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# Interactive Effects of Light and Planting Density on the Growth and Yield of Soybean

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## Abstract
The objective of this study was to investigate the effect of different planting density and light intensities on the growth and yield of soybean. This was with the view to provide appropriate information on planting densities and actual light intensities required for the growth and yield of soybean. A screenhouse was constructed to minimize extraneous factors such as pests and rodents, supply of water other than the amount specifically applied. The intensity of light was also determined using a digital luxmeter LX 1000. The intensities of average light determined were 5764 (100%) and 3517 (61%). The four treatments of light regimes are $L_1$ = 100% light, $L_2$ = 61% light, $L_{10}$ = 5 weeks in 100% light, thereafter in 61% light and $L_{20}$ = 5 weeks in 61% light, thereafter in 100% light. The seeds of the soybean were sown at the rate of five seeds ($P_5$), three seeds ($P_3$) and one seed ($P_1$). They were watered daily with 200 ml of tap water in the morning and 200 ml of tap water in the evening until they were fully established. The results obtained showed shoot height, number of leaves and leaf area of soybeans were more enhanced under 61% light or partial light intensity and when sown at the rate three seeds ($P_3$). The yield components of soybean were more enhanced when placed in 5 weeks in 100% light, thereafter in 61% light and when sown at the rate three seeds ($P_3$). This study concluded that better growth and yield were obtained with partial light ($L_2$) with three planting density ($P_3$).

## 1. Introduction

Growth and yield in plants is the result of the interaction of many complex processes, each of which is influenced either directly or indirectly by various environmental factors such as light, nutrient availability, water, temperature, etc. Light is one of the abiotic factors which influence the morphological growth and yield of plants. Light plays an important role in seed germination, plant development and yield. As a primary source of energy, light is one of the most important environmental factor for plant growth [8]. The intensity and quality of light are essential for the growth, morphogenesis and other physiological responses of plants [10] [4] [7]. The activating process in plants results in quantitative modification of growth and developmental pattern in response to changes in the environmental factors such as light and temperature.

Plant density which can be defined as the number of plants per square meter, has a major influence on growth, biomass, crop yield and economic profitability of plants [1] [3]. Plant density can affect canopy architecture, light conversion efficiency, duration of vegetative growth, dry matter production, seed yield and ultimately, the productivity of a crop. Therefore, optimizing plant density, which may be defined by both the number of plants per unit area and the arrangement of plants on the ground, is a prerequisite for obtaining higher productivity. This is because the number of plants per unit area is an important determinant of final seed yield, it is the first yield component to be established at the early crop cycle. Planting density promote land management and resources used, increase in yield per unit area, quality production of fruit crops, ease intercropping operation, plant protection and harvesting [6].

Soybean (*Glycine max* (L.) Merril, belongs to the family Leguminosae, subfamily Papilionoidae. It is a short-day plant (i.e. flowering occurs when the nights begin to lengthen) grow well on almost all types of soil, with the exception of deep sands with poor water retention. With respect to climate, the soybean grows best in temperate and tropical zones [15]. Soybeans have been grown as a food crop for thousands of years in China and other countries of East and South East Asia and in Africa.

In spite of the vast potentials of soybeans, it is still constrained by a number of problems which include limitations posed by soil and other environmental factors such as light and high temperature. The shading effect of taller intercrops and the shadowing effect received from the skies during the production season of soybeans in this area could limit the performance of the crop. Producers therefore need information on basic soybean production practices including determination of optimum seeding rates. Soybean growers are also adopting reduced tillage practices and need more information on cultivar and seeding rate performance with higher residue planting conditions. Previous researches have been mainly focused on the effects of different light intensities on the growth and development of soybeans [5]. However, very little is known about the effects of different light intensities and planting density on the growth, yield of soybean. For these reasons, it is necessary to investigate the suitable planting density and light intensities combined for the production of soybean. Hence, this study.

