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Influence of spacing and sowing practices on urdbean growth attributes in the Malwa Region of Madhya Pradesh

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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 Urdbean. The experiment was laid out in a split plot design with three replications, comprising two main plot treatments (flat bed and raised bed sowing) and four subplot treatments of spacing (broadcasting, 30×30 cm, 45×30 cm, and 60×30 cm), resulting in eight treatment combinations (T₁-T₈). Urdbean variety T-9 was sown using a seed rate of 15 kg ha⁻¹ with a recommended fertilizer dose of 20:40:20 kg N:P:K ha⁻¹. Raised bed sowing recorded a higher plant population compared to flat bed sowing, with 25.