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Influence of Plant Spacing and Time of Fertilizer Application on the Growth and Grain Yield of Soybean (*Glycine max* (L.) Merril)

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ABSTRACT: Time of fertilizer application and proper spacing increases yields, nutrient use efficiency, reduces nutrient losses and prevents damage to the environment. The objective of this study was to determine the optimum plant spacing and time of fertilizer application for growth and grain yield of soybean (Glycine max (L.) Merril) using a 3 x 5 factorial in a Randomized Complete Block Design (RCBD) and several parameters measured. Results obtained show that plant height increased significantly with earliness to times of fertilizer application up to 6 WAP and decreased at 8 WAP and this trend was observed to be similar for the number of leaves, branches and leaf size. Total dry matter and grain yield increased at the earliest time of fertilizer application from planting to 4 WAP, a decrease in plant spacing from 20 cm x 50 cm to 10 cm x 50 cm increased the grain yield (18.45% and 28.08%) and total dry matter (15.30% and 23.89%) in both cropping seasons. To maximize grain yield of soya bean, farmers in this locality should adopt narrower spacing of either S_1 (10cm x 50cm) or S_2 (15cm x 50cm) and early application of fertilizer at T_0 (at planting) to T_2 (4 WAP).

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Soybean (*Glycine max* L. Merril) is a leguminous grain crop that grows in tropical, subtropical and temperate climates. It cultivation is increasing in Nigeria because of its importance as a major food and cash crop and its wide use in the food and feed industry (Sanginga *et al*., 2002). The crop is unique among the other food legumes because it is used as a cheap source of protein. Soybean contains 35.1 % of protein while the green gram and cowpea contain only 22.9 % and 21.7 % of protein, respectively. It is highly nutritious and beneficial to human health and used in production of poultry feed as a raw material in supplementing the protein. It can be processed in to a wide range of food products for human consumption, such as textured vegetable protein (TVP), soya curd (tofu), soya ice cream, soya source, soya milk and soya oil. Apart from being a rich source of protein, it consist of 30 % carbohydrate, vitamins and minerals. It also contains 25 % oil, which makes it the most important crop for producing edible oil (IITA, 2009). In Nigeria, the crop is mostly produced in the savanna zones by smallholder farmers, where soils are depleted of nutrients with low yields. There is a huge gap between Nigeria's soybean consumption and total production, which leads to huge imports from other countries and this has implication for the import bill of the government and an overall effect on local currency. Mbanya, (2011) reported that small scale and commercial farmers can improve their productivity by using improved agronomic practices. The use of fertilizer and proper row spacing are considered important factors in increasing crop yield. Fertilizer should be applied at the right time, according to the growth stage and phenology of the plant. Fixen and Reetzs (2006) established that fertilizer best management practices are based on the concept of applying the fertilizer at the right rate, time and place. This implies that the exogenous nutrient for optimum yield must be applied as near as possible to the time the crop needs them in order to achieve optimum crop use efficiency and minimize its potential for environmental pollution. Plant spacing is another

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important agronomic factor that can cause substantial increase or decrease in yield of most crops hence, appropriate plant spacing is vital for the interception of enough sunlight necessary for optimum photosynthesis. Proper spacing ensures optimum plant growth through adequate utilization of moisture, light, and nutrients. Information on the right time of fertilizer application for soybean production is not substantial. As such, the present study sought to determine the optimum plant spacing and time of fertilizer application on the growth and grain yield of soybean (*Glycine max* L. Merril).

MATERIALS AND METHODS

Experimental site: A two-year (2016 and 2017 growing seasons) study was carried out from May to August, at the Research Farm, Department of Crop Science, Faculty Agriculture, University of Benin, Nigeria. The location lies between latitude 6º 14' and 7º 34' N and longitude 5º 40' and 6º 43' E on elevation of 162 m above sea level, in the rainforest agro-ecology of Nigeria. The monthly rainfall distribution pattern for the area is bimodal with peaks in June and September. Annual rainfall ranges from 1200 to 1450 mm spanning over eight months (March to October) with a dry spell in August. Temperatures show some variations throughout the years, with average monthly temperature varying between 24 ^{0}C and 33.5 ^{0}C. The soil is characterized by an ultisol derived from coastal sediments.

