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Influenced of Planting Distance and Fertilization on the Production Performance of Select Manchuria Soybean (Glycine max (L.) Merrill) in Tupi, South Cotabato

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Abstract

Soybean considered one of the largest food protein sources, soybeans are widely used for industrial purposes, and most soybean oil meal is used for animal feed. A series of experimental studies on the varietal adoption in some places in the Philippines, the development of a package of technology to increase yield performance was conducted. The study was conducted at Tupi, South Cotabato, from January 8 to April 7, 2025. The purpose of the study was to determine yield performance of Manchuria Select soybean relative to the planting distance and fertilization rates applied. The study carried out using Split Plot Randomized Complete Block Design (RCBD). Factor A as main plot with three (3) different planting distances while Factor B as sub-plot with fertilization composed of 4 treatments replicated 3 times. The effects of the two factors relative to the yield performance of Manchuria select soybean were not significantly different relative to plant height, number of plants harvested per plot, number of unfilled pods, number of seeds per pod, weight of 100 seeds, seed yields per plot, computed seed yield per hectare, shattering and lodging. However, the number of pods per plant and the number of filled pods were significantly influenced by both the planting distance and with no significance difference on the fertilizer applied. A significant effect on the interaction of planting distance shows that plants planted in wider spacing and full inorganic fertilization together promote the best pod development. Additionally, similar trends were observed for the number of filled pods relative to the effect in terms of planting distance and fertilizer applied.

The study concludes that Select Manchuria soybean planted in the closest spacing at A1 (50cm x10 cm), combined with B2 (100% Inorganic) and B4 (50% organic + 50% inorganic) fertilizers consistently produced higher yields with comparable results A2 (40cm x10 cm). On the other hand, soybean planted on the widest spacing at A3 (70cm x10 cm) underperformed in yield metrics despite relatively good seed weights. On the other hand, soybean planted on the widest spacing at A3 (70cm x 10 cm) underperformed in yield metrics despite relatively good seed weights. The findings indicate that 100% inorganic fertilization at 50 cm × 10 cm spacing is the most economically viable option, offering the highest yields, net income, and ROI. While 100% organic fertilization aligns with environmentally sustainable goals, it is less profitable and more costly, especially when used exclusively. The combination treatment presents a viable compromise, with moderate costs and returns, potentially suitable for integrated sustainable farming practices. Furthermore, planting distance plays a critical role, with closer spacing significantly improving productivity and profitability.

Keywords: *planting distance; Select Manchuria; Soil Analysis; Pod; Yield*

1.0 Introduction

Agriculture remains relevant as the primary source of food, jobs, and supporting the economy ensuring food security and economic growth most especially in rural areas. One important crop is soybean, which is used for making oil, animal feed, and many food products.

Soybean (Glycine max L. Merrill), commonly known as "Utaw" in the Philippines, is a legume crop belonging to the family Leguminosae or Fabaceae and sub-family Papilionaceae. In other Asian countries, it is known as "Wonder bean," "Great treasure," "gift from God," and "source of liquid gold" (Bureau of Plant Industry Library, n.d.).

Soybean is an industrial crop primarily used as a source of oil and protein. Considered one of the largest food protein sources, soybeans are widely used for industrial purposes, and most soybean oil meal is used for animal feed (FAO-UN, 2023). Further, comparable to milk and eggs, soybean seeds have a high protein content of 35 to 40%. It is also high in minerals, vitamins, and oil (20%). As a primary source of protein, it is commonly utilized in feed composition. In the Philippines, it is commonly used for processed foods and food additives such as soya milk, soy sauce, tokwa, tofu, and many more. Also, the soybean plants are used as silage and animal fodder for livestock production.

Based on worldwide production, Brazil has the highest soybean production, followed by the United States and Argentina, respectively (World Population Review, 2022). According to Agflow, 99% of the soybeans imported from the United States cover our demand, and only 1% comes from local production. Relative to these statistics, our country had a lower supply of soybeans than our demand, thus, we are highly dependent on imports to address the increasing domestic needs, whether for food or feed.

The national government started the national soybean production program to boost local production and meet the requirements of the increasing demand for livestock and poultry. A series of experimental studies on the varietal adoption in some places in the Philippines, the development of a package of technology to increase yield performance was conducted decades ago; however, despite the government support, even up to now, the dream of an import fee commodity is still beyond reach.

In order to minimize import dependence, the Department of Agriculture initiated the development of the soybean industry through the Bureau of Plant Industry and the Institute of Plant Breeding of the University of Los Banos, Laguna. To continue this endeavor, the Department of Agriculture released Memorandum Order No. 15, Series of 2021, to include soybeans under the National Corn Program which aims to increase local production and improve soybean quality which will address the crops shortage, increase also farmer's income and to ensure stable supply of animal feeds ingredients on the increasing growth of livestock and poultry (Department of Agriculture, 2021). Hence, the need to increase soybean local production through various research on Soybean technology development, such as fertilization recommendation and crop management technology, is significant to achieve this objective.

This study aimed to determine the performance of Select Mancuria soybean relative to the planting distance, fertilization rate applied and significant difference in the growth and yield of the study. This research will provide significant insights and could be a basis of production technology with location-specific results to help the farmers increase the local production of soybean in the region.

2.0 Methodology

2.1 Research Design

The study carried out using Split Plot Randomized Complete Block Design (RCBD). Factor A as main plot with three (3) different planting distances while Factor B as sub-plot with fertilization composed of 4 treatments replicated 3 times (Meena et al., 2023). Factor A represented different planting distance A_1 (50cmx10cm), A_2 (40cmx10cm), and A_3 (70cmx10cm) at 3-5cm depth, while the Factor B comprised of different fertilization applied B_1 (No fertilization0, B_2 (100% Inorganic Fertilizer), B_3 (100% Organic Fertilizer) and B4 (50% Inorganic Fertilizer + 50% Organic Fertilizer). Fertilization rate was based on the result of soil analysis.

