Original Research Article

# Assessing the Role of Spacing and Sowing Strategies on Soybean (*Glycine Max* L.) morphology in the Malwa Region of Madhya Pradesh


## ABSTRACT

The present investigation was conducted at the Research Farm, Mandsaur University, Mandsaur (Madhya Pradesh), India, during the *Kharif* season (June–December 2024). The experiment aimed to evaluate the impact of different sowing methods and spacing treatments on the growth and yield of soybean. The study was carried out using a Split Plot Design with three replications and eight treatment combinations, resulting in 24 experimental plots. The gross plot size was 14.40 m², and the net plot size was 11.70 m². Soybean was sown with a seed rate of 80 kg/ha and recommended fertilizer doses of 20 kg N, 40 kg P, and 20 kg K per hectare.

Results showed that the raised bed method ($B_2$) significantly increased the plant population at both 30 DAS and at harvest compared to the flat bed method ($B_1$).Among the subplot treatments, broadcasting ($S_1$) resulted in the highest plant population at 30 DAS, while raised bed + broadcasting ($T_5$) produced the highest population at harvest. The number of pods at 90 days after sowing (DAS) in soybean (*Glycine max L.*). Two main sowing methods, flat bed ($B_1$) and raised bed ($B_2$), were evaluated with four spacing treatments: broadcasting ($S_1$), 30×30 cm ($S_2$), 45×30 cm ($S_3$), and 60×30 cm ($S_4$). The best pod production occurred with the raised bed + 60×30 cm spacing combination ($T_8$), yielding (21.13) pods per tagged plant. The fresh and dry weight of soybean at 30 days after sowing (DAS) showed the highest fresh and dry weight was observed in the raised bed + broadcasting combination ($T_5$), with (138.02) g and (18.51 g) respectively. These findings suggest that raised bed sowing with broadcasting or 30×30 cm spacing optimizes early biomass accumulation in soybean.


***Keywords:*** *Glycine Max*, Kharif , Malwa, Spacing and Yield,

## INTRODUCTION

Soybean (*Glycine max L.*) is an essential legume belonging to the Leguminosae family, Papilionaceae subfamily, and Glycine genus [14]. It has been cultivated in China since 3000 B.C. Soybean (*Glycine max* L.) is becoming a key oilseed crop in India [4]. It is a legume from the Fabaceae family, sub-family Papilionaceae. Globally, soybean is known as the "Golden Bean," "Miracle Crop," or "Yellow Jewel" due to its role as an affordable and nutritionally balanced oilseed [12]. It is primarily cultivated during the Kharif season (July-October) in rainfed regions of India [17]. The chemical composition of soybean includes 35-40% protein, 20% oil, 25-30% carbohydrates, 17% dietary fiber, 5% minerals, and other nutrients like vitamins [3]. Soybean seeds consist of approximately 8% seed coat, 90% cotyledons, and 2% hypocotyl[1]. It is also a rich source of calcium, iron, zinc, phosphate, magnesium, B vitamins (thiamine, riboflavin, niacin), and folic acid, which are highly bioavailable [2]. The fat-free soybean meal is an important, cost-effective protein source for animal feed and many processed foods [15].

Soybean, originally from China and introduced to India in 1882, is now cultivated in various countries worldwide. In the 2019-2020 periods, Brazil had the largest soybean cultivation area, covering 36.90 million hectares, followed by the USA (30.96 million hectares), Argentina (17.00 million hectares), and India (11.34 million hectares). Brazil was the top producer in 2021-2022, with 144 million tonnes, while India ranked 5$^{th}$ producing 11.20 million tonnes at a productivity rate of 1,126 kg per hectare [14].In India, soybean farming is primarily concentrated in Madhya Pradesh, Uttar Pradesh, Rajasthan, and Maharashtra. In 2022-2023, India had the annual production (13.98 mt) and yield (1158kg/ha) with area (12.07 mha) [17]. Maharashtra dedicated 46.01 lakh hectares to soybean cultivation, yielding 36.29 lakh tonnes at a productivity rate of 1,054 kg per hectare. Vidarbha, a region in Maharashtra, is the leading producer, benefiting from average rainfall of 800 to 1,000 mm and fertile black cotton soils, which are well-suited for soybean cultivation. In 2019-2020, Vidarbha produced 48.25 lakh tonnes of soybeans from 41.24 lakh hectares, with a productivity rate of 853 kg per hectare [13,24].

