International Journal of Agriculture and Environmental Sciences
ISSN: 3108-088X | Volume 2 Issue 3, 10-16, July-September 2026
DOI: https://doi.org/10.64137/3108088X/IJAES-V2I3P102

Received: 19/05/2026 Revised: 28/06/2026 Accepted: 02/06/2026 Published: 14/07/2026

Scholastic Research Publication

Original Article

Effect of Plant Spacing on Growth and Yield Performance of Soybean (Glycine max L. Merrill) in Wannune, Tarka Local Government Area, Benue State, Nigeria

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ABSTRACT: *A field experiment was conducted during the 2025 cropping season at the Teaching and Research Farm of the Federal Polytechnic, Wannune, Benue State, Nigeria, to evaluate the effect of plant spacing on the growth and yield performance of soybean (Glycine max L. Merrill). The experiment was laid out in a Randomized Complete Block Design (RCBD) comprising four spacing treatments: 15 cm × 30 cm, 20 cm × 35 cm, 30 cm × 38 cm and 30 cm × 40 cm, replicated four times, resulting in 16 experimental plots. Data were collected from 80 randomly selected plants on plant height, leaf area, number of leaves, number of flowers, number of pods and number of seeds per plant. The data obtained were subjected to Analysis of Variance (ANOVA), and treatment means were separated using the Least Significant Difference (LSD) test at a 5% probability level. Results indicated that spacing had no significant effect on vegetative growth parameters during the early growth stages but significantly influenced growth and yield attributes at later stages. The widest spacing (30 cm × 40 cm) produced the highest plant height, leaf area and number of leaves, whereas the spacing of 30 cm × 38 cm recorded the highest number of flowers, pods and seeds per plant. The smallest values for all measured parameters were consistently obtained at the spacing of 15 cm × 30 cm. The study concluded that 30 cm × 38 cm spacing optimized plant population and resource utilization, achieving better yield performance under the agro-ecological conditions of Wannune, Benue State. In this sense, the 30 cm × 38 cm spacing is indicated for soybean crops in the area studied and similar areas.*

KEYWORDS: *Soybean, Plant Spacing, Growth, Yield, RCBD, Benue State, Wannune, Tarka.*

1. INTRODUCTION

Soybean (Glycine max L. Merrill) is one of the world's most important grain legumes because of its high nutritional value and extensive industrial applications. Cultivated for 1000s of years and a key source for plant protein & edible oil, soybean is native to East Asia. It is used in making soy milk, tofu, soy sauce and fermented bean paste; defatted soybean meal (with a great quantity of the oil extracted from it) provides an inexpensive high-quality protein formula for animal feeds as well as processed foods.

Soybean seeds consist of 38–45% protein and around 20% oil, making soybean the most nutrient-dense grain legume crop. Soybean has great importance due to its contribution towards food security, animal nutrition and industrial production (manufacture of vegetable oil, biodiesel pharmaceuticals and cosmetics as well as a number of applications in the chemical industry) Berglund et al. (2010), Hartman et al., 2011).

In addition to its nutritional value, soybean contains a number of health-promoting properties attributed to the presence of bioactive components such as isoflavones and phytoestrogens. The consumption of soybean products has been linked to reduced risk factors for cardiovascular diseases, osteoporosis, certain cancers and menopausal symptoms (Messina 2009) Furthermore; this crop acts on the improvement of soil fertility through symbiotic nitrogen fixation thus decreasing dependence on inorganic nitrogen fertilizers which contributes with the sustainability of cropping systems Salvagiotti etal., 2008.

Soybean production steadily increased over the years in Nigeria owing to high demand from households, livestock industries and agro-processing sectors. Benue State, tagged as the Food Basket of the Nation, remains one of the soybean-producing states in Nigeria. Even so, average yields of barley obtained by farmers still fall far below the yield potential of this crop as it is constrained to a large extent due to inadequate agronomic management practices (low soil fertility conditions), diseases and pests pressure in addition to an inappropriate plant population density which leads harvest losses up tf 70% every year proposed Sanginga et al.

Plant spacing directly affects plant population per unit area and is an important agronomic factor in the efficient use of growth resources, such as solar radiation, water, nutrients and space. Unnecessarily small spacing can lead to plants competing more, less airflow, and therefore disease issues and poor individual plant performance. On the other extreme, overly spacious spacing causes underutilization of land and low yield per unit area. Proper spacing promotes canopy architecture, light interception and photosynthetic efficiency, ultimately improving grain yield (Zhang et al.; Van et al.). The importance of proper spacing in soybean production has therefore received considerable attention among agronomists worldwide.