2.2 Field Layout

A total area of 1078 square meters used in this study for the evaluation of soybean plants. The row length was at 5 m and number of rows was 4 which based in the guidelines set by the National Cooperative Test- Field Technical Working Group. At the distance of 10 cm in between hill, the number of hills in every plot was 50. The width was determined based on the planting distance multiplied by 4 rows. Outside boarder of 5 meters and 0.5 meter in between treatment were provided.

2.3 Research Locale

The study conducted at Tupi Research and Experiment Station located at Barangay Bololmala, Tupi, South Cotabato, Philippines, from January 8, 2025 to April 11, 2025. Soil sampling was conducted at the experimental site prior to the start of the study to identify level of nutrients in the soil such as pH, NPK content and organic matter.

2.4 Experiment of Crop

Select Manchuria variety of Soybean seed used in this study and sourced out at Tupi Research and Experiment Station. This variety officially registered under the National Seed Industry Council (NSIC) as NSIC 2020 Sy 16. The seed were properly selected, sorted and subjected to germination test result of 87% were used in this study.

2.5 Cultural Practices

2.5.1 Land Preparation

The area for planting soybeans prepared thoroughly, well-drained, free of weeds. Four-wheel drive tractor was used during the land preparation where plowing and harrowing were alternately done to allow soil moisture conservation, uniform seedling emergence, weed control and proper root development. After the land preparation, measured the required size and established the experimental site based on the experimental lay-out.

2.5.2 Seed Inoculation

Soybean seeds were inoculated using the Slurry method at the ratio of 100 grams of inoculant per 10 kilograms of Soybean seeds and moisten with 1 glass of water. Soybean seeds were put on the sacks and mixed thoroughly with inoculant and little amount of amount until the seed were evenly coated and dry. The inoculated seeds were placed in a cool dry place not directly exposed to sunlight and sowed immediately (Department of Agriculture, Regional Field Office No. 02, 2021).

2.5.3 Seed Sowing and Seeding Rate

Seed sowing was done using the hill method by dropping 2 seeds/hill at 10 cm apart along the furrows of 40 cm, 50 cm & 70 cm distance. The hill spacing at 10 cm apart and the seeds with soil at a depth of 3-5 cm (Department of Agriculture RFO 12, n.d.).

2.5.4 Fertilizer Application

Readily available inorganic and organic fertilizers were bought from the local market. Fertilization rate recommendation was based on the result of soil analysis. Every crop has fertilizer recommendations to reach its optimum yield. For soybean, below are the recommended fertilizer rates based on Bureau of Soils and Water Management.

Based on the soil analysis result, it was noted that the nitrogen level was low, Phosphorus was high and Potassium was low with the soil pH of 6.5. Therefore, the recommended rate of the nutrient of NPK were 30-10-40.

The soil test recommendation result in kilogram per hectare (kg/ha). Determined the amount of fertilizer material, using the below formula;

$$\text{Amount of Fertilizer (kg)} = \frac{\text{Recommended Rate of the Nutrient (RR)}}{\text{\% Nutrient (kg/bag) in the fertilizer}}$$

Table 1. Amount of Inorganic Fertilizer per planting distance

Factor A (Planting Distance	ASP (m²)	Urea		Ammonium Phosphate		Muriate of Potash	
		(kg/ha)	(g/plot)	(kg/ha)	(g/plot)	(kg/ha)	(g/plot)
A_1 - 50cm x 10 cm	10		48.00		50.00		67.00
A_2- 40cm x 10 cm	8	48.00	38.40	50.00	40.00	67.00	53.60
A_3- 70cm x 10 cm	14		67.20		70.00		93.80

For organic fertilizer treatment, the used of organic compost fertilizer which were bought from the local market with nutrient content of Nitrogen (N) at 0.9%, Phosphorus (P) at 3.92% and Potassium (K) of 1.18%.

Using the formula,

$$\text{No. of bags/ha} = \frac{\text{Nutrient Requirement (RR)}}{\text{Nutrient Content (\%) x 50 (kg/bag) in the fertilizer}}$$

The limiting factor is the nutrient having the greatest number of bags and to convert into the requirement per plot, below is the formula used;

$$\text{Amount of Fertilizer (kg)} = \frac{\text{amount of fertilizer (bag)} \times PS \times 50}{10{,}000}$$

Where: PS = plot size

Table 2. Amount of Organic Fertilizer per planting distance

Factor A (Planting Distance)	PS (m^2)	Organic Fertilizer	
		(bag/ha)	(kg/plot)
A_1 - 50cm x 10 cm	10		3.40
A_2 - 40cm x 10 cm	8		2.72
A_3 - 70cm x 10 cm	14	68	4.70

2.5.5 Water Application

There is no irrigation used during the study. It was solely dependent on the rainfall since during the study duration enough rainfall was occurred sufficient to meet the water requirement of the soybean.

2.5.6 Crop Protection

Pest control was carried out by using fungicide 5 days after planting and pesticide application 15 and 25 days after planting. To control the weed population, manual weeding was applied. Synthetic pest control was brought at the local market.

2.5.7 Harvesting

Harvesting of mature crops 80-90 days after planting depending on the variety. This was determined by the yellowing and shredding of leaves and the change in color of the pods from green to brown. Harvesting done by uprooting or cutting the stalk at the base during the early morning or late afternoon to avoid the shattering losses. Harvested plants were sun-dried for two days before data gathering. (Department of Agriculture, Regional Field Office No. 02).

2.5.8 Threshing and Drying

The soybean planted in the two inner rows were subject to manual threshing, while the other two outer row and boarder were subjected to mechanical threshing.