Soybean is a highly nutritious oilseed, containing 40-42% protein, 20% oil, 30% carbohydrates, and essential vitamins [12,19].It is commonly used in food products such as soy milk, tofu, and soy flour, and is recognized for its health benefits, including reducing the risk of heart disease and cancer due to its high isoflavone content[11]. Often referred to as the "Wonder Crop" or "Golden Bean" of the 21$^{st}$ century, soybean is also utilized in cosmetics and medicinal products for its role in preventing cardiovascular diseases and diabetes [10,13].

In India, soybean is predominantly grown in Madhya Pradesh, Uttar Pradesh, Rajasthan, and Maharashtra, with Vidarbha being the leading producer. Sowing techniques like ridge and furrow and Broad Bed Furrow (BBF) are employed to conserve moisture and enhance yields, particularly in regions with unpredictable rainfall patterns. Proper spacing between plants is crucial for promoting growth and maximizing yield, as it allows for better nutrient absorption, improved airflow, and sufficient light exposure. This method also minimizes the need for extra inputs such as seeds, fertilizers, and pesticides, making soybean farming more economical.

## MATERIAL AND METHODS

The present investigation titled "Effect of Various Agronomic Manipulations In Spacing and Sowing Methods On Growth And Yield Attributes of Soybean (*Glycine Max* L.) In Malwa Region (M.P)". The present experiment was conducted at Research Farm, under Mandsaur University, Mandsaur (Madhya Pradesh). It is situated at latitude 24$^{0}$C 4'36.61''N, longitude 75$^{0}$4'9.46'' E and at an altitude of 442.16 meters above the mean sea level. The experiment involved two main plot treatments: $B_1$ for flat bed sowing and $B_2$ for raised bed sowing. There were four sub-plot treatments based on spacing: $S_1$ for broadcasting, $S_2$ for 30×30 cm spacing, $S_3$ for 45×30 cm spacing, and $S_4$ for 60×30 cm spacing. The treatment combinations were as follows: $T_1$: Flat bed + Broadcasting ($B_1S_1$),$T_2$: Flat bed + 30×30 cm spacing ($B_1S_2$),$T_3$: Flat bed + 45×30 cm spacing ($B_1S_3$),$T_4$: Flat bed + 60×30 cm spacing ($B_1S_4$),$T_5$: Raised bed + Broadcasting ($B_2S_1$),$T_6$: Raised bed + 30×30 cm spacing ($B_2S_2$), $T_7$: Raised bed + 45×30 cm spacing ($B_2S_3$) and$T_8$: Raised bed + 60×30 cm spacing ($B_2S_4$). The experiment was laid out using a split plot design with three replications. There were eight treatments in total, and the experiment was conducted in 24 plots. The gross plot size was 3.60 × 3.90 meters, which equals 14.40 m², while the net plot size was 3.0 × 3.90 meters, totaling 11.70 m². The gross plot area was calculated to be 424.70 m². For the soybean crop, the recommended fertilizer doses were 20 kg N, 40 kg P, and 20 kg K per hectare. The seed rate used for the experiment was 80 kg per hectare.

**RESULT AND DISCUSSION**

1. **Plant height at 90 days (DAS) of Soybean (5 tagged plants per plot)**

Data pertaining to plant height at 90 Days After Sowing (DAS), as presented in the (Table 1), indicate the main effects of different sowing methods (flat bed and raised bed) and spacing treatments (broadcasting and various row spacing) on the plant height in Soybean. These factors significantly affected the plant height at 90 DAS, with distinct trends observed throughout the growing stages.

**Main Effect of Sowing Methods:**

In general, the raised bed method ($B_2$) resulted in a higher plant height at 90 DAS compared to the flat bed method ($B_1$). Soybean plants sown under raised beds ($B_2$) had a plant height of (53.43 cm) while those sown under flat beds ($B_1$) measured (53.06 cm) at 90 DAS. In general, the raised bed method ($B_2$) resulted in a higher number of pods at 90 DAS compared to the flat bed method at 90 DAS. The current study aligns with previous reports by [5,7,8].

**Main Effect of Spacing Treatments:**

Among the different spacing treatments, significant variations in plant height were observed. The broadcasting treatment ($S_1$) led to the highest plant height at 90 DAS, with a measurement of (58.13 cm). In contrast, the broadcasting ($S_1$) resulted in the lowest plant height of (50.16 cm) at 90 DAS. In line with the current experiment, the findings suggest as per in Soybean [8,9].

**Interaction Effects of Sowing Method and Spacing:**

The interaction between the sowing method and spacing treatments revealed significant differences in plant height. The highest plant height was observed under the raised bed + broadcasting ($B_2S_3$) combination, with a plant height of (59.10 cm) followed by the combination raised bed + 45×30 cm spacing ($B_2S_2$) which showed a plant height of (58.53 cm) and $B_1S_4$ (Flat bed +60×30 cm spacing) (56.40 cm). However, the minimum height was recorded under the flat bed + 30×30 cm spacing ($B_1S_2$), with a height of (46.33 cm). The results obtained here are in contrast with the conclusions in Soybean [8,9,15].

