Effects of inter-row spacing on growth, seed yield and yield components of Soybean (*Glycine max*) in Makurdi, Benue State-Nigeria

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Abstract

Despite the numerous benefits of soybean, its grain yield per unit area in Nigeria is low estimated at 1.2 tons ha^{-1} compared to the worldwide average yield of 2.5 tons per hectare. The low yield is due in part to limited use of phosphorous fertilizer and poor crop management practices including low plant populations. Farmers in northern Nigeria including Benue State sow seeds in rows spaced 75cm. There has been little recommendation as to the exact row spacing that will give higher yield in soybean especially in Benue State. It is this gap that this research work seeks to address. This study was designed to determine the effects of row spacing on agronomic traits and yield of soybean in Makurdi, Benue state. The experiment was a 2 (row spacing) x 6 (soybean varieties) factorial arrangement laid out in a Randomized Complete Block Design (RCBD) with three replications.

Data collected were subjected to Analysis of variance (ANOVA) and treatments means were separated using Duncan's Multiple Range Test (DMRT) at 5% and 1% level of probability. Also cost benefit ratio (CBR) was calculated as gross return divided by cost of production. This study shows that reducing row spacing or plant population from 75cm x 10cm to 50 cm x 10 cm significantly increased the plant height from 67.24 to 72.07cm. Meanwhile, it reduced the number of branches per plant from 7.37 to 5.01 and number of pods per plant from 55.90 to 49.69 pods. With respect to varieties, TGX-1951-4F, TGX-1951-3F and TGX-1945-1F had the highest grain yield of 3.9, 3.5 and 3.5 tons per hectare respectively as compared to other varieties which had lower yields. Cost Benefit Ratio (CBR) showed high advantage in growing soybean at 50cm inter-row spacing than at 75cm inter-row spacing. Therefore, grain yield in soybean is largely a function of plant population per m^2. To increase soybean productivity in Makurdi Benue State of Nigeria, it is recommended that closer row spacing of 50cm x 10cm should be adopted for the soybean varieties tested.

Keyword: Soybean, row spacing, plant population, cost benefit ratio.

Introduction

Soybean [*Glycine max* (L.) Merrill] is an annual legume that belongs to the legume family *Fabaceae*. It is a strictly self-pollinating legume with 2n = 40 chromosomes[25]. Soybean is among the major industrial and food crops grown in every continent. The crop can be successfully grown in the tropical, subtropical and temperate climates[11,22]. It originated from South East Asia from where it spread into many parts of the world[20]. Soybean has an average protein content of 40% and is more protein-rich than any of the common vegetable or animal food sources found in Nigeria.

The seeds contain about 20% oil on dry matter basis and some appreciable amounts of vitamins and minerals[8]. The beans can be cooked and eaten as vegetable as well as processed into many food products such as soy milk, soy yoghurt, soy flour[18], baby weaning food, soy sauce and dawadawa[19,25].

It has therefore, become a major source of high quality and cheap protein for the poor and rural households in Nigeria[8]. Soybean cultivation in Nigeria has expanded as a result of its nutritive and economic importance and diverse domestic usage. The rapid growth in the poultry sector has also increased the demand for soybean meal in Nigeria[5]. Agronomically, soybean improves soil fertility by hosting the bacteria that convert atmospheric nitrogen into nitrates for its own use and benefit the succeeding cereal like maize and sorghum grown in rotation. It is also important in the management of *Striga hermonthica*[21].

The world total production of soybean in 2012 was estimated at 348.7 million metric tons[9]. The U.S., Argentina, Brazil, China and India are the world's largest soybean producers and represent more than 90% of global soybean production[23]. The average worldwide yield for soybean crops in 2018 was 2.79 tons per hectare[10]. The three largest producers had average nationwide soybean crop yields of about 3 tons per hectare[10].

Nigeria alone accounted for about 758033 metric tons of Africa's total production in 2018[10]. Benue State accounted for about 45% of the total production in the Nigeria[6].