Although several studies have reported the influence of plant spacing on soybean growth and yield, recommendations are often location-specific because crop response varies with environmental conditions, soil characteristics, rainfall distribution, and management practices. In Wannune, Tarka Local Government Area of Benue State, soybean production is widely practiced; however, there is limited information regarding the optimum spacing required to maximize growth and yield under the prevailing agro-ecological conditions of the area.

2. OBJECTIVE OF THE STUDY

Consequently, this study was undertaken to evaluate the effect of plant spacing on the growth and yield performance of soybean in Wannune, Benue State, Nigeria.

Specifically, the study aimed to:

- The Effect of Different Planting Spaces on the Growth and Production of Soybean
- optimize spacing related to maximum soybean growth and yield under the soil and climatic conditions of Wannune.
- determine the impacts of planting density on soybean yield and its components.

The current study was therefore designed to test the hypothesis that varying planting spacings would have a considerable effect on soybean plant growth and yield, and further find out what optimum spacing can be established for maximum production from soybeans under the agro-ecological conditions of Wannune in Benue State.

3. MATERIALS AND METHODS

3.1. EXPERIMENTAL SITE

The experiment was conducted at the Teaching and Research Farm of the Federal Polytechnic, Wannune, Benue State, Nigeria. Wannune lies within the Southern Guinea Savanna agro-ecological zone of Nigeria. This area has an average annual rainfall of 1,200–1,500 mm with a rainy season from April through October and dry weather between November and March. The experimental area soil is mostly sandy loam, which is appropriate for soybean growth.

3.2. EXPERIMENTAL MATERIALS

The materials used for the experiment included:

- Certified soybean (Glycine max) seeds
- Measuring tape
- Cutlass
- Hoe
- Rope and pegs
- Recording book
- Pen and pencil
- Weighing balance
- Single Super Phosphate (SSP) fertilizer
- Knapsack sprayer
- Insecticide (Combat)

3.3. LAND PREPARATION

The experimental field was cleared manually with a cutlass and hoe. The land was plowed and harrowed to obtain a fine tilth before ridges were constructed. All weeds, roots, and other unwanted materials were removed from the field before planting.

3.4. EXPERIMENTAL DESIGN AND TREATMENTS

The experiment was laid out in a Randomized Complete Block Design (RCBD) with four treatments replicated four times, giving a total of sixteen (16) experimental plots. Each plot was measured appropriately with adequate spacing between plots and blocks to minimize interference.

The treatments consisted of four planting spacings:

- T_1: 15 cm × 30 cm
- T_2: 20 cm × 35 cm
- T_3: 30 cm × 38 cm
- T_4: 30 cm × 40 cm

These spacing treatments were evaluated for their effects on the growth parameters of soybean.

3.5. PLANTING

Planting was carried out at the onset of the rainy season. Two soybean seeds were sown per hole at the designated spacing treatments. Seedlings were later thinned to one healthy plant per stand after establishment to ensure a uniform plant population.

3.6. FERTILIZER APPLICATION

Single Super Phosphate (SSP) fertilizer was applied at the recommended rate two weeks after planting using the side-placement method approximately 15 cm away from each plant stand.

3.7. WEED CONTROL

Weeding was done by labor with a hoe realizado. The first weeding was carried out two weeks after planting; The second before flowering, to reduce competition with weeds.

3.8. PEST AND DISEASE MANAGEMENT

Pests and diseases were controlled using Combat insecticide applied according to the manufacturer's recommendation during the flowering stage of the crop.

3.9. DATA COLLECTION

There were five (10) randomly selected plants per plot to determine growth characters and yield. A total of 160 plants were sampled and assessed during the whole experiment since there are 16 plots (4 treatments × 4 replications). The parameters recorded were:

- Plant height (cm)
- Leaf area (cm^2)
- Number of leaves per plant
- Number of flowers
- Number of pods per plant
- Number of seeds per plant

3.10. HARVESTING

Harvesting was carried out when the soybean pods turned brown and reached physiological maturity. The pods were harvested manually, threshed, cleaned by winnowing, and the grains were weighed for analysis.

3.11. STATISTICAL ANALYSIS

Data collected on the growth and yield parameters were subjected to Analysis of Variance (ANOVA) appropriate for a Randomized Complete Block Design (RCBD). Treatment means were separated using the Least Significant Difference (LSD) test at the 5% level of probability ($P \leq 0.05$) where significant differences existed.