Source of planting materials: The soybean variety 'TGX 1440' (early maturing, erect type) was obtained from Institute of Agricultural Research and Training (IAR&T), Ibadan. The fertilizer used was procured from ADP, Benin City, Nigeria.

Experimental design and field layout: The experiment was laid out on a 3 × 4 factorial in a Randomized Complete Block Design (RCBD) with three replications. The treatments consisted of three planting space S_1 (10 cm × 50 cm) S_2, (15 cm × 50 cm) and S_3 (20 cm × 50 cm) giving a plant population of 200,000, 133,333 and 100,000 plants ha $^{-1}$ respectively and five times of fertilizer application T_0 (at planting), T_1 (2 WAP), T_2 (4 WAP), T_3 (6 WAP) and T_4 (8 WAP).

Cultural Practices: Two seeds were planted per stand at a depth of 5 cm and spaced at 50 cm between rows and 10, 15 and 20 cm within row. Plants were thinned to 1 seedling per stand 2 weeks after planting. Three manual weeding, with the use of the native hoe were done at 3, 6 and 9 weeks after planting (WAP). Hand pulling of weed was done when necessary and compound fertilizer NPK 15:15:15 was applied at the rate of 300 kg/ha depending on the treatment. Soybean was harvested at 80% physiological maturity when the pods have turned brown and seeds were at the hard-dough stage with moisture content between 14 and 16 % (Dugje *et al*., 2009). The moisture content of grain samples was determined with the Farmex MT-16 grain moisture tester.

Data Collection: Vegetative parameters on five randomly selected plants taken at 8 weeks after sowing were plant height (cm) measured with a meter rule as (distance from the ground level to the main shoot apex), number of leaves per plant and number of branches (were visually counted and the average recorded per plant) , leaf size (was taken as the product of the length and width of fully expanded leaves from five randomly selected plants and the average recorded per plant) while the reproductive characters measured were days to 50 % flowering (taken by counting the number of days from when crop was sown to when 50 % flowered), days to maturity (number of days from planting to physiological maturity), At harvest, (when at least 80 % of pods have dried and turned brown), number of pods /plant (were visually counted and the average recorded per plant), weight of pods/plant (g) and weight of grains (were taken with a digital scale (Furi spec) as the weight of pods and grains harvested from five plants and the average recorded (g)/plant), The weights of leaf, stem, empty pods and grain were expressed as g/m ^{2} and summed to obtain total dry matter (TDM) and shelling % and grain yield (kg/ha) were calculated.

Data Analysis: The data collected were subjected to statistical analysis of variance (ANOVA) using statistical analysis system (SAS) statistical package. Significant means were separated using least significant difference (LSD).

RESULTS AND DISCUSSION

Plant height was not significantly ($p < 0.05$) influenced by spacing however, the number of leaves (62.32) were highest at a wider spacing of 20 cm x 50 cm compared with narrower spacing of 10 cm x 50 cm and 15 cm x 50 cm which produced significantly lower number of leaves (50.21 and 54.33) respectively. Number of branches increased from 13.44 to 16.13 as spacing increased from 10 cm x 50 cm to 15 cm x 50 cm and a further increase in spacing did not result in a significant increase in the number of branches (Table1). In both years, time of fertilizer application had significant differences in all the vegetative parameters measured except for number of leaves in 2016, planting season (Table 1). Early application of fertilizer at planting up to 6 WAP significantly ($p < 0.05$) produced a positive response of most of the vegetative characters measured compared with late application of fertilizer at 8 WAP. Application of fertilizer at 8 WAP significantly produced the lowest value for most parameters measured. Plant height increased from 37.83 cm to 45.90 cm in 2016 cropping season with early application of fertilizer at planting while significant decrease in plant height was observed in both years when fertilizer was applied late at 8 WAP. This trend was observed to be similar for the number of leaves, branches and leaf size (Table 1).