Despite the numerous benefits of the crop, soybean grain yield per unit area in Nigeria is low, estimated at 970 kg ha^{-1} compared to the worldwide average yield of 2791 kg ha^{-1}.[9] The low yield is due in part to limited use of phosphorous fertilizer and poor crop management practices including low plant populations[15].

Farmers in northern Nigeria including Benue State plant seeds in rows spaced 75cm. All tractor and animal mounted ridgers available have a fixed width of 75cm, leaving farmers with no option to reduce the row spacing[16]. Higher yields of soybean can be obtained in narrow-row spacing if plant stands are well established and weeds are adequately controlled[4]. Gary and Dale[10] in an experiment comparing of 75cm rows versus 30cm rows and 90cm rows versus 30cm rows found out that the narrow row spacing gave 28 percent and 31 percent respectively higher yield over the wider row spacing.

Despite the numerous research work done by other researchers, there has been little recommendation as to the exact row spacing that will give higher yield in soybean especially in Benue State. It is this gap that this research work seeks to address. This study was designed to determine the effects of row spacing on agronomic traits and yield of soybean in Makurdi, Benue state.

Material and Methods

Planting Material: Six soybean varieties obtained from the Molecular Biology Laboratory, University of Agriculture, Makurdi, were used for this study.

Experimental site: The experiment was conducted at the Federal University of Agriculture Makurdi, Teaching and Research Farm (7.76°N and longitude 8.62°E and at the elevation of about 103 m above sea level). The soil at the site is well drained sandy loam.

Experimental Design and Treatments: The experiment was a 2 x 6 factorial arrangement laid out in a Randomized Complete Block Design (RCBD) with three replications. The main-plot factor was row spacing while the sub-plot factor was soybean varieties. Each replication consisted of two blocks representing the two row spacing and each block consisted of six (6) plots of 3 x 3 m to which the six varieties were assigned.

Table 1
Varieties of Soybean used for the Research

S.N.	Variety	Maturity Period
1	TGX-1945-1F	102 – 111 DAP (M)
2	TGX-1951-3F	100 – 105 DAP (M)
3	TGX-1448-2E	115 - 120 DAP (L)
4	TGX-1935-3F	79 – 102 DAP (E)
5	TGX-1904-6F	101 – 108 DAP (M)
6	TGX-1951-4F	101 – 107 DAP (M)

Source[2]. DAP = Day after planting; M = Medium; L = Late; E = Early

Agronomic Practices during the Experiment: The land was first sprayed with glyphosate and later ridged manually according to the different row spacing. The six varieties were treated with seed dressing chemical (seedrex) and sow at the intra row spacing of 10 cm x 3 seeds/hill for all the row spacings and later thinned to 2 plants per hill at 14 DAS. NPK 15:15:15 at the rate of 100 kg/ha and SSP at the rate of 138.8 kg/ha were mixed to get a formulation of NPK 15:40:15 ai/ha and applied for both treatment. The fertilizer was drilled by the sides of soybean rows at seven days after sowing (7DAS).

The sown field was first sprayed with pendemetaline mixed with paraquate at the rate of 250 ml and 300 ml respectively, mixed in 20 litre Knapsack sprayer to control pre-emergence and emerged weed seeds at sowing. Hand weeding was also done at 50% podding to keep the field clean. Harvesting was done manually with cutlass by cutting the plants at the ground level at 85 % and 80 % pod maturity for the non-shattering varieties and shattering varieties respectively as recommended by Dugje et al[8]. Each plot was harvested separately, tied and weighed. The harvested soybean was sun-dried for two (2) weeks before threshing and winnowing.

Observations were recorded on the following parameters; days to first flower, days to 50 % flowering, plant height at 50% flowering and 95 % podding, number of branches per plant, number of pods per plant, number of seeds per pod, hundred (100) seed weight, grain yield (kg) per ha and harvest index.

Data collected were subjected to Analysis of variance (ANOVA) using statistical analysis system[17] and treatments means were separated using Duncan's Multiple Range Test (DMRT) at 5 % level and 1 % level of probability. Also cost benefit ratio (CBR) was calculated as gross return divided by cost of production. CBR value above 1 is considered as advantage[18].