# 2. Materials and Methods

## 2.1. Experimental Seeds

The Seeds of soybean (*Glycine max* of variety TGx1740 - 2F) used for this experiment were collected from the Institute of Agricultural Research and Training, (IAR and T) Ibadan, Oyo State, Nigeria. A screenhouse was constructed to minimize extraneous factors such as pests and rodents, supply of water other than the amount specifically applied. The mean daily temperature under the screenhouse was taken with the aid of a thermometer. The intensity of light was also determined using a digital luxmeter LX 1000. Relative humidity was measured using a hygrometer.

## 2.2. Raising of Seedlings

Seventy- two plastics pots (of 21 cm in diameter and 20 cm in depth) containing bored holes of about 3 mm each at the bottom to allow for proper drainage and prevent water logging during the course of the experiment. These pots were filled with 5 kg of collected soil. These pots were divided into four treatments of light regimes which are $L_1$ = 100% light, $L_2$ = 61% light, $L_{10}$ = 5 weeks in 100% light, thereafter in 61% light and $L_{20}$ = 5 weeks in 61% light, thereafter in 100% light. The seeds of the soybean were sown at the rate of five seeds $P_5$, three seeds $P_3$ and one seed $P_1$ per pot. They were watered daily with 200 ml of tap water in the morning and 200 ml of tap water in the evening until they were fully established.

## 2.3. Measurement of Growth and Yield Parameters

Sampling was carried out after three weeks of sowing when the seedlings were fully established. This was further done at 5-days interval. Measurements of growth parameters were taken. These parameters include shoot height, leaf length and leaf width, these were measured with the aid of a metric rule calibrated in cm. Number of leaves were counted manually. Leaf area (LA) was determined as follows;

LA = L x W x 0.75. L and W are the leaf's length and width respectively and 0.75 is the correction factor of the leaf (Vile *et al.,* 2005).

LAR = LA/Ws . Ws represents the dry weight

At harvest, the following yield parameters were taken. The number of pods per plant and number of seeds per pod were counted manually. Seed fresh weight and seed dry weight, pod weights were measured after seeds shelling with the aid of digital balance. Treatment wise, 50 seeds from each regime were selected at random and weighed on a digital balance. These were used to determine the crop yield.

All the data collected were subjected to Analysis of variance (ANOVA) and means were separated using Least Significant Difference (LSD) Post–hoc at $p \geq 0.05$ level of probability.

# 3. Results and Discussion

## 3.1. Effect of Different Regimes of Light and Planting Density on the Growth Parameters of Soybean

The shoot heights of soybean at different treatment increases gradually from the beginning to the end of the experimental period. The result showed that shoot height of ($L_2$ was the highest and ($L_{10}$) had the lowest shoot height.

There was no significant difference in shoot height among the light treatments at $p \leq 0.05$ (Figure 1).

The shoot heights of the soybean at different planting densities increase gradually from the beginning to the end of the experimental period. At the end of the experimental period, the shoot height of $P_3$ was the highest and $P_1$ had the lowest shoot height. There was no significant difference in shoot height of $P_5$, $P_3$ and $P_1$ at $p \leq 0.05$ (Figure 2).

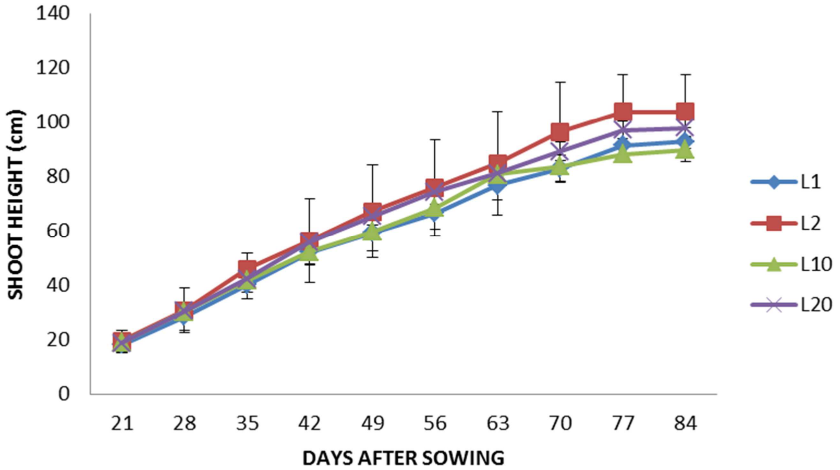


***Figure 1.*** *Shoot Height of Soybean Under Different Light intensity. L1 = 100% light, L2 = 61% light, L10 = 5 weeks in 100% light, thereafter in 61% light and L20 = 5 weeks in 61% light, thereafter in 100% light.*