Prior to manual threshing, pre-drying was done of the harvested soybean to ensure optimal moisture level of 13-15% MC. This was done to to improve the threshing efficiency where soybean pods open easiliy during threshing and to help reduce seed loss and breakage. Manual threshing done by placing the harvested soybean to sack or bag and gently beat the sack with stick. For the mechanical method, the used of multi-crop thresher or soybean thresher subject for the speed of 3,500 to 4,000 rpm speed. (Department of Agriculture, Regional Field Office No. 02).

After threshing, the seeds were dried 4 days from the date of threshing until reached the 14% moisture content. Weigh the dried seeds from the two center rows.

2.6 Data Gathering Procedure

2.6.1 Plant Height

Plant height was measured from the ground up to the tip of the main stem. This was carried out from the selected 10 samples in each plot, randomly. It was measured during the harvest.

2.6.2 Number of plants harvested per plot (plant stand)

This was taken during the harvest by counting the number of plants harvested from each plot. This indicated the density of planting and also helped in explaining the low yields in plots within the stand.

2.6.3 Number of Pods per Plant

The number of pods per plant was counted during harvest from the 10 samples randomly selected and determined the mean.

2.6.4 Number of Filled Pods per Plant

The number of pods was counted from the ten sample plants, the filled pods were separated and counted, and then the mean was calculated.

2.6.5 Number of Unfilled Pods per Plant

The number of unfilled pods per plant was determine during harvest from the ten samples randomly selected, the calculated the mean.

2.6.6 Number of Seeds per Pod

The number of seeds per pod was counted from the ten samples randomly selected and determined the mean.

2.6.7 Weight of 100 Seeds

The 100 seeds from each plot were randomly selected and recorded their weight.

2.6.8 Seed Yield per Plant

The seeds were obtained from the ten sample plants were sun-dried for four days until 14% MC was attained, then determined the mean.

2.6.9 Computed Seed Yield per Hectare

The seed yield per sample area was used in determining the computed seed yield per hectare using the following formula

$$\text{Bean Yield} \quad \frac{\text{Bean weight/plot (g)}}{1000} \times \frac{10{,}000}{\text{ASP}}$$

Where: ASP = area of sample plot

2.6.10 Shattering

Rate of shattering characteristics of the entries at harvest using the following indices:

Percent Shattering	Shattering Index	Reaction
No Shattering	1	Good
1% to 10% shattered seeds	2	Fair
10% to 25% shattered seeds	3	Fair
25% to 50% shattered seeds	4	
Over 50% shattered seeds	5	Poor

2.6.11 Lodging

Rate of lodging prior to harvesting based on the following scales:

Scale	Description	Reaction
1	No lodging	Good
2	All plants leaning slightly or 10% to 25% of the plants down	Fair
3	All plants leaning slightly or 26% to 50% of the plants down	Fair
4	All plants leaning considerably 51% to 80% of the plants down	
5	Almost all plants down	Poor

2.7 Data Analysis

The data gathered in this experiment was statistically analyzed using the Analysis of Variance (ANOVA) technique, following the experiments in a Split Plot Randomized Complete Block Design using Statistical Tool for Agriculture Research (STAR). The significant difference between or among the treatment means was compared using the Least Significant Difference (LSD) test (Meena et al., 2023).

3.0 Results and Discussion

The Select Manchuria soybean emerged 4 days after planting (DAP). Adequate soil moisture caused the early emergence of the seeds since the planting last January 8, 2025, and the occurrence of rainfall aided it as shown on Appendix D on the 10-Day weather forecast for Region XII relative to rainfall occurrence. Similarly, this result was the same as the previous observation conducted by Chauhan et al. (2013).

It was observed that the days of flowers at 50% occurred at 36 days DAP. Early flowering results with favorable weather after the early planting. In addition, Manchuria select variety typically reached the flowering stage 35 to 45 days after planting, which was noted within the range of its flowering stage.

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Full maturity of the Manchuria select soybean was recorded at 86 days from the date of emergence with approximately 95% of pods in the plot are mature.

3.1 Plant Height

The effects of plant height of Select Manchuria soybean, varying the planting distance and different fertilization, as well as its interactions, are shown in Table 3. As per the result, the interaction of both treatments had no significant difference.

The maximum mean for the planting distance is noted in the planting distance of A_2 at 70.48cm, followed by A_1 at 65.03 and A_3 at 63.17cm, respectively. This implies that the plants grown in the narrow planting distance recorded the maximum plant height due to more competition from other plants for sunlight. This result was similar to the previous observation conducted by Chauhan et al. (2013) where the soybean planted at narrow spacing at A_2 recorded the highest plant height. While shorter plants were observed at A_3 with less competition occurring among neighboring plants.

This finding is consistent with research indicating that higher planting densities can enhance vegetative growth. For instance, a study by Zhang et al. (2021) found that high planting density increased soybean plant height by 8.2% compared to normal planting density, likely due to improved canopy light interception and photosynthetic efficiency.

On the other hand, the effect of plant height relative to fertilization noted the maximum plant height ranged from 60.17cm to 74.37cm with an average of 66.23cm. The highest mean was noted on plants applied with 100% inorganic fertilizer, with comparable results with the combined application of organic and inorganic. Organic fertilizer had improved growth compared to the control, with no fertilization noted the least plant height.

Soybeans planted in closer planting distances at high population densities with balanced fertilizer application promote plant height and potential yield; however, it is crucial to consider also other growth parameters that could affect their overall yield performance.