Results and Discussion

The summary of the analysis of variance showing the yield and nine agronomic traits for soybean cultivars as affected by row spacing is presented in table 2. The data indicated that there was highly significant difference with respect to row spacing for all the parameters measured at 1 % level of probability, except for 100 seed weight where significant difference exists at 5 % level of probability. However, days to first flower were not significantly different.

Varietal effect showed highly significant difference at 1 % level of probability for days to first flower, days to 50 % flower, plant height at 95 % podding, number of branches per plant, grain yield per hectare and 100 seed weight. Also significant difference at 5 % level of probability was observed for harvest index. Meanwhile, there was no significant varietal effect for number of pods per plant and number of seed per pod.

Row spacing × variety interaction showed highly significant difference for number of pods per plant, seed per pod and 100 seed weight at 1 % level of probability whereas there was significant difference at 5 % level of probability for days to 50 % flower, plant height at flowering and plant height at 95 % podding. For all other parameters studied, there was no significant row spacing × variety interaction effect.

Table 3 presents the mean performance of five agronomic traits of soybean cultivars evaluated. Inter row spacing did not have effect on soybean cultivars for days to first flower. There were cultivar differences in terms of days to first flower. For example, the cultivar TGX-1935-3F which is the early maturing cultivar was the first to flower at 37.67 days after sowing followed by the medium maturing cultivars-TGX-1945-1F, TGX-1951-3F, TGX-1951-4F TGX-1904-6F which flowered at 41.83, 42.38 and 44.83 days after sowing respectively. The late maturing cultivar TGX-1448-2E was the last to flower at 45.0 days after sowing.

In some of the soybean cultivars evaluated, as the inter-row spacing increased, the number of days to 50 % flower also increased. For example, days to 50 % flower increased in cultivars TGX-1935-3F, TGX-1951-3F and TGX-1951-4F as inter-row spacing increased from 50 cm to 75 cm.

In most of the soybean cultivars, plants were taller at flowering for 50cm inter row spacing except for cultivar TGX-1448-2E which is a late maturing cultivar that grew taller at 75cm inter row spacing. A similar trend was observed for plant height at 95 % podding except for cultivar TGX-1951-4F which is a medium maturing cultivar that attained higher plant height at inter row spacing of 75 cm.

Inter row spacing of 75cm produced higher number of pods per plant except in cultivar TGX-1935-3F an early maturing and TGX-1448-2E which is late maturing cultivar that produced higher number of pods at 50 cm inter row spacing.

For number of seed per pod, there was no difference for both row spacing and cultivar. However, wider inter row spacing gave the highest number of branches per plant for all the cultivars tested. A similar trend was also observed for 100 seed weight for most of the cultivars tested except TGX-1448-2E which produced larger seed at narrow row spacing.

Table 2
Analysis of Variance for Yield and Nine Agronomic Traits of Soybean Cultivars grown under different Row Spacing at Makurdi in 2013

Source of Variation	DFF	D50_F	PLTHTF	PLH95_PD	PDPLT	SDPD	BRPLT	YLDHA	100SDWT	HI
ROWSP (R)	0.05ns	2.25**	211.46**	211.85**	468**	0.05ns	49.94**	7947606.73**	0.43*	0.03**
VARIETY (V)	37.47**	15.25**	69.73**	69.70**	45.83ns	0.02ns	1.83**	195282.40**	11.27**	0.003*
R X V	1.07ns	1.65*	47.65*	47.65*	244.49**	0.18**	2.30**	38408.52ns	0.89**	0.0003ns
ERROR	4.06	2.25	65.08	50.93	89.37	0.33	0.92	107803.65	0.55	0.004
CV	4.67	3.16	11.58	12.43	18.08	9.5	15.49	9.63	5.49	19.76

*= significant at P≤ 0.05, **= highly significant at P≤ 0.001, ns= not significant, DFF= Days to first flower, D50-F= Days to 50 percent flower, PLTHTF= Plant height at flowering, PLH95-PD= Plant height at 95 percent podding, PDPLT= Number of pods per plant, SDPD= Number of seeds per pod, BRPLT = Number of branches per plant, YLDHA= Grain yield Kg per hectare, 100SDWT= 100 seed weight, HI= Harvest index.