4. RESULTS AND DISCUSSIONS

4.1. RESULT

At 2 weeks after sowing (2 WAS), the tallest plants were recorded in T4 (3.75 cm), followed by T3 (3.50 cm), while T1 produced the shortest plants (2.88 cm). Since the result was not significant (NS), the differences among treatments were due to chance and not because of treatment effects.

At 4 WAS, T3 recorded the highest plant height (8.12 cm), followed by T2 (7.70 cm) and T4 (7.22 cm), whereas T1 remained the lowest (5.12 cm). As before, the differences were not statistically significant, and treatments did not significantly affect plant height at this stage.

The effect of treatments on plant growth also became important at the 5% probability level at 6 WAS. The tallest plants were found in T4 (15.40 cm) versus the average for each treatment was quite similar with 14.82 cm, 15.05 and therefore T2 >T3>t1 being smaller (11.25cm). Since the LSD value was 0.92, the difference between T1 and the other treatments exceeded the LSD value, indicating real treatment effects.

The result in Table one revealed that treatments had little influence on plant height during the early stages of growth but significantly affected plant height during the later growth stage. T4 was the best treatment for plant height development.

TABLE 1 Effect of Spacing on Plant Height (cm) at Different Growth Stages

Treatment	2WAS	4WAS	6WAS
T1	2.88	5.12	11.25
T2	3.12	7.70	14.82
T3	3.50	8.12	15.05

T4	3.75	7.22	15.40
LSD (5%)	1.23	3.84	0.92
Significance	NS	NS	*

Source: Self

At 2 WAS, the highest leaf area was recorded in T2 (9.23 cm²) followed by T4 (8.43 cm²), while T3 produced the smallest leaf area (7.25 cm²). The differences were not significant.

At 4 WAS, T2 maintained the highest leaf area (16.93 cm²) followed by T1 (16.12 cm²) and T4 (15.70 cm²), while T3 remained the lowest (15.55 cm²). The treatments still had no significant effect.

The treatment means at only 6 WAS were significant with T4 having the largest leaf area (30.05 cm²), followed by T3 (28.78cm²) and then finally T2 (27.87cm²)-with a smallest value of leaf area for treated control plants-T1(26.15 cm).

This problem is totally goes out of This suggested That treatments had no impact on leaf area in a early growth stages, significant different Terms was seen from 6 WAS. T4 produced the largest leaf area and therefore had the greatest potential for photosynthesis and dry matter accumulation.

TABLE 2 Effect of Spacing on Leaf Area (cm^2) at Different Growth Stages.

Treatment	2WAS	4WAS	6WAS
T1	7.43	16.12	26.15
T2	9.23	16.93	27.87
T3	7.25	15.55	28.78
T4	8.43	15.70	30.05
LSD (5%)	3.44	2.94	2.13
Significance	NS	NS	*

Source: Self

At 2 WAS, T4 recorded the highest number of leaves (3.75) followed by T3 (3.25), while T1 and T2 had the lowest values (3.00 each). The differences were not significant.

The number of leaves ranged from 5.50 to 5.57 with little variation among treatments at 4 WAS, and the differences were non-significant (P >0, 05).

There were substantial differences at 6 WAS. T4 followed by T3 and T2 produced more number of leaves (14.75), (14.50) and (13.75) respectively under plant whereas a minimum leaf was found in the treatment contains no KIN which occurred with less tally (12.25) as shown in T1

Pruning treatments significantly influenced leaf production only during early phases of growth. Treatment effects were significant from 6 WAS, but T4 stimulated the highest leaf production.

TABLE 3 Effect of Spacing on Number of Leaves per Plant at Different Growth Stages

Treatment	2WAS	4WAS	6WAS
T1	3.00	5.57	12.25
T2	3.00	5.50	13.75
T3	3.25	5.50	14.50
T4	3.75	5.50	14.75
LSD (5%)	1.31	1.01	1.69
Significance	NS	NS	*

Source: Self

The number of flowers per plant changed significantly over the different treatments at 6 WAS. The highest Flower Number was produced by T3 (7.00) followed with T4 (6.25), T2 (5.50), and the lowest is found on T1 (3, 75).

The same pattern emerged at 8 WAS. T3 had the highest number of flowers (6.75) and was significantly higher than T4 (5.50) and T2 (4.75); however, it did not differ from other treatments compared to one another; meanwhile, T1 remained lower in numbers of flowerings at 3.25

The significance level signifies that treatment effects were significant by all measures at both stages.