Table 3. Plant Height of Select Manchuria Soybean as Influenced by Planting Distance and Fertilization, Tupi, South Cotabato, 2025

Factor B2/ Fertilization (Sub-plot)	Factor A Mean1/ Planting Distance (Main Plot)	Mean of B

	50cm x 10 cm	40cm x 10 cm	70cm x 10 cm	
Control (No fertilization)	61.80	70.73	63.00	65.18
100% Inorganic Fertilizer	66.57	74.37	60.17	67.04
100% Organic Fertilizer	65.47	67.27	64.73	65.82
Combination (50% Inorganic Fertilizer + 50% Organic Fertilizer)	66.27	69.57	64.77	66.87
Means of A	**65.03**	**70.49**	**63.17**	**66.23**

CV (a) = 8.79%,1/ -ns; CV (b) = 5.31%, 2/ -ns

3.2 Number of Plants Harvested per Plot

On average, the number of plants harvested per plot of Select Manchuria soybean at 99.42, influenced by planting distance and different fertilization. The detailed averages for each treatment combination can be found in Table 4.

The data indicate that the number of plants harvested per plot was relatively consistent across the different planting distances, with A_3 at 99.83 showing a slight increase over A_2 and A_1 (99.75 and 98.67, respectively). This suggests that the Select Manchuria soybean variety may have a flexible planting distance requirement without a significant impact on plant survival.

The fertilization treatments did not significantly affect the number of plants harvested per plot with average number ranged 99.22 to 99.56 indicating the used of soybean seed with good germination rate with optimal survival results. Comparable result was noted on plants applied with 100% inorganic fertilizer and no fertilization applied. This finding aligns with the leguminous nature of soybeans, which can fix atmospheric nitrogen through symbiotic relationships with rhizobial bacteria, potentially reducing the need for external nitrogen inputs.

The interaction between planting distance and fertilization treatment did not result in significant differences in the number of plants harvested per plot. This suggests that the effects of planting distance and fertilization are independent of each other concerning plant survival in the Select Manchuria soybean variety.

Table 4. Number of Plant Harvested per Plot of Select Manchuria Soybean as Influenced by Planting Distance and Fertilization, Tupi, South Cotabato, 2025

Factor B[2/] Fertilization (Sub-plot)	Factor A Mean[1/] Planting Distance (Main Plot)			Mean of B
	50cm x 10 cm	40cm x 10 cm	70cm x 10 cm	
Control (No fertilization)	99.33	100.00	99.33	99.55
100% Inorganic Fertilizer	98.67	100.00	100.00	99.56
100% Organic Fertilizer	98.33	99.67	100.00	99.33
Combination (50% Inorganic Fertilizer + 50% Organic Fertilizer)	98.33	99.33	100.00	99.22
Means of A	**98.67**	**99.75**	**99.83**	**99.42**

CV (a) = 1.14%, 1/ -ns; CV (b) = 1.24%, 2/ -ns

3.3 Number of Pods per Plant

On average, the number of pods per plant of Select Manchuria soybean was 78.08, varying with the planting distance and fertilization as shown in Table 5. As per result, significant different was observed relative to planting distance with no significant difference on the different fertilization applied.

Based on the data presented, the plants with the widest planting distance had the highest number of pods per while the plants with the narrowest distance had the least number of pods. Upon analysis, soybeans planted in wider spaces had more access to sunlight and soil nutrients, enhancing pod development, while in narrow distances with the densest spacing, increased competition resulted in a lower number of pods per plant. For instance, a study by Soares et al. (2019) found that reducing row spacing from 30 cm to 15 cm increased plant height and the height of the first pod setting, suggesting that closer planting distances can influence pod development.

However, this may also lead to increased competition among plants, potentially reducing the number of pods per plant. Conversely, wider spacing may reduce competition and allow for better pod development.

Moreover, relative to the effect of the number of pods varying with the different fertilization applied to the plant, the highest number of pods was recorded on the plants applied with B_2 at 84.54. This was followed by the B_4 at 76.14 with combination of 50% inorganic and 50 % organic fertilizer. The plants with no fertilization (B_1) and the 100% organic fertilizer (B_3) applied were not comparable in terms of several pods with average of 75.89 and 75.72, respectively.

Upon analysis, the inorganic fertilizers used during pod development were directly available and efficiently absorbed, promoting optimal pod development, whereas organic fertilizer indicates a later nutrient release or decreased immediate availability to plants which resulted in a lower number of pods.

Meanwhile, the LSD test showed that planting distances of A_1 and A_3 are not significant, and A_2 is significantly lower than the other two. A significant effect on the interaction of planting distance shows that plants planted in wider spacing and full inorganic fertilization together promote the best pod development with maximum treatment mean of 88.10 pods. On the other hand, denser spacing combined with organic or mixed fertilization might not supply enough resources to maximize pod development.

Table 5. Number of Pods per Plant of Select Manchuria Soybean Influenced by Planting Distance and Fertilization, Tupi, South Cotabato, 2025

Factor B[2/] Fertilization (Sub-plot)	Factor A Mean[1/*] Planting Distance (Main Plot)			Mean of B
	50cm x 10 cm	40cm x 10 cm	70cm x 10 cm	
Control (No fertilization)	69.37	77.57	80.73	75.89
100% Inorganic Fertilizer	84.13	81.40	88.10	84.54
100% Organic Fertilizer	81.40	69.53	76.23	75.72
Combination (50% Inorganic Fertilizer + 50% Organic Fertilizer)	83.23	67.90	77.30	76.14

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Means of A	**79.53**	**74.10**	**80.59**	**78.08**

CV (a) = 4.24% 1/*- significant; CV (b) = 12.68% 2/ -ns

3.4 Number of Filled Pods per Plant

The number of filled pods per plant of Select Manchuria soybean varies with the planting distance and different fertilization, as well as their interactions, as shown in Table 6. A significant effect was obtained on the filled pods per plant in planting distance, while the interaction of different fertilization applied had no significant difference.