Table 3
Mean Performance of Five Agronomic Traits of Soybean Cultivars Grown under Different Row Spacing at Makurdi in 2013

	DFF			D50_F			PLTHF			PLH95_PD			PODPLT		
	Row spacing			Row spacing			Row spacing			Row spacing			Row spacing		
Variety	50cm	75cm	Mean	50cm	75cm	Mean	50cm	75cm	Mean	50cm	75cm	Mean	50cm	75cm	Mean
TGX 1448-2E	45.00	44.67	44.83	49.00	49.00	49.00	54.04	55.27	54.66	62.67	62.65	62.66	52.47	51.40	51.94
TGX 1904-6F	45.00	45.00	45.00	48.67	48.67	48.67	59.17	46.23	52.70	70.10	67.90	69.00	37.27	60.53	48.90
TGX 1935-3F	37.67	38.67	38.17	43.33	45.67	44.50	63.58	59.6	61.59	82.00	68.20	75.10	59.60	46.07	52.84
TGX 1945-1F	42.67	42.00	42.34	48.00	47.33	47.67	59.18	56.27	57.73	73.43	69.60	71.52	49.53	62.27	55.90
TGX 1951-3F	42.33	41.33	41.83	46.67	47.67	47.17	62.41	52.1	57.23	74.23	62.06	68.15	49.93	55.13	52.53
TGX 1951-4F	41.33	42.33	41.83	47.33	47.67	47.50	60.75	60.6	60.68	70.01	73.00	71.51	49.33	60.00	54.67
Mean	42.33	42.33		47.17	47.67		59.86	55.01		72.07	67.24		49.69	55.90	
SE Row Spacing	0.48ns			0.35**			1.68**			1.90**			2.23**		
SE Variety	0.8**			0.61**			2.91**			3.29**			3.86ns		
SE Row Spacing x Variety	1.16ns			0.87*			4.12*			4.66**			5.46**		

*= significant at P≤ 0.05, **= highly significant at P≤ 0.001, ns: non-significant difference, SE: standard error. DF: Days to first flower, D50-F: Days to 50 percent flower, PLTHTF: Average plant height at flowering, PLH95-PD: Average plant height at 95 percent podding, PDPLT: Average number of pods per plan.

In all the soybean cultivars tested, 50 cm inter row spacing produced higher Harvest index. However, cultivar differences existed; TGX-1951-4F, TGX-1951-3F and TGX-1904-6F gave the highest harvest index. This was followed by TGX-1935-3F, TGX-1945-1F and TGX-1448-2E.

Figure 1 indicates that reducing inter row spacing from 75cm to 50cm in soybean has significantly increased grain yield per hectare in Makurdi from 3038 – 3877 kg/ha. However, cultivar differences existed; TGX-1935-3F (4086 kg/ha), TGX-1951-3F (4017 kg/ha) and TGX-1951-4F (4017 kg/ha) produced the highest grain yield per hectare while TGX-1945-1F (3904 kg/ha) TGX-1448-2E (3628 kg/ha) and TGX-1904-6F (3612 kg/ha) produced grain yield at 50 cm inter row spacing.

At 75 cm inter row spacing, TGX 1951-4F, TGX 1945-1F, TGX 1951-3F, TGX 1935-3F, TGX 1448-2E and TGX 1904-6F had grain yield of 3785, 3097, 2999, 2859, 2781 and 2708 respectively in kg/ha.

The table 5a and 5b show that variable cost for the production of soybean per hectare in Makurdi for 50cm inter row spacing is NGN 28, 730 higher compared to the production at 75 cm inter row spacing. However, the total output (grain yield per hectare) is 839 kg higher in 50cm inter row spacing compared to 75 cm inter row spacing. Also the total income incurred for the production of soybean at inter row spacing of 50cm is NGN 71, 315 higher compared to 75 cm inter row spacing.