This means that flowering was significantly influenced by the treatments. T3 significantly increased flower production, indicating that it was even more effective at driving reproductive growth than the other treatments ($P<0.05$).

TABLE 4 Effect of Spacing on Number of Flowers per Plant at Different Growth Stages

Treatment	6WAS	8WAS
T1	3.75	3.25
T2	5.50	4.75
T3	7.00	6.75
T4	6.25	5.50
LSD (5%)	1.22	1.73
Significance	*	*

Source: Self

Treatments differed greatly at 6 WAS in the number of pods per plant. Maximum number of pods (16.00) were produced in treatment T3 followed by treatments T4 and T2 having (15.50) and (14.75), while minimum pod production was recorded under control i.e., T1 (13.25).

Seed count per plant also displayed prominent variation at 8 WAS. The highest number of seeds per plant was obtained from T3 (55.00), followed by T4 (47.75), and then T2 (43.50). The significance level at 8 WAS indicates a highly significant difference among treatments.

The treatments significantly affected yield components. T3 was the best treatment for pod and seed production, indicating that it was the most effective treatment for improving yield.

TABLE 5 Effect of Spacing on Number of Pods and Number of Seeds per Plant at Different Growth Stages

Treatment	6WAS	8WAS
T1	13.25	38.79
T2	14.75	43.50
T3	16.00	55.00
T4	15.50	47.75
LSD (5%)	1.22	1.46
Significance	*	**

Source: Self

4.2. DISCUSSION

4.2.1. TABLE 1: EFFECT OF SPACING ON PLANT HEIGHT AT DIFFERENT GROWTH STAGES

The results in Table 1 showed that plant spacing had little influence on soybean plant height during the early stages of growth but became increasingly important as the crop matured. At 2 weeks after sowing (2 WAS), plant height ranged from 2.88 cm in T1 to (3.75 cm) in T4, while at 4 WAS, the values varied from (5.12) cm in T1 to 8.12 cm in T3. Differences observed across spacing treatments during these early stages, however, were generally non-significant.

At 6 WAS, though differences were significant T4 was the highest (15.40 cm) followed by T3 (15.05 cm), while lowest value of plant height at this stage observed in T1 (11.25cm). This increased stem height at closer or optimum spacing is likely due to intra-plant competition for light, which stimulated upward extension of the plant.

This finding is in agreement with Zhang et al. (2024), who noted that optimized canopy spacing for soybean production enhances morphological developmental characteristics as well as increases in plant height under high water conditions. Similarly, Stokes et al. (2025) stated that the effects of row spacing for soybean growth and canopy development depend on environmental conditions and plant density.

The results therefore indicate that plant spacing significantly influenced soybean vegetative growth under the agro-ecological conditions of Wannune.

4.2.2. TABLE 2: EFFECT OF PLANT SPACING ON LEAF AREA OF SOYBEAN

Leaf area increased progressively with crop age irrespective of treatment. At 2 WAS, leaf area ranged from (7.25 cm^2) to (9.23 cm^2), while at 4 WAS, values ranged from (15.55 cm^2) to (16.93 cm^2. Differences among treatment groups during these periods were not significant.

As early as 6 WAS, large differences were observed with T4 yielded maximum leaf area (30.05 cm²) followed by T3 (28.78cm²), T2 (27.87cm²), and the least was recorded in a treatment plot T1 which showed minimum leaf area i.e., (26.15cm²).

Hence, the larger leaf area observed under optimum spacing might be due to better utilization of environmental resources, including sunlight, soil nutrients and moisture. Provision of adequate space prevents excessive competition and promotes leaf expansion, leading to better photosynthetic efficiency.

Previous studies have shown that canopy configuration optimization can improve radiation interception and photosynthetic capacity in soybean production systems. Adequate spacing, which leads to better canopy architecture, promotes leaf area development and is associated with higher yield.

Therefore, the results suggest that appropriate plant spacing enhanced canopy development and photosynthetic activity of soybean in Wannune.

4.2.3. TABLE 3: EFFECT OF PLANT SPACING ON NUMBER OF LEAVES PER PLANT

The number of leaves per plant increased steadily with crop age in all treatments. The values from (3.00) leaves per plant in T1 and T2 to (3.75) leaves in the treatment T4 at two WAS, whereas at four WAS were slightly changed ranging from (5.50) to (5.57) leaves/plant There were no statistically significant differences between these.