2. **Fresh and Dry weight (g) of Soybean at 30 DAS**

The fresh and dry weight of soybean at 30 DAS varied significantly across sowing methods and subplot treatments as presented in (Table 2).

**Main Effect of Sowing Methods:**

Soybean plants grown on raised beds ($B_2$) had a higher fresh weight (114.78 g) and dry weight (16.79 g) compared to those grown on flat beds ($B_1$), which had a fresh weight of 89.89 g and a dry weight of 14.82 g. These factors may improve nutrient and water uptake, allowing for greater biomass accumulation both in terms of fresh and dry weight. In contrast, flat bed sowing, while still effective, may not provide the same level of optimal conditions for early growth, leading to lower fresh and dry weights in plants grown on flat beds. Our results substantiate the findings of past studies conducted in Soybean [15,18,19].

**Main Effect of Spacing:**

Among the subplot treatments, the plants grown with 30×30 cm spacing ($S_2$) had the highest fresh weight of (114.85 g) and the highest dry weight of (16.99 g) followed by 60×30 cm spacing ($S_4$) showed a fresh weight of (105.15g) and a dry weight of (16.00g) and broadcasting ($S_1$) resulted in a fresh weight of (100.54 g) and a dry weight of (15.76 g). The 45×30 cm spacing ($S_3$) had the lowest fresh weight at (88.81 g) and dry weight at (14.46 g). The 45×30 cm spacing, however, resulted in the lowest fresh and dry weights, suggesting that this spacing may cause increased competition among plants for resources, leading to stunted growth. The evidence we present echoes the results reported by [21,23,24].

**Interaction Effects of Sowing Method and Spacing:**

The combination of $B_2S_1$ (Raised bed + Broadcasting) produced the highest fresh weight (138.02 g) and dry weight (18.51 g) followed by $B_2S_2$ (Raised bed + 30×30 cm spacing) resulted in a fresh weight of (125.33g) and a dry weight of (18.25g) and $B_2S_3$ (Raised bed + 45×30 cm spacing) resulted in a fresh weight of (123.36 g) and a dry weight of (18.13g). The treatment $T_8$ $B_2S_4$ (Raised bed + 60×30 cm spacing) resulted in the lowest fresh weight (72.27g) and dry weight (13.50 g). The highest fresh and dry weights was observed under the treatment $T_8$ ($B_2S_4$) raised bed + 60×30 cm spacing combination, followed by treatment $T_5$ ($B_2S_1$) raised bed + broadcasting and treatment $T_2$ $B_1S_2$ (Flat bed +30×30 cm spacing) ($B_1S_2$). However, the minimum fresh and dry weights was recorded under the treatment $B_2S_2$ (Raised bed + 30×30 cm spacing) with 12.66 pods at 90 DAS. The results obtained here are in contrast with the conclusions of [18,20,22].

**3. Days to Maturity at 90 DAS of Soybean (5 tagged plants gross weight)**

Data pertaining to the days to maturity at 90 DAS**,** as presented in **(**Table 3) indicate the main effects of different sowing methods (flat bed and raised bed) and spacing treatments (broadcasting and various row spacings) on the days to maturity in Soybean. These factors significantly influenced the maturity period, with variations observed across the treatments.The raised beds ($B_2$) observed for days to maturity, while flat beds ($B_1$) was the second best to days to maturity. This suggests that the raised bed method provides a more favorable environment for earlier maturation. Our study is well corroborated with the findings in Soybean [21,23,24].

**Main Effect of Sowing Methods:**

The raised beds ($B_2$) observed **(**8.62) for days to maturity**,** while flat beds ($B_1$) took **(**10.08) days to maturity**.** The raised beds ($B_2$) observed for days to maturity, while flat beds ($B_1$) was the second best to days to maturity. This suggests that the raised bed method provides a more favorable environment for earlier maturation. Our study is well corroborated with the findings of in Soybean **[19,20,22]**.

**Main Effect of Spacing:**

The 30×30 cm spacing ($S_2$) treatment led to the minimum days to maturity at 90 DAS, with (7.86) days, followed by treatment ($S_3$) 45×30 cm spacing, which observed (6.98) days. In contrast, the treatment ($S_1$) broadcasting treatment resulted maximum (9.76) days. This suggests that closer spacing may promotes quicker maturity, possibly due to more efficient use of space and resources. Past researches also showed similar and significant results in Soybean [17,18,19].