The study indicates that row spacing has no significant effect on days to first flower. However, narrow row spacing reduced the number of days to 50 % flower probably by facilitating crop canopy growth that reached maximum light interception that aids flowering. This confirmed the finding of Lee[17].

The higher plant height observed at flowering and 95 % podding in the narrow row spacing is largely attributed to the early canopy closure which encouraged apical growth over branching. The result agrees with Sarkodie et al[21], who reported that narrow row spacing increases the plant height.

The higher number of branches observed in the wider rows over the narrow rows could be because the plants in the wider row had more space to branch. The result agrees with those who reported that plants in wider spacing are capable of apportioning more resources to increase branch number per plant than plants in narrow rows.

The higher number of pods per plant recorded for wider rows could be as a result of the higher number of branches observed in the wider rows per plant. This confirm the report of Boquet[7] and Jukusko et al[13] that number of pods per plant decreases with increasing plant density per unit area which invariably results in less number of branches produced per plant.

The non-significant difference observed in the number of seed per pod for both narrow and wider row spacing is an indication that number of seed per plant is an inherent character in plants and is not affected by the row spacing. This result agrees with Sarkodie et al[21] who reported that row spacing does not affect number of seed per pod, but contrasted with Jukusko et al[13] who reported an increase in pod length and seed number per pod with increase in row and plant spacing in cowpea.

Table 4
Mean performance of yield and yield components traits for Soybean cultivars grown under different row spacing at Makurdi

	SDPOD			**BRPLT**				**SD100WT**		**HI**		
	Row spacing			**Row spacing**			**Row spacing**			**Row spacing**		
Variety	50cm	75cm	Mean	50cm	75cm	Mean	50cm	75cm	Mean	50cm	75cm	Mean
TGX 1448-2E	1.73	1.93	1.83	5.07	9.00	7.04	12.77	11.70	12.23	0.32	0.27	0.30
TGX 1904-6F	1.93	1.77	1.85	5.67	6.40	6.04	11.82	12.10	11.98	0.37	0.31	0.34
TGX 1935-3F	2.13	1.60	1.87	5.47	7.40	6.44	12.28	13.60	12.94	0.35	0.28	0.32
TGX 1945-1F	2.07	1.87	1.97	4.87	6.60	5.74	14.58	14.80	14.67	0.36	0.28	0.32
TGX 1951-3F	1.77	2.10	1.94	4.53	8.27	6.40	14.79	15.20	15.00	0.35	0.31	0.33
TGX 1951-4F	1.77	2.10	1.94	4.47	6.53	5.50	14.83	15.00	14.91	0.41	0.33	0.37
Mean	1.90	1.90	1.90	5.01	7.37	6.19	13.51	13.70		0.36	0.30	
SE Row Spacing	0.04ns			0.23**			0.18*			0.01**		
SE Variety	0.07ns			0.39**			0.30**			0.02*		
SE RSP x Variety	0.10**			0.55**			0.43**			0.37ns		

*= significant at P≤ 0.05, **= highly significant at P≤ 0.001, ns: non-significant difference, SE: standard error, RSP: row spacing, Var : variety

Table 5a
Effect of Row Spacing on Cost Benefit Ratio

	Production cost/ha (₦)	**Treatment**		**Difference (₦)**
		75cm (₦)	**50cm (₦)**	
Labour	Spraying	3000	3000	
	land preparation	20000	25000	5000
	planting/ fertilizer application	10000	10000	
	Weeding	8000	8000	
	Harvesting	8000	8000	
	Threshing	8000	10000	2000
Farm Input	Seed	14000	21000	7000
	seed dressing (seedrex)	1120	1680	560
	Herbicide	10000	10000	
	Fertilizer	28328	28328	
	TOTAL	116448	125008	8560
	Yield (Average)	3,038kg/ha	3,877kg/ha	839kg
Sales (₦85/kg)		**258,230**	**329,545**	**71,315**
Cost Benefit Ratio		**2.2**	**2.6**	**8.3**