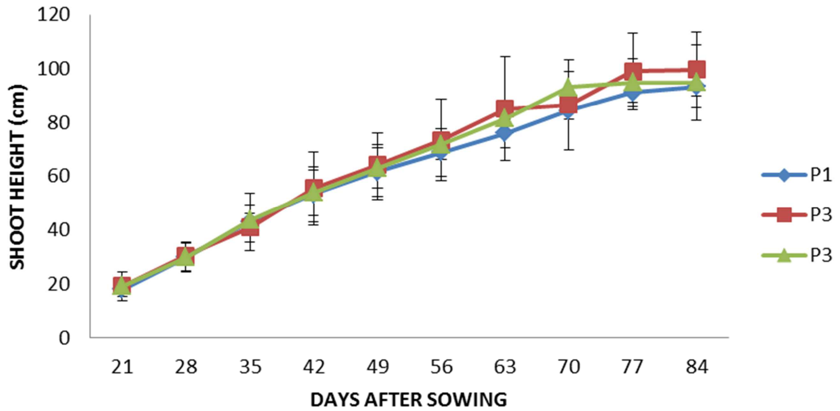


***Figure 2.*** *Shoot Height of Soybean Under Different Planting density. P5 = five seeds, P3 = three seeds and P1 = one seed.*

The number of leaves of soybean increases from the beginning to the end of the experiment. $L_2$ recorded the highest number of leaves while $L_{10}$ was the lowest. $L_2$ was significantly different from other treatments at $p \leq 0.05$. (Figure 3). There was no significant difference among $L_1$ and $L_{20}$ from 56th day of the experiment to the end of the experiment The number of leaves $P_3$ TGx1740-2F variety was the highest and $P_1$ and $P_5$ had the lowest. There was significant difference in number of leaves $P_1$ to $P_3$ and $P_5$ treatments at $p \leq 0.05$ but there was no significant difference in number of leaves $P_3$ to $P_5$. (Figure 4).

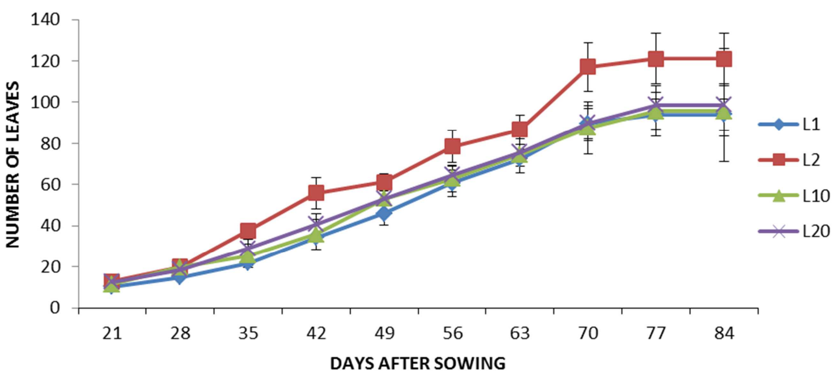


***Figure 3.*** *Number of Leaves of Soybean Under Different Light intensity. L1 = 100% light, L2 = 61% light, L10 = 5 weeks in 100% light, thereafter in 61% light and L20 = 5 weeks in 61% light, thereafter in 100% light.*