Table1: Row spacing and time of fertilizer application influenced some vegetative characters of soybean (*Glycine max* (L.) plant

	2016	2017	2016	2017	2016	2017
Treatments	Plant height (cm)	Plant height (cm)	Number of leaves	Number of leaves	Number of branches	Number of branches
Spacing (cm)						
10 x 50	40.12^{a}	24.49^{a}	50.21^{b}	22.75^{a}	13.44^{b}	7.58^{a}
15 x 50	38.43^{a}	22.21^{a}	54.33^{b}	20.21^{a}	16.13^{a}	6.68^{a}
20 x 50	37.26^{a}	32.49^{a}	62.32^{a}	20.21^{a}	16.56^{a}	6.60^{a}
Significance	Ns	Ns	*	Ns	*	Ns
Fertilizer application (WAP)						
At planting	45.90^{a}	23.79^{a}	47.87^{a}	23.72^{a}	17.67^{a}	7.39^{a}
2	42.44^{ab}	24.38^{a}	62.87^{a}	22.11^{a}	17.41^{a}	7.03^{ab}
4	40.82^{ab}	24.56^{a}	54.13^{a}	23.33^{a}	15.50^{ab}	7.72^{a}
6	44.54^{ab}	23.17^{a}	51.50^{a}	22.86^{a}	14.92^{ab}	7.92^{a}
8	37.83^{b}	18.42^{b}	50.89^{a}	15.12^{b}	13.02^{b}	5.14^{b}
Significance	*	*	Ns	*	*	*

Means with the same letter are not significantly different at 5% level of significance; Ns - not significant at 5% level of probability
** - Significant at 5% level of probability*

Narrower spacing of 10 cm x 50 cm and 15 cm x 50 cm flowered earlier than plants that were widely spaced at 20 cm x 50 cm, however, there were no significant differences in days to maturity as influenced by spacing. Earliest days to 50% flowering and days to maturity were attained at application time of 2 – 4 WAP, application of fertilizers at 6 and 8 WAP prolonged days to 50% flowering and days to maturity (Table 2). In 2016, number of pods per plant increased with increase in time of fertilizer application, from planting to 4 WAP and then decreased at 6 and 8 WAP and this result is similar to 1000 seeds weight (g) recorded in both years. Significantly lower 1000 seed weights of 95.51 g and 66.22 g and 95.14 g and 64.09 g were produced at 6 and 8 WAP respectively while spacing of 15 cm x 50 cm increased pod weight from 9.15 g to 10.22 g in 2017, (Table 3).

Harvest index increased with earliness in fertilizer application. Plants that received fertilizer at planting up to 4WAP in the 2016 cropping season increased in their harvest index compared with other treatments (Table 4). Similarly, in 2017 cropping season, application of fertilizer 2WAP increased harvest from 0.33 to 0.35 and decreased significantly to 0.29, 0.26 and 0.25 at 4, 6 and 8 WAP respectively.

Table 2: Leaf size (cm), days to 50% flowering and maturity of soybean (*Glycine max* (L.) plant as influenced by row spacing and time of fertilizer application

	Cropping seasons					
	2016	**2017**	**2016**	**2017**	**2016**	**2017**
Treatments	**Leaf size (cm^2)**	**Leaf size (cm^2)**	**Days to 50% flowering**	**Days to 50% flowering**	**Days to maturity**	**Days to maturity**
Spacing (cm)						
10 x 50	34.93^{a}	17.94^{a}	52.52^{b}	53.11^{ab}	93.20^{a}	94.79^{a}
15 x 50	37.56^{a}	14.78^{ab}	52.71^{b}	52.32^{b}	95.13^{a}	95.32^{a}
20 x 50	35.41^{a}	13.43^{b}	53.28^{a}	53.20^{a}	95.21^{a}	95.38^{a}
Significance	Ns	*	*	*	Ns	Ns
Fertilizer application (WAP)						
At planting	31.15^{b}	12.81^{b}	52.89^{b}	54.16^{b}	92.16^{b}	93.02^{b}
2	48.11^{a}	18.46^{a}	52.71^{b}	54.24^{b}	93.11^{b}	93.13^{b}
4	30.19^{b}	16.38^{ab}	52.62^{b}	54.51^{a}	93.23^{b}	94.17^{a}
6	31.45^{a}	13.89^{ab}	53.20^{ab}	55.03^{ab}	95.19^{a}	95.03^{a}
8	37.28^{ab}	13.03^{ab}	55.08^{a}	55.32^{a}	95.14^{a}	95.01^{a}
Significance	*	*	*	*	*	*

Means with the same letter are not significantly different at 5% level of significance; Ns - not significant at 5% level of probability
** - Significant at 5% level of probability*

Table 3: Effect of row spacing and time of fertilizer application on number of pods, pod weight/plant (g) and 1000 seeds weight (g) of soybean (*Glycine max* (L.) plant