Note: Cost Benefit Ratio ≤ 1 is advantage

Table 5b
Effect of Row Spacing on Quantity Cost Implications of Inputs used per Hectare

Input/labour used	**Quantity Used/ha**		**Cost (₦)**
	50cm	**75cm**	
Seed	84kg/ha	56kg	250/kg
Fertilizer (NPK)	100kg/ha	100kg	6000/50kg bag
Fertilizer (SSP)	138.8kg/ha	138.8kg	6000/50kg bag
Seedrex	21 satchet/ha	14 satchet	80/satchet
Herbicide (Pendeline)	2 litres/ha	2 litres	1500/litre
Herbicide (Paraquat)	3 litres/ha	3 litres	1000/Litre
Glyphosate	4 Litres	4 litres	1000/Litre
Spraying (Land Preparation) Spraying (Pre-emergence)	4 liters/ha 2 liters/ha	4 liters/ha 2 liters/ha	500/liter 500/liter

The higher 100 seed weight obtained from the wider row spacing over narrow row spacing could be due to better availability of nutrients and better translocation of photosynthates from the source to sink and may be due to higher accumulation of photosynthates in the seed as reported by Ahmed et al.[3] The result however, disagreed with the reports of Jason[12] and Boquet[7] that row spacing does not have effect on seed size.

The higher harvest index recorded for narrow row spacing could be as a result of the higher plant population per area in the narrow row spacing. Yemare et al[26] recorded lower harvest index in the wider spacing in onion and concluded that it might have been due to the production of more vegetative parts including flower parts which may direct to assimilate away from the economically important bulbs.

Kabir and Sarkar[14] also reported a significant interaction effect of row spacing on harvest index of Mung bean. They recorded the highest value from varieties at closer spacing and suggested that it was probably due to reduced vegetative biomass.

The grain yield per hectare was observed to be higher in the narrow row spacing than the wider row spacing. The higher grain yield in the narrow row spacing could be as a result of the higher plant population found in the narrow row spacing and the higher harvest index was also found in the narrow row spacing over the wider row spacing.

Kamara et al[16], Boquet[7] and Ball et al[5] reported similar results and concluded that reducing row spacing or increasing plant population reduces yield of individual plant, but increases yield per unit area.

The result also indicates that varieties TGX-1935-3F, TGX-1951-3F and TGX-1951-4F which gave the highest grain yield values of 4.0 tons and above were more adapted to narrow row spacing in Makurdi, Benue State than varieties TGX-1945-1F, TGX 1448-2E and TGX-1904-6F which had less than 4.0 tons per hectare. The result agrees with Jukusko et al[13] who reported similar result in cowpea and concluded that short duration varieties are more adopted to narrow row spacing than the late maturing varieties.