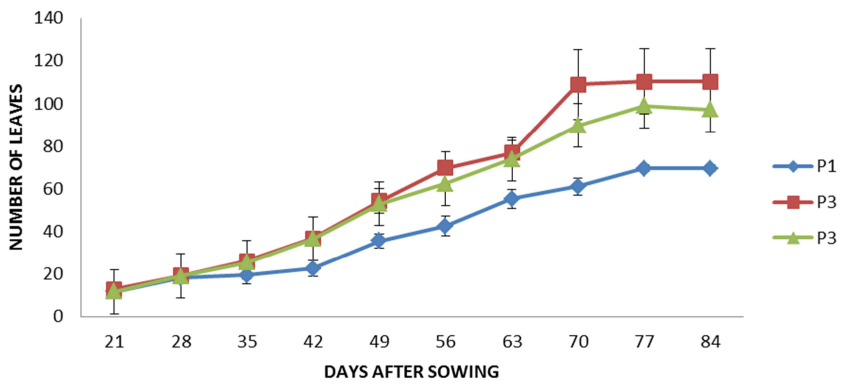


***Figure 4.*** *Number of Leaves of Soybean Under Different Planting density. P5 = five seeds, P3 = three seeds and P1 = one seed.*

The leaf area of soybean plant under different light regimes increases gradually from the beginning up till the 56th day where there was sharp decline in the leaf area till the end of the experiment. At the 56th day the leaf area of $L_2$ was the highest and $L_{10}$ was the lowest. There was no significant difference in leaf area of all the treatments towards the end of the experiment at $p \leq 0.05$. (Figure 5 and 6).

The leaf area of soybean plant at different planting density increases gradually from the beginning up till the 56th day where there was sharp decline in the leaf area till the end of the experiment. At the 56th day the leaf area of $P_3$ TGx1440 was the highest and $P_1$ was the lowest. There was no significant difference in leaf area of all the treatments towards the end of the experiment at $p \leq 0.05$.

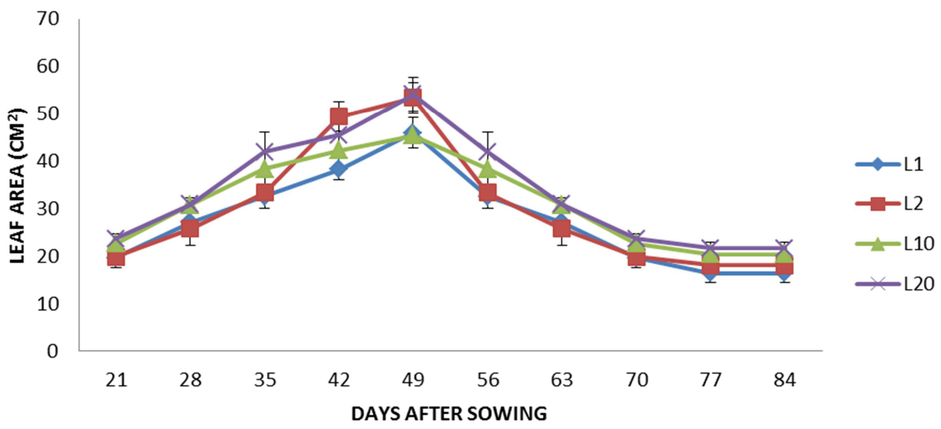


***Figure 5.*** *Leaf Area of Soybean Under Different Light intensity. L1 = 100% light, L2 = 61% light, L10 = 5 weeks in 100% light, thereafter in 61% light and L20 = 5 weeks in 61% light, thereafter in 100% light.*

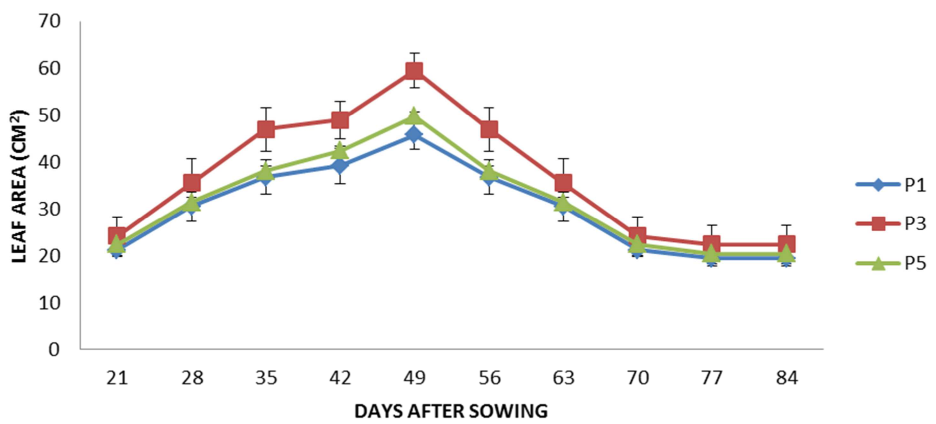


***Figure 6.*** *Leaf Area of Soybean Under Different Planting density. P5 = five seeds, P3 = three seeds and P1 = one seed.*