It was revealed that the different planting distances had a significant effect on the filled pods of the soybean. This implies that the spacing or distance at which plants are planted affects how many pods are filled, suggesting that planting distances may affect yield. Based on the result, soybeans planted at A_3 at 78.88 had the maximum number of filled pods, followed by A_1 at 77.98, and A_2 had the least number of filled pods at 72.24 with the narrowest furrow distance.

On the other hand, based on the different fertilization applied, there was no significant difference among the treatments; however, based on the data, it was revealed that B_2 showed the highest mean number of filled pods with average of 83.03 filled pods, suggesting that synthetic fertilizers efficiently support pod development. B_4 and B_3 had similar lower values at 74.91 and 73.51, respectively, and B_1 recorded the lowest mean of 74.01 with no fertilization applied.

Meanwhile, the LSD test showed that planting distances of A_1 and A_3 are not significant, and A_2 is significantly lower than the other two. Notably, plant spacing significantly affects the growth, development, and yield of plants. Similarly, Ahmad et al. (2020) found that soybeans planted at 70 cm spacing produced more filled pods than closer spacing, attributing the improvement to better nutrient availability and root expansion.

The interaction effects between the planting distance and fertilization were noted at A_3 x B_5 (70cm x 10cm with 100% inorganic fertilizer) with a maximum treatment mean of 86.87 pods.

Table 6. Number of Filled Pods of Select Manchuria Soybean as Influenced by Planting Distance and Fertilization, Tupi, South Cotabato, 2025

Factor B 2/ Fertilization (Sub-plot)	Factor A Mean 1/* Planting Distance (Main Plot)	Mean of B

	50cm x 10 cm	40cm x 10 cm	70cm x 10 cm	
Control (No fertilization)	68.27	75.77	78.00	74.01
100% Inorganic Fertilizer	82.50	79.73	86.87	83.03
100% Organic Fertilizer	79.40	66.87	74.27	73.51
Combination (50% Inorganic Fertilizer + 50% Organic Fertilizer)	81.73	66.60	76.40	74.91
Means of A	**77.98**	**72.24**	**78.88**	**76.37**

CV (a) = 5.13%, 1/* - significant; CV (b) = 13.06%, 2/ -ns

3.5 Number of Unfilled Pods per Plant

The number of unfilled pods per plant of Select Manchuria soybean varies with the planting distance and different fertilization, as well as their interactions, as shown in Table 7. The interaction between the two treatments on the unfilled pods per plant had no significant difference.

Based on the data relative to different planting distance applied, it was revealed that numerically A_2 resulted in the highest average number of unfilled pods at 1.86, followed by A_3 at 1.71, and A_1 at 1.56. This suggests that too close spacing may increase competition among plants, leading to more unfilled pods, although there were no significant treatments.

Moreover, for the different fertilization applied the combined fertilizer treatment B_4 produced the fewest unfilled pods at 1.23, suggesting this is the most effective at promoting pod filling. In contrast, 100% organic B_3 resulted in the most unfilled pods at 2.21, possibly due to slower nutrient release compared to inorganic sources.

The interaction effects between the planting distance and fertilization revealed that a combination of inorganic and organic fertilization B_4 and a planting distance of A_3 are most effective in reducing the number of unfilled pods with minimum treatment mean of 0.90.

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Table 7. Number of Unfilled Pods of Select Manchuria Soybean as Influenced by Planting Distance and Fertilization, Tupi, South Cotabato, 2025

Factor B[2/] Fertilization (Sub-plot)	Factor A Mean[1/] Planting Distance (Main Plot)			Mean of B
	50cm x 10 cm	40cm x 10 cm	70cm x 10 cm	
Control (No fertilization)	1.10	1.80	2.73	1.88
100% Inorganic Fertilizer	1.63	1.67	1.23	1.51
100% Organic Fertilizer	2.00	2.67	1.97	2.21
Combination (50% Inorganic Fertilizer + 50% Organic Fertilizer)	1.50	1.30	0.90	1.23
Means of A	**1.56**	**1.86**	**1.71**	**1.71**

CV (a) = 36.98%, 1/ -ns; CV (b) = 33.07%; 2/ -ns

3.6 Number of Seeds per Pod

On average, the number of seeds per pod of Select Manchuria soybean was 2.52, varying with the planting distance and fertilization as shown in Table 8. The result shows there were no significant differences among the different treatments.

Based on the data, it was presented that A_2 resulted in the highest average number of seeds per pod at 2.53, followed by A_1 at 2.53, and A_3 at 2.44. The results suggest that closer planting distances may enhance pod development, possibly due to reduced competition among plants for resources, leading to better pod filling. However, excessively narrow spacing can lead to overcrowding, potentially increasing competition for light, nutrients, and water, which may negatively impact seed development. Therefore, optimal spacing is crucial for maximizing seed yield.

On the other hand, based on the different fertilization applied, there was no significant difference among the treatments however, based on the data, it was revealed that B_3 with 100% Organic showed the highest mean number of seeds per pod at 2.56 followed by B_2 at 2.53. B_4 and B_1 recorded had comparable results at 2.51 and 2.50, respectively.

The application of organic fertilizers (B_3) appears to have a slightly positive effect on seed development compared to inorganic fertilizers. Organic fertilizers can improve soil structure and microbial activity, leading to better nutrient availability and uptake by plants. This can enhance overall plant health and seed production.

Treatment A_2 x B_3 (40 cm x 10 cm with 100% Organic Fertilizer) combination yielded the highest number of seeds per pod (2.70), indicating a synergistic effect between closer planting distance and organic fertilization while A_3 x B_2 (70 cm x 10 cm with 100% Inorganic Fertilizer) produced the lowest number of seeds per pod (2.37), suggesting that wider spacing with inorganic fertilization may not be as effective in enhancing seed development.