	Cropping seasons					
	2016	**2017**	**2016**	**2017**	**2016**	**2017**
Treatments	**Number of pods\plant**	**Number of pods\plant**	**Pod weight/plant (g)**	**Pod weight/plant (g)**	**1000 seeds weight (g)**	**1000 seeds weight (g)**
Spacing (cm)						
10 x 50	50.11^{a}	35.23^{a}	15.58^{b}	9.15^{b}	98.82^{a}	68.71^{a}
15 x 50	53.24^{a}	37.42^{a}	16.63^{ab}	9.22^{a}	99.20^{a}	62.26^{a}
20 x 50	54.56^{a}	35. 84^{a}	16.21^{a}	10.91^{a}	101.84^{a}	75.05^{a}
Significance	Ns	Ns	*	*	Ns	Ns
Fertilizer application (WAP)						
At planting	56.46^{a}	38.36^{a}	14.65^{ab}	9.78^{ab}	104.50^{a}	74.30^{a}
2	54.79^{ab}	39.75^{a}	13.16^{b}	9.90^{ab}	98.84^{a}	70.45^{a}
4	57.42^{a}	45.19^{a}	16.58^{a}	12.34^{a}	100.96^{a}	72.90^{a}
6	53.84^{b}	37.42^{a}	13.73^{ab}	9.89^{b}	95.51^{b}	66.22^{b}
8	53.92^{b}	34. 45^{a}	14.41^{ab}	8.80^{b}	95.14^{b}	64.09^{b}
Significance	*	Ns	*	*	*	*

Means with the same letter are not significantly different at 5% level of significance; Ns - not significant at 5% level of probability
** - Significant at 5% level of probability*

Early application of fertilizer from planting to 4 WAP increased shelling percentage, lower shelling percentage of 54.06 % and 51.66% were produced at 6 and 8 WAP. Total dry matter (2.85 t/ha and 2.07 t/ha) were lowest with the widest spacing of 20 cm x 50 cm while grain yield (1.38 t/ha and 1.14 t/ha) was highest at narrower spacing of 10 cm x 50 cm in both cropping season. Total dry matter and grain yield increased at the earliest time of fertilizer application from planting to 4 WAP and further increase with time to 6 and 8 WAP decreased the yield (Table 5). The positive response in some of the vegetative and yield characters with earliness to fertilizer application shows that the time of applying NPK fertilizer can affect the availability and the absorption of nutrients needed by plants, so that these factors can also be a limiting factor for growth and yield of soybean plants. This invariably tends to enhance photosynthetic activities and hence performance of the crop better than late application and so plants should be fertilizer with fertilizers high in nitrogen and phosphorus contents especially during their initial growth period.

Table 4: Effect of row spacing and time of fertilizer application on harvest index of soybean (*Glycine max* (L.) plant

	Cropping seasons	
Treatments	**2016 Harvest index**	**2017 Harvest index**
Spacing (cm)		
10 x 50	0.35^{a}	0.33^{a}
15 x 50	0.34^{ab}	0.31^{b}
20 x 50	0.33^{b}	0.30^{b}
Significance	Ns	*
Fertilizer application (WAP)		
At planting	0.31^{a}	0.33^{a}
2	0.33^{a}	0.35^{a}
4	0.34^{a}	0.29^{b}
6	0.29^{b}	0.26^{b}
8	0.28^{b}	0.26^{b}
Significance	Ns	*

Means with the same letter are not significantly different at 5% level of significance; Ns - not significant at 5% level of probability
** - Significant at 5% level of probability*

Table 5: Yield and yield attributes of soybean (*Glycine max* (L.) plant as influenced byrow spacing and time of fertilizer application

