

Uguru, M.I. (1996) Estimate of variability and genetic gain in vegetable cowpea (*Vigna unguiculata* [L.] Walp). Ghana Journal of agricultural Science, 29, 47-51. DOI: https://doi.org/10.4314/gjas.v29i2.1989

USDA Foreign Agricultural Service (2016) Gain report: Nigeria – soybeans and products. NST – Nigerian seminars and trainings.com/articlespg/30-gain-report-nigeria-soybean-and-products. Available at: http://www.nigerianseminarsandtrainings

Vega, M.R., Paller, E.C., Madrid, M.T. (1970) Weed control in soybeans. In: proceedings of 3rd annual conference of Legume Workers Association, Los Banos, Philippines, 6 – 8 April 1970, 51-53.

Wudiri, B.B. (1990) Welcome address. In: proceedings of 3rd annual conference of the Nigerian Soybean Association, Badeggi, Nigeria, 26 – 29 March 1990, 11-13.