Table 8. Number of Seeds per Pod of Select Manchuria Soybean as Influenced by Planting Distance and Fertilization, Tupi, South Cotabato, 2025

Factor B2/ Fertilization (Sub-plot)	Factor A Mean1/ Planting Distance (Main Plot)			Mean of B
	50cm x 10 cm	40cm x 10 cm	70cm x 10 cm	
Control (No fertilization)	2.47	2.57	2.47	2.50
100% Inorganic Fertilizer	2.63	2.60	2.37	2.53
100% Organic Fertilizer	2.40	2.70	2.57	2.56
Combination (50% Inorganic Fertilizer + 50% Organic Fertilizer)	2.63	2.53	2.37	2.51
Means of A	**2.53**	**2.60**	**2.44**	**2.52**

CV (a) = 7.58%, 1/ -ns; CV (b) = 7.06%, 2/ -ns

3.7 Weight of 100 Seeds

The effects of the weight of 100 seeds of Select Manchuria soybean, varying the planting distance and different fertilization, as well as their interactions, are shown in Table 9. An average weight of 12.54 grams was recorded. The interaction of both treatments had no significant difference.

Based on the result, A_3 yielded the highest mean weight of 12.61 grams, suggesting that wider spacing allowed plants better access to sunlight, nutrients, and space, leading to better seed filling while A_1 followed with 12.56 grams, and A_2 recorded the lowest mean at 12.44 grams, possibly due to competition from tighter spacing. Similar results conducted on dry season (2021-2022) at 12.9 grams (BPI-NSIC, 2023).

On the other hand, the highest average 100-seed weight was obtained under B_2 at 12.77 grams, highlighting the effectiveness of complete inorganic fertilization in promoting heavier seeds. This was followed by B_4 at 12.54 grams and B_3 at 12.50 grams. The control treatment B_1, with no fertilization, had the lowest seed weight at 12.33 grams, indicating that nutrient supplementation plays a crucial role in seed development.

Notable interactions were observed at B_3 at A_3 (12.95 g) – Organic fertilizer with wide spacing produced the single highest seed weight, while B_2 at A_1 12.89 g – Inorganic fertilizer at moderate spacing also performed very well. These results indicate that both fertilizer type and planting distance interactively influence seed weight.

The application of 100% inorganic fertilizer significantly improved the seed weight of Select Manchuria soybeans. Additionally, a wider planting distance tended to favor heavier seeds. However, combinations such as organic fertilization under wider spacing also showed promising results, implying that integrated nutrient management and spacing optimization can enhance yield quality.

Table 9. Weight of 100 Seeds of Select Manchuria Soybean as Influenced by Planting Distance and Fertilization, Tupi, South Cotabato, 2025

Factor B2/ Fertilization (Sub-plot)	**Factor A Mean1/ Planting Distance (Main Plot)**			**Mean of B**
	50cm x 10 cm	40cm x 10 cm	70cm x 10 cm	
Control (No fertilization)	12.28	12.47	12.25	12.33
100% Inorganic Fertilizer	12.89	12.75	12.65	12.77
100% Organic Fertilizer	12.22	12.33	12.95	12.50
Combination (50% Inorganic Fertilizer + 50% Organic Fertilizer)	12.85	12.19	12.60	12.54
Means of A	**12.56**	**12.44**	**12.61**	**12.54**

CV (a) = 3.98%, 1/ -ns; CV (b) = 4.85%; 2/ -ns

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3.8 Seed Yield per Plot

The number of seed yields per plot of Select Manchuria soybean varying the planting distance and different fertilization, as well as its interactions, is shown in Table 10. The interaction between the two treatments on the seed yield per plot had significant difference.

Upon analysis, based on the effect of planting distance it was noted the highest overall average yield of A_3 at 1,329.87 g/plot, followed by A_1 at 1,319.42 g/plot and A_2 at 1,016.79 g/plot. A_3 and A_1 had comparable results with significant difference to A_1 planted on the narrow distance. The results suggest that a wider planting distance (A_3) coupled can enhance soybean yield. This finding aligns with studies of Reyes et al. (2021) indicating that wider row spacing can improve light interception and reduce plant competition, leading to increased yield.

On the other hand, based on the different fertilization applied, there was significant difference from B_1 compared to other three different treatments (B_2, B_3 and B_4). Based on the data, it was revealed that B_2 showed the highest mean at 1,320.50 g/plot. On the treatment both B_3 and B_4 performed similarly well with 1,278.84 g/plot and 1,253.00 g/plot, respectively. B_1 noted the least mean among treatment at 1,034.72 g/plot with no fertilization applied.

The interaction effects between the planting distance and fertilization revealed that inorganic fertilization B_2 and a planting distance of A_1 yielded highest at 1,471 g/plot. The application of 100% inorganic significantly increase the yield due to immediate nutrient availability.

Meanwhile, the LSD test showed that planting distances of A_1 and A_3 are not significant, and A_2 is significantly lower than the other two. Relative to the fertilization applied, the yields in B_2, B_3 and B_4 were significantly produces higher yield than B_1. Notably, plant spacing significantly affects the growth, development, and yield of plants.

Table 10. Seed Yield Per Plot of Select Manchuria Soybean as Influenced by Planting Distance and Fertilization, Tupi, South Cotabato, 2025

Factor B[2/*] Fertilization (Sub-plot)	Factor A Mean[1/*] Planting Distance (Main Plot)			Mean of B
	50cm x 10 cm	40cm x 10 cm	70cm x 10 cm	
Control (No fertilization)	1,102.00	786.83	1,215.33	1,034.72[b]
100% Inorganic Fertilizer	1,471.00	1,122.67	1,367.83	1,320.50[a]
100% Organic Fertilizer	1,465.5	1,042.01	1,329.00	1,278.84[a]

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Combination (50% Inorganic Fertilizer + 50% Organic Fertilizer)	1,239.17	1,112.50	1,407.33	1,253.00[a]
Means of A	**1,319.42[a]**	**1,016.79[b]**	**1,329.87[a]**	**1,221.76**

CV (a) = 9.53%, 1/ -significant; CV (b) = 10.19%, 2/ -significant

3.9 Computed Seed Yield per Hectare

The number of computed seed yield per hectare of Select Manchuria soybean varying the planting distance and different fertilization, as well as its interactions, is shown in Table 11. The interaction between the two treatments shows significant difference among treatments.