**Interaction Effects of Sowing Method and Spacing:**

The interaction between sowing method and spacing treatments showed distinct results. The treatment $T_8$ with Raised bed + 60×30 cm spacing ($B_2S_4$) resulted in the earliest maturity with **(**6.98) days followed by the treatment $T_3$ with Flat bed + 45×30 cm spacing ($B_1S_3$) resulted in the earliest maturity with (7.73) days and the treatment $T_4$ Flat bed +60×30 cm spacing ($B_1S_4$) reported **(**8.75) days, respectively, indicating an intermediate maturity period. In contrast, treatment $T_5$ with raised bed + broadcasting ($B_2S_1$) resulted in a longer maturity period of **(**10.53) days**.** The interaction between sowing method and spacing treatments showed distinct results. The treatment $T_8$ with Raised bed + 60×30 cm spacing ($B_2S_4$) resulted in the earliest maturity with followed by the treatment $T_3$ with Flat bed + 45×30 cm spacing ($B_1S_3$) resulted in the earliest maturity with and the treatment $T_4$ Flat bed +60×30 cm spacing ($B_1S_4$) reported respectively, indicating an intermediate maturity period. In contrast, treatment $T_5$ with raised bed + broadcasting ($B_2S_1$) resulted in a longer maturity period. This shows that the spacing method, when paired with a suitable sowing method, plays a significant role in determining the maturity timeline. Similar findings were also noticed by in Soybean [6,9,15].

## CONCLUSION

The raised bed method ($B_2$) consistently resulted in a higher plant height at 90 Days after sowing compared to the flat bed method ($B_1$). The best combination for plant population was raised bed + broadcasting ($B_2S_1$), while flat bed with wider spacing (60×30 cm) showed the lowest. Soybeans grown on raised beds ($B_2$) had maximum number of Pods at 90 DAS of Soybean (5 tagged plants per plot) than those on flat beds ($B_1$). The raised bed + broadcasting ($B_2S_1$) combination produced the highest Fresh and Dry weight (g) of Soybean at 30 DAS, while raised bed + 60×30 cm spacing ($B_2S_4$) had the lowest. Raised beds ($B_2$) led to more pods compared to flat beds ($B_1$).

## COMPETING INTRESTS

The authors declare that there are no competing interests regarding the publication of this research. The study was conducted without any financial or personal relationships that could have influenced the results or interpretation of the findings.

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**Table 1 Plant height (cm) at 90 DAS of Soybean (5 tagged plants per plot)**

| | | **Main Plot** | | |
|---|---|---|---|---|
| **S. No.** | **Treatments** | **Sowing method** | Plant height at 90 DAS (5 tagged plants per plot) | |
| 1 | $B_1$ | Flat bed | 53.06 | |
| 2 | $B_2$ | Raised bed | 53.43 | |
| | | **Sub plot treatments** | | |
| 1 | $S_1$ | Broadcasting | 50.16 | |
| 2 | $S_2$ | 30×30cm | 58.13 | |
| 3 | $S_3$ | 45×30cm | 53.33 | |
| 4 | $S_4$ | 60×30cm | 51.36 | |
| | | | | |
| **S.No.** | **Treatments** | **Treatment combination** | Plant height at 90 DAS (5 tagged plants per plot) | |
| 1. | $T_1$ | $B_1S_1$ (Flat bed+Broadcasting) | 53.73 | |
| 2. | $T_2$ | $B_1S_2$ (Flat bed +30×30 cm spacing) | 46.33 | |
| 3. | $T_3$ | $B_1S_3$ (Flat bed +45×30 cm spacing) | 55.46 | |
| 4. | $T_4$ | $B_1S_4$ (Flat bed +60×30 cm spacing) | 56.40 | |
| 5. | $T_5$ | $B_2S_1$ (Raised bed + Broadcasting) | 46.60 | |
| 6. | $T_6$ | $B_2S_2$ (Raised bed + 30×30 cm spacing) | 58.53 | |
| 7. | $T_7$ | $B_2S_3$ (Raised bed + 45×30 cm spacing) | 59.10 | |
| 8. | $T_8$ | $B_2S_4$ (Raised bed + 60×30 cm spacing) | 48.13 | |
| | | **Factors** | **C.D.** | **SE(m) ±** |
| | | Factor A (Sowing methods) | 2.14 | 1.13 |
| | | Factor B (Spacing) | 1.95 | 0.95 |
| | | Factor (A×B) | 1.61 | 0.80 |