The higher shoot heights, number of leaves and leaf area observed in the plant treatments made to receive light at 61% ($L_2$) or moderate light was a result of sufficient light available to these plants under his condition. The lowest shoot heights, number of leaves and leaf area observed in the plant treatments five weeks in 100% light thereafter in 61% may be due to increase and thereafter decrease in the light intensities. However, this maybe as a result of its non-adaptability to shading and an adaptation to reduce water loss at all levels of treatments.

The higher shoot heights, number of leaves and leaf area observed in the plant treatments with three planting densityy ($P_3$) and lowest in the treatment with one planting density ($P_1$) was as a result of the environmental resources which are more efficiently utilized and converted to biomass by mixed stands of crops ($P_3$) than by pure stands ($P_1$) [9]. Meanwhile, the effect of plant density was more pronounced on the leaf area formed. One can infer that differences in soybean leaf area varied with the intensity of competition of light, water and nutrients.

### 3.2. Yield and Yield Components of the Two Soybean Varieties Under Different Light Intensity and Planting Density Regimes

The number of pods of soybean increased nominally from the beginning to the end of the experiment, follow by a sharp decreased and increase nominally towards the end of experimental period. The $L_2$ treatment was the highest while the $L_1$ treatment was the lowest. The $L_2$ was significantly different from other treatments. There was significant different in all other treatments except for L20 and $L_{10}$ in which there is no significant different among the treatments at $p \leq 0.05$. (Table 1). The highest pod length recorded in $L_{20}$ plants might be as a result of enough light enrichment leading to high rate of photosynthesis in this treatments compared to $L_{10}$ treatments with the lowest pod length. Therefore, changing the light intensity from low to high favors increase in pod length.

The number of pods of soybean at different planting density of all the treatments increased gradually from the beginning to the end of the experimental period. From the results obtained, there was no significant different in the number of pods among the treatments ($P_1$, $P_3$ and $P_5$) from the beginning to the end of the experiment in the two varieties at $p \leq 0.05$. (Table 1). However, most of the research results have been reported that yield per unit area was higher when cuttings are densely planted [12] [7] [12]. This account for the highest pod length in $P_5$ plants compared to other treaments in both varieties. Mean size (length) of plant parts tends to diminish as plant are crowded. This does not conform to this study because as plant density is increased the pod length also increases. Therefore, observations of the density dependence of plant growth are helpful in assessing competitive interference in plants [14].

The number of seed per pod of soybean subjected to different light intensity and density regimes is shown in Table 1. The $L_{10}$ regime had the highest number of seed per plant with 2%, 8% and 23% increase than $L_{20}$, $L_2$ and $L_1$ regimes respectively. The highest number of seeds recorded in $L_2$ plant might be due to ability of these plants to explore available resources with less competition compared to other treatments [12].

For the density regimes, The $P_1$ regime had the lowest number of seed per pod. There was no significant difference among $P_3$ and $P_5$ at $p \leq 0.05$. Plant density affects the total yield. By increasing plant density, yield increases [2]. This accounts for highest number of seeds in $P_5$ plants. This may also be attributed to higher number of root nodules in the $P_5$ plants compared to other treatments.

The pod weight of the two varieties of soybean subjected to different light intensity and density regimes as shown in Table 1. For the light regimes, $L_{10}$ had the highest pod weight of with $L_1$ having the lowest pod weight. The highest pod weight of $L_{10}$ plants with $L_1$ plants having the lowest pod weight in both varieties was because of the higher light interception and light use efficiency of this plants compared to other treatments. Considering the density regimes, the pod weight of $P_3$ was significantly higher than $P_1$ and $P_5$ respectively at $p \leq 0.05$. There was no significant difference between $P_1$ and $P_5$ at $p \leq 0.05$. The pod weight of $P_3$ plants which was significantly higher than other treatments is attributed to better water utilization, better radiant energy utilization, increased photosynthesis and increase leaf production.