Based on the result, a significant difference relative to planting distance was revealed A_1 yielded the highest mean weight of 2,638.83 kg/ha with comparable result A_2 at 2,547.02 kg/ha, and A_3 recorded the lowest mean 1,899.82 kg/ha, possibly due to competition from tighter spacing. Narrower spacing at denser planting results in higher yield, possibly due to better space utilization and canopy coverage.

The effects of fertilization on the computed seed weight per hectare had significant difference among treatments. Soybean planted with B_1 is relatively lower than three other treatments (B_2, B_3 and B_4). Highest mean yield revealed at B_2 at 2,567.57 kg/ha, comparable results at B_3 and B_4 were noted at 2,487.55 and 2,423.35 kg/ha, respectively. Treatment at B_1 (Control) at 1,158.35 kg/ha yielded the least result.

As per observations, the highest Yield with the combination of A_1 (50 cm x 10 cm) and B_2 (100% Inorganic Fertilizer) produced the highest yield: 2,942.00 kg/ha. This suggests that close spacing and full inorganic fertilization are highly productive for this crop. The lowest Yield was A_3 (70 cm × 10 cm), and B_1 (Control) yielded the least: 1,736.19 kg/ha, indicating that wider spacing and no fertilization limit productivity.

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Table 11. Computed Seed Yield Per Hectare of Select Manchuria Soybean as Influenced by Planting Distance and Fertilization, Tupi, South Cotabato, 2025

Factor B2/* Fertilization (Sub-plot)	Factor A Mean1/* Planting Distance (Main Plot)			Mean of B
	50cm x 10 cm	40cm x 10 cm	70cm x 10 cm	
Control (No fertilization)	2,204.00	1,967.08	1,736.19	1,969.09[b]
100% Inorganic Fertilizer	2,942.00	2,806.67	1,954.05	2,567.57[a]
100% Organic Fertilizer	2,931.00	2,633.09	1898.57	2487.55[a]
Combination (50% Inorganic Fertilizer + 50% Organic Fertilizer)	2,478.33	2,781.25	2,010.48	2423.35[a]
Means of A	**2,638.83[a]**	**2,547.02[a]**	**1,899.82[b]**	**2,361.89**

CV (a) = 8.80%, 1/ -significant; CV (b) = 9.25%; 2/ - significant

3.10 Shattering

Detailed interpretation of Table 12 on the shattering of Select Manchuria soybean as influenced by planting distance and fertilization. The interaction between the two treatments shows no significant difference among treatments.

Based on data revealed the values across all treatments are very consistent, ranging between 1.00 and 1.33. Both factors on the planting distance and fertilization, had no significant effects, and most of the values remain constant at 1. This implies that no substantial difference in shattering as influenced by planting distance or fertilization types under the conditions of this study.

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Table 12. Shattering of Select Manchuria Soybean as Influenced by Planting Distance and Fertilization, Tupi, South Cotabato, 2025

Factor B[2/] Fertilization (Sub-plot)	Factor A Mean[1/] Planting Distance (Main Plot)			Mean of B
	50cm x 10 cm	40cm x 10 cm	70cm x 10 cm	
Control (No fertilization)	1.00	1.00	1.00	1.00
100% Inorganic Fertilizer	1.00	1.00	1.00	1.00
100% Organic Fertilizer	1.33	1.00	1.00	1.00
Combination (50% Inorganic Fertilizer + 50% Organic Fertilizer)	1.00	1.00	1.00	1.00
Means of A	**1.08**	**1.00**	**1.00**	**1.03**

CV (a) = 16.22%, 1/ -ns; CV (b) = 16.22%, 2/ -ns

3.11 Lodging

Detailed interpretation of Table 13 on lodging of Select Manchuria soybean as influenced by planting distance and fertilization. Based on the result, A_3 had the least lodging overall with a mean score of 2.17, suggesting that wider row spacing improved plant stability. The A_2 had the most lodging, with the highest mean score of 2.58, likely due to increased competition and weaker stems, and A_1 was intermediate with a mean lodging score of 2.25.

On the effect of Fertilizer Treatment, there is no significant difference at B_2 with 100% Inorganic and B_3 with100% Organic treatments, both had the lowest average lodging scores at 2.22 while B_1 with no fertilizer and B_4 with combination of inorganic and organic had the highest lodging scores at 2.44.

The interaction effect suggested at 70cm spacing with or without fertilizer, especially inorganic, performed best in reducing lodging, and Inorganic fertilizer seems to strengthen stem structure more effectively than other treatments.

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Table 13. Lodging of Select Manchuria Soybean as Influenced by Planting Distance and Fertilization, Tupi, South Cotabato, 2025

Factor B[1/] Fertilization (Sub-plot)	Factor A Mean[1/] Planting Distance (Main Plot)			Mean of B
	50cm x 10 cm	40cm x 10 cm	70cm x 10 cm	
Control (No fertilization)	2.33	3.00	2.00	2.44
100% Inorganic Fertilizer	2.00	2.67	2.00	2.22
100% Organic Fertilizer	2.33	2.00	2.33	2.22
Combination (50% Inorganic Fertilizer + 50% Organic Fertilizer)	2.33	2.67	2.33	2.44
Means of A	**2.25**	**2.58**	**2.17**	**2.33**

CV (a) = 4.24%, 1/ -ns; CV (b) = 12.68%, 2/ -ns

3.12 Financial Analysis

The gross income of Select Manchuria was calculated. The cost of all production was deducted from the income. Detailed interpretation of Table 14 on Financial Analysis of Select Manchuria soybean as influenced by planting distance and fertilization.