**Table 2 Fresh and Dry weight (g) of Soybean at 30 DAS**

| | | Main Plot | | | | |
|---|---|---|---|---|---|---|
| **S. No.** | **Treatments** | **Sowing method** | Fresh weight (g) at 30 DAS | | Dry weight (g) at 30 DAS | |
| 1 | $B_1$ | Flat bed | 89.89 | | 14.82 | |
| 2 | $B_2$ | Raised bed | 114.78 | | 16.79 | |
| | | **Sub plot treatments** | | | | |
| 1 | $S_1$ | Broadcasting | 100.54 | | 15.76 | |
| 2 | $S_2$ | 30×30cm | 114.85 | | 16.99 | |
| 3 | $S_3$ | 45×30cm | 88.81 | | 14.46 | |
| 4 | $S_4$ | 60×30cm | 105.15 | | 16.00 | |
| | | | | | | |
| **S.No.** | **Treatments** | **Treatment combination** | Fresh weight (g) at 30 DAS | | Dry weight (g) at 30 DAS | |
| 1. | $T_1$ | $B_1S_1$ (Flat bed+Broadcasting) | 88.17 | | 14.36 | |
| 2. | $T_2$ | $B_1S_2$ (Flat bed +30×30 cm spacing) | 89.46 | | 14.56 | |
| 3. | $T_3$ | $B_1S_3$ (Flat bed +45×30 cm spacing) | 106.33 | | 15.85 | |
| 4. | $T_4$ | $B_1S_4$ (Flat bed +60×30 cm spacing) | 75.76 | | 13.28 | |
| 5. | $T_5$ | $B_2S_1$ (Raised bed + Broadcasting) | 138.02 | | 18.51 | |
| 6. | $T_6$ | $B_2S_2$ (Raised bed + 30×30 cm spacing) | 125.33 | | 18.25 | |
| 7. | $T_7$ | $B_2S_3$ (Raised bed + 45×30 cm spacing) | 123.36 | | 18.13 | |
| 8. | $T_8$ | $B_2S_4$ (Raised bed + 60×30 cm spacing) | 72.273 | | 13.50 | |
| | | **Factors** | **C.D.** | **SE(m) ±** | **C.D.** | **SE(m) ±** |
| | | Factor A (Sowing methods) | N/A | 1.88 | 2.65 | 1.35 |
| | | Factor B (Spacing) | 2.76 | 1.38 | 2.21 | 1.14 |
| | | Factor (A×B) | 2.02 | 1.01 | 1.42 | 0.71 |

**Table 3 Days to Maturity at 90 DAS of Soybean (5 tagged plants gross weight)**

| | | | |
|---|---|---|---|
| | | **Main Plot** | |
| **S. No.** | **Treatments** | **Sowing method** | Days to maturity at 90 DAS (5 tagged plants per plot) |
| 1 | $B_1$ | Flat bed | 10.08 |
| 2 | $B_2$ | Raised bed | 8.62 |
| | | **Sub plot treatments** | |
| 1 | $S_1$ | Broadcasting | 9.76 |
| 2 | $S_2$ | 30×30cm | 7.86 |
| 3 | $S_3$ | 45×30cm | 9.50 |
| 4 | $S_4$ | 60×30cm | 10.26 |
| | | | |
| **S.No.** | **Treatments** | **Treatment combination** | Days to maturity at 90 DAS (5 tagged plants per plot) |
| 1. | $T_1$ | $B_1S_1$ (Flat bed+Broadcasting) | 8.99 |
| 2. | $T_2$ | $B_1S_2$ (Flat bed +30×30 cm spacing) | 9.00 |
| 3. | $T_3$ | $B_1S_3$ (Flat bed +45×30 cm spacing) | 7.73 |
| 4. | $T_4$ | $B_1S_4$ (Flat bed +60×30 cm spacing) | 8.75 |
| 5. | $T_5$ | $B_2S_1$ (Raised bed + Broadcasting) | 10.53 |
| 6. | $T_6$ | $B_2S_2$ (Raised bed + 30×30 cm spacing) | 10.00 |
| 7. | $T_7$ | $B_2S_3$ (Raised bed + 45×30 cm spacing) | 12.79 |
| 8. | $T_8$ | $B_2S_4$ (Raised bed + 60×30 cm spacing) | 6.98 |

| | | | | |
|---|---|---|---|---|
| | | **Factors** | **C.D.** | **SE(m) ±** |
| | | Factor A (Sowing methods) | 2.31 | 1.19 |
| | | Factor B (Spacing) | 2.41 | 1.20 |
| | | Factor (A×B) | 2.80 | 1.42 |