	Cropping seasons					
	2016	**2017**	**2016**	**2017**	**2016**	**2017**
Treatments	**Shelling (%)**	**Shelling (%)**	**Total dry matter (t ha^{-1})**	**Total dry matter (t ha^{-1})**	**Grain yield (t ha^{-1})**	**Grain yield (t ha^{-1})**
Spacing (cm)						
10 x 50	60.15^{a}	55.18^{a}	3.88^{a}	3.37^{a}	1.38^{a}	1.14^{a}
15 x 50	58.34^{a}	54.07^{a}	3.71^{a}	2.80^{a}	1.27^{a}	0.87^{a}
20 x 50	56.79^{a}	52.48^{a}	2.85^{b}	2.07^{b}	0.95^{b}	0.64^{b}
Significance	Ns	Ns	*	*	*	*
Fertilizer application (WAP)						
At planting	61.10^{a}	55.49^{ab}	3 .65^{a}	2.32^{a}	1.15^{ab}	0.78^{ab}
2	61.17^{a}	55.97^{ab}	3.51^{a}	3.20^{a}	1.07^{ab}	1.12^{a}
4	62.33^{a}	58.13^{ab}	3.82^{a}	2.17^{a}	1.30^{a}	0.65^{ab}
6	51.78^{a}	54.06^{bc}	2.95^{b}	2.13^{ab}	0.87^{b}	0.57^{b}
8	56.79^{a}	51.66^{c}	2.97^{b}	1.92^{b}	0.84^{b}	0.51^{b}
Significance	Ns	*	*	*	*	*

Means with the same letter are not significantly different at 5% level of significance; ns - not significant at 5% level of probability
** - Significant at 5% level of probability*

Novizan, (2002) stated that efficiency of fertilizer use can be achieved through right dosage, right way, right application time and balance according to the needs of plants. The low values observed in the vegetative and yield characters with 8 WAP compared with early applications of 2, 4 and 6 WAP could probably be due to the fact that fertilizer application was delayed and plants had to rely on nutrients from the soil alone for a longer period and this may not meet the nutrient needs of plants. Again, nitrogen which is an integral part of chlorophyll and enzymes essential for plant growth process may have been limiting in the soil system, the supply of N from soils and nodules may not have been adequate to fully meet the crop needs before active nodules form on roots and in these cases soybean growth and yield can be increased by early application of fertilizer to the plant from soil. Relying on nutrients from the soil alone will not meet the needs of plants. Therefore, plants need to be given additional nutrients from the outside, in the form of fertilizers (Prihmantoro, 2001), especially in their early growth stage. Application of NPK fertilizer in appropriate time and amount will increase the availability of sufficiently large nitrogen in the soil and this availability is useful for the process of protein formation which is used in the process of cell division and rapid growth of tissues and organs. Application of chemical fertilizers is necessary for enhancing crop yields and sustaining soil fertility. However, inappropriate or excessive fertilizer application does not guarantee constant increase in yields, it might result in low nutrient use efficiency, and can cause environmental problems in agro-ecosystems. The favorable response in number of leaves and branches with the wider spacing especially in 2016 cropping season could probably be due to less competition for light interception and utilization than those narrowly spaced plants. The wider spacing could probably have improved the root growth both vertically and horizontally as compared with the narrower spacing. The improved leaf size and earliness to flowering with the narrower spacing might be attributed to the amount of light intercepted by the crop, especially in the early stages of growth, which is a simple function of plant population and row spacing (Charles-Edwards and Lawn, 1984). Board *et al*., (1992) reported that, soybean crops sown in narrow rows are able to achieve full light interception faster with lower leaf area index than those in wide rows, and consequently have higher yield potential. Liu and Su (2016) reported that leaves exposed to optimum light are thicker, have a greater mass per area, a higher volume of photosynthetic machinery per unit leaf area and higher growth rates. The increase in harvest index and seed weight due to earliness in fertilizer application can be attributed to increase in nutrient uptake and assimilates by plants which mobilized into seeds and ultimately increase in the harvest index (Araei *et al*., 2014). The superior improvement in Shelling percentage (SP) in 2017, cropping season with respect to early application of fertilizer is an indication of more kernels with fewer by-product, suggesting a great potential in the enhancement of SP through breeding (Yol *et al*., 2018). The higher grain yield and total dry matter (TDM) with the narrower spacing could be attributed to greater crop biomass found with the narrower spacing as supported by Falodun *et al.* (2015). Bowers *et al*., (2000) stated that narrow rows should be used to optimize yield in early maturity soybean cultivars.

Wider spacing reduced yield due to total reduction in plants per hectare and consequently space is not fully utilized. This result supports the work of James *et al*., (1996) who concluded that, high plant population and narrow row spacing in early cultivars of soybean utilized environmental factors effectively, to produce substantial higher yield.

Conclusion: Narrow plant spacing and early application of fertilizer increased total dry matter and grain yield of soybean. Since early-maturing soybean varieties generally do not produce a dense canopy, the planting space should be reduced to ensure early canopy closure so as to maximize light interception, grain and total dry matter yield of soybean plant.

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