Among all treatments, the control with no fertilization exhibited the lowest cost of production, ranging from PhP 28,065.00 to PhP 29,185.00. Conversely, the 100% organic fertilizer treatment incurred the highest costs, ranging from PhP 62,065.00 to PhP 63,185.00. This suggests that organic fertilizer is significantly more expensive due high production cost and high input requirements per hectare at 68 bags.

Moreover, 100% inorganic fertilizer treatment yielded the highest gross and net incomes across most planting distances. The gross income at the A_1 spacing reached PhP 147,100.00, resulting in a net income of PhP 112,144.00. Comparatively, the control treatment achieved a maximum net income of only PhP 81,575.00, while the 100% organic fertilizer reached PhP 83,925.00 at best.

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The combination treatment, although more cost-effective than the organic, still lagged behind the inorganic fertilizer in net profitability.

In terms of profitability, 100% inorganic fertilizer with 50 cm × 10 cm spacing generated the highest ROI at 321%, indicating a strong return relative to the cost. The control treatment had ROI values ranging from 209% to 285%, while the 100% organic treatment displayed significantly lower ROI values, from 53% to 134%. The combination treatment offered moderate ROI results (108%–182%), demonstrating a balance between sustainability and economic feasibility.

Table 14. Financial Analysis of Select Manchuria Soybean Planted as Influenced by Planting Distance and Fertilization, Tupi, South Cotabato, 2025

Particular	Fertilization			
	Control (No fertilization)	100% Inorganic Fertilizer	100% Organic Fertilizer	Combination (50% Inorganic Fertilizer + 50% Organic Fertilizer)
Total Cost of Production (PhP)				
50cmx10cm	28,625.00	34,956.00	62,625.00	49,790.00
40cmx10cm	29,185.00	35,516.00	63,185.00	49,350.00
70cmx10cm	28,065.00	34,396.00	62,065.00	48,230.00
Gross Income (PhP)				
50cmx10cm	110,200.00	147,100.00	146,550.00	123,917.00
40cmx10cm	98,354.00	140,334.00	131,655.00	139,063.00
70cmx10cm	86,810.00	97.703.00	94,929.00	100,524.00
Computed Seed Yield (kg/ha)				
50cmx10cm	2,204.00	2,942.00	2,931.00	2,478.33
40cmx10cm	1967.08	2806.67	2,633.09	2,781.25
	1736.19	1954.05	1898.57	2010.48

70cmx10cm				
Farm Gate Price (PhP)	50.00	50.00	50.00	50.00
Net Income, (PhP)				
50cmx10cm	81,575.00	112,144.00	83,925.00	75,126.00
40cmx10cm	69,169.00	104,818.00	68,470.00	89.712.00
70cmx10cm	58,745.00	63,307.00	32,864.00	52,294.00
Return of Investment (%)				
50cmx10cm	285	321	134	154
40cmx10cm	237	295	108	182
70cmx10cm	209	184	53	108

4.0 Conclusion

Based on the findings of the analysis of the data gathered from the study, it can be concluded that Select Manchuria soybean planted in the closest spacing at A_1 (50cm x10 cm), combined with B_2 (100% Inorganic) and B_4 (50% organic + 50% inorganic) fertilizers consistently produced higher yields with comparable results A_2 (40cm x10 cm). On the other hand, soybean planted on the widest spacing at A_3 (70cm x10 cm) underperformed in yield metrics despite relatively good seed weights.

A_2 (40cm x 10 cm) may optimize overall productivity at a hectare scale due to higher plant density, while A_3 (70cm x 10 cm) loses out at this scale despite having higher individual plot yields.

The findings indicate that 100% inorganic fertilization at 50 cm × 10 cm spacing is the most economically viable option, offering the highest yields, net income, and ROI. While 100% organic fertilization aligns with environmentally sustainable goals, it is less profitable and more costly, especially when used exclusively. The combination treatment presents a viable compromise, with moderate costs and returns, potentially suitable for integrated sustainable farming practices. Furthermore, planting distance plays a critical role, with closer spacing significantly improving productivity and profitability.

5.0 Recommendations

Based on the findings of the analysis of the study, the following recommendations are hereby presented:

1. The use of A_1 (50cm x 10 cm) consistently high yields per plot and performed best per hectare in terms of balance between plant density and resource availability. Although A2 (40cm x 10 cm) yielded individual plants were likely stressed, resulting in lower per plot yields but it yielded more per hectare due to plant density with comparable results at A_1. A_3 (70 cm x 10 cm) performed best per plot, but yield per hectare suffered due to lower plant population. This suggests that maximizing plant population per hectare, in conjunction with appropriate nutrient management, is key to optimizing crop yield.

2. Adopt 50% Inorganic + 50% Organic Fertilizer at 40cm or 50cm x 10cm spacing. The use of balanced fertilizer balances yield performance with improved soil health and environmental benefits. This combination promotes sustainable soil management, high yield performance, and is cost-effective compared to full inorganic fertilization.

3. Further trials are recommended to validate these findings across seasons or province.

6.0 Contributions of Authors

All the authors were responsible for the conceptualization of the study. Julie Mie Y. Belongan conducted and collected the necessary data, analyzed the study, and drafted the manuscript. Junito P. Marcelino provided technical guidance, supervised the research process, and reviewed and edited the manuscript.

7.0 Conflict of Interest

The author declares no conflicts of interest, financial or otherwise, that could have influenced the study's findings or conclusions.

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