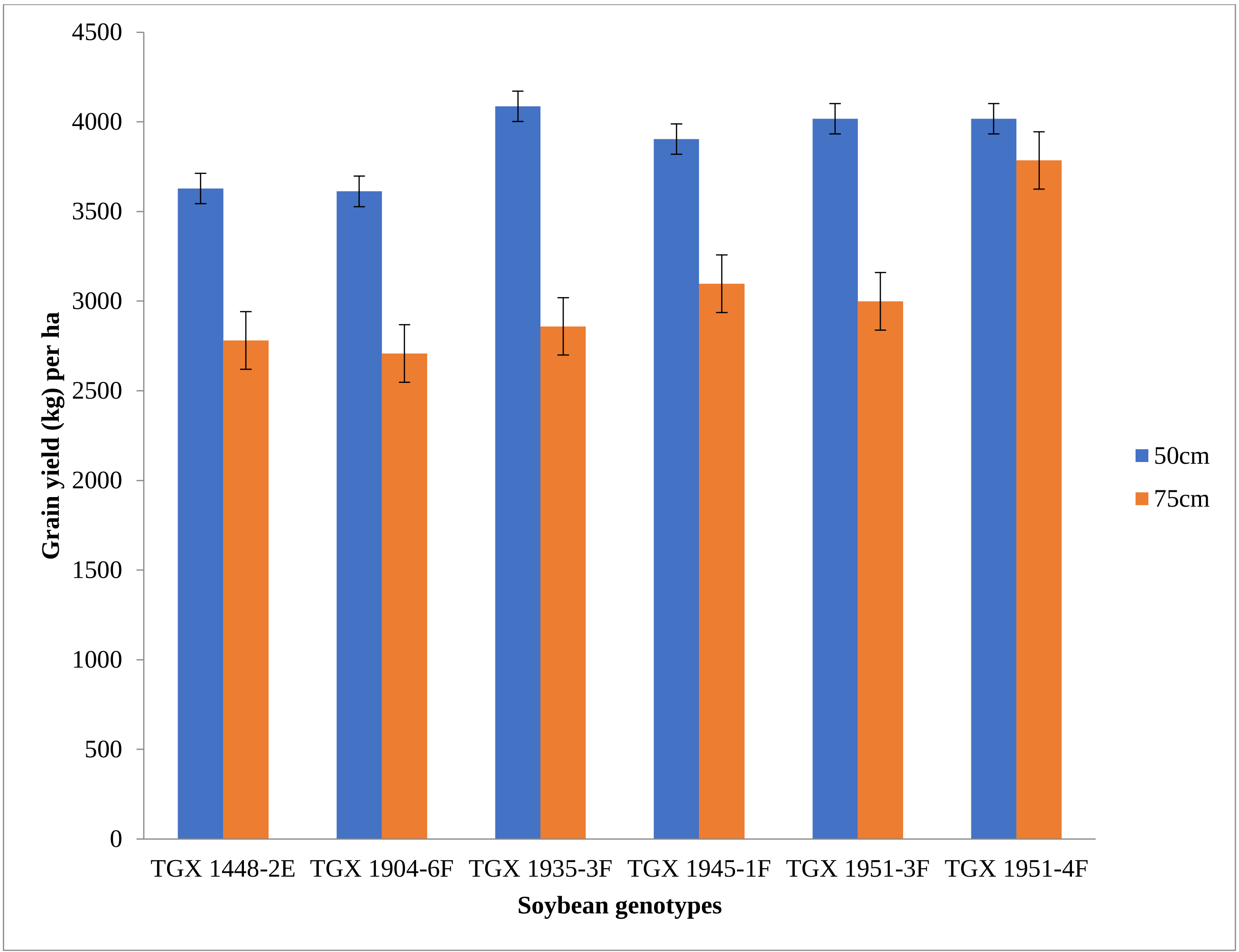

Figure 1: Effects of Inter-row Spacing on Grain Yield of Soybean Genotypes in Makurdi

Finally, the result of benefit cost ratio (BCR) also showed a high economic benefit of 8.9 when soybean was planted at narrow row spacing. The result agrees with the report of Jason[12].

Conclusion

This study shows that reducing row spacing or plant population from 75 cm x 10 cm to 50 cm x 10 cm significantly increased the plant height from 67.24 to 72.07 cm. Meanwhile, it reduced the number of branches per plant from 7.37 to 5.01 and number of pods per plant from 55.90 to 49.69 pods. However, the overall seed yield per plot and grain yield per hectare were found to be higher in 50cm x 10cm row spacing with an average of 3.9 tons per hectare. With respect to varieties, TGX-1951-4F, TGX-1951-3F and TGX-1945-1F had the highest grain yield of 3.9, 3.5 and 3.5 tons per hectare respectively as compared to other varieties which had lower yields. Cost Benefit Ratio (CBR) showed high advantage in growing soybean at 50 cm inter-row spacing than at 75 cm inter-row spacing.

Therefore, reducing inter-row spacing or increasing plant population reduces the performance of other yield parameters but increases the grain yield per m^2. Therefore, grain yield in soybean is largely a function of plant population per m^2. To increase soybean productivity in Makurdi Benue State of Nigeria, it is recommended that closer row spacing of 50 cm x 10 cm should be adopted for the soybean varieties tested.

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