Spacing treatments, however, had highly significant effects on leaf production at 6 WAS. T4 produced the maximum leaves (14.75), followed by T3 (14.50) and T2 (13.75), whereas the minimum number of leaves was found in T1 (12.25).

The increased number of leaves recorded in T4 and T3 could be attributed to better access to resources associated with growth, as well as more effective arrangement or formation of foliage. More leaf area produces more photosynthetic surfaces, leading to increases in biomass and reproduction.

Li et al. Soybean 611 (2025) optimized row spacing for increased canopy transmittance, supporting branching and vegetative growth in soybean. Likewise, proper spacing is shown to increase the number of leaves in soybean plants because light penetrates better into the canopy.

4.2.4. TABLE 4: EFFECT OF PLANT SPACING ON NUMBER OF FLOWERS PER PLANT

The number of flowers per plant is an important reproductive parameter because it directly influences pod formation and grain yield. All spacing treatments differed significantly in both observations.

The maximum number of flowers per plant was observed at T3 (7.00), and the minimum value was produced by T1 3.75). Likewise, at 8 WAS T3 was still the best with (6.75) flowers per plant followed by T4 (5.50),T2(4.75) whereas poorest performance exhibited in all other transplantation levels(T1)(3.25).

The flowering performance of T3 was the best, demonstrating that this spacing treatment provided the ideal compromise between plant population and resource availability. Narrow spacing can create intense competition for nutrients and light, while wide-planted trees may not fully exploit the land available to them.

Findings by van Versendaal et al., 09 (2025) propose that adequate spacing among the plants decreases intra-specific competition and improves leaf coverage, which favors reproductive growth in soybean. Moreover, it is known that modern soybean cultivars respond differently to optimized spacing because of more favorable assimilate partitioning towards reproductive organs.

4.2.5. TABLE 5: EFFECT OF PLANT SPACING ON NUMBER OF PODS AND SEEDS PER PLANT

Yield components represent the ultimate measure of treatment effectiveness in soybean production. The results showed significant differences among treatments for both pod and seed production. Uncontrolled multi-line spacing At 6 WAS, number of pods per plant were recorded higher rate in T3 treatment (16.00) and lower value found at T1 with 13.25 pod/plant (Table 10). Likewise, seeds plant-1 at 8 WAS was highest in T3 (55.00) followed by T4 and with least inT1with a mean of (38.79), (43.50) and (47.75) seeds perplant respectively T2.

The best pod and seed production with T3 indicates that this spacing treatment ensured the most appropriate balance between inter-plant competition for light and nutrients and soil moisture utilization. Ayan and Kafle (2013) reported that soybean plants under optimum spacing produce more branches, flowers and pods owing to better allocation of resources. Studies have revealed that the yield of soybean can be improved by adjusting canopy spacing, which affects photosynthetic efficiency, which is a result of Canopy architecture and resource use efficiency. Zhang et al. Seraglio et al. (2024) observed yield increases in the range of 5% under optimized spacing configurations. When optimum spacing is maintained, soybean plants can compensate for most of the changes in vegetative density by branching and pod formation Huang et al.

Therefore, T3 appeared to represent the optimum spacing treatment for soybean production under the environmental conditions of Wannune, Tarka Local Government Area of Benue State.

5. CONCLUSION

The study demonstrated that plant spacing significantly affected soybean growth and yield in Wannune. While spacing had minimal influence during the early stages of growth, significant effects became evident during the reproductive phase.

The findings showed that:

- T4 produced the best vegetative growth, recording the highest plant height, leaf area and number of leaves.
- T3 produced the highest reproductive and yield parameters, including flowers, pods and seeds per plant.
- T1 consistently produced the lowest values, indicating poor performance under the prevailing environmental conditions.
- Overall, T3 emerged as the optimum spacing treatment for soybean production in Wannune, Tarka Local Government Area of Benue State.

5.1. RECOMMENDATIONS

Based on the findings of this study, the following recommendations are made:

- Farmers in Wannune and similar agro-ecological zones should adopt the spacing represented by T3 for soybean production because it produced the highest number of flowers, pods and seeds.
- Farmers interested in obtaining vigorous vegetative growth for purposes such as fodder production may adopt the spacing represented by T4.
- Extension agents should educate farmers on the importance of proper plant spacing in soybean production to improve productivity and profitability.
- Soybean growers should avoid excessively narrow or excessively wide spacing because both conditions may reduce yield through increased competition or underutilization of land resources.
- Agricultural institutions and researchers should promote the use of optimum spacing recommendations suitable for the Southern Guinea Savanna ecology of Benue State.

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