The fresh seed weight of the two varieties of soybean subjected to different light intensity and density regimes as shown in Table 1 revealed that $L_{10}$ had the highest fresh seed weight and $L_1$ had the lowest fresh seed weight. The fresh seed weight of $L_{10}$ was found to be significantly different from $L_{20}$ but the fresh seed weight of $L_1$ and $L_2$ were not significantly different at $p \leq 0.05$. The observed higher fresh seed weight in $L_{10}$ and the lowest fresh seed weight of $L_1$ plants in both varieties is as a result of increased photosynthesis which is the sole cause of biomass production of the crop. Low light intensity enhanced reduced accumulation of photosynthates. This resulted to the lowest fresh seed weight observed in $L_1$ plants. The $P_1$ regime had the highest fresh seed weight plant with 49% and 33% increase than $P_3$ and $P_5$. [11] reported that an increase in density probably cause the increase in competition between plants and hence, lead to decrease in availability of nutrients to each plants. This resulted to the higher fresh seed weight observed in $P_1$ plants compared to $P_3$ and $P_5$ with higher densities.

The dry seed weight of the two varieties of soybean subjected to different light intensity and density regimes is shown in Table 1. Considering the light intensities regimes, $L_{10}$ had the highest dry seed weight while $L_2$ the dry seed weight of $L_2$ was the lowest. There was no significant difference between the dry seed weights of $L_1$ and $L_{20}$ but a significant difference was observed between the dry seed weights of $L_2$ and $L_{10}$ at $p \leq 0.05$. The highest dry seed weight observed in $L_{10}$ plants in both varieties was due to water, light and nutrient utilization of these plants compared to other treaments For the density regimes, $P_1$ was found to be. The significant difference of $P_1$ from $P_3$ and $P_5$ was as a result of shading effects among $P_3$ and $P_5$ plants and less competition for the same resource use in $P_1$ plants compared to $P_3$ and $P_5$ plants.

***Table 1.*** *Yield and Yield Components of Soybean Varieties Evaluated under different Light intensity and Planting density regime.*

| TRAITS | No of pod per plant | No of seed per plant | pod weight (g) | Fresh seed weight (g) | Dry seed weight (g) |
|---|---|---|---|---|---|
| Light regime | | | | | |
| $L_1$ | 48.89[b] | 43.22[a] | 10.79[b] | 7.66[c] | 4.69[a] |
| $L_2$ | 38.22[b] | 49.61[a] | 7.94[b] | 8.29[bc] | 4.34[b] |
| $L_{10}$ | 90.33[a] | 53.34[a] | 13.94[b] | 15.38[a] | 6.27[a] |
| $L_{20}$ | 80.78[a] | 52.28[a] | 10.96[a] | 13.03[ab] | 5.37[a] |
| LSD | 17.24 | 16.13 | 4.11 | 4.77 | 2.36 |
| Density | | | | | |
| $P_1$ | 56.25[a] | 45.99[c] | 10.41[a] | 13.73[a] | 6.30[a] |
| $P_3$ | 69.13[a] | 51.13[a] | 11.60[a] | 9.24[b] | 4.20[b] |
| $P_5$ | 68.29[a] | 51.7[a] | 10.73 | 10.30[ab] | 4.56[ab] |
| LSD | 18.56 | 13.97 | 3.56 | 4.13 | 2.05 |
| Mean | 64.56 | 11.40 | 10.91 | 11.09 | 5.62 |
| CV | 63.25 | 48.83 | 56.55 | 64.54 | 33.23 |

* Means with the same letter within the same Colum are not significantly different at $P < 0.05$ by LSD test. L1 = 100% light, L2 = 61% light, L10 = 5 weeks in 100% light, thereafter in 61% light and L20 = 5 weeks in 61% light, thereafter in 100% light. P5 = five seeds, P3 = three seeds and P1 = one seed

## 4. Conclusion

The interactive effects of light and planting density enhances the growth and yield of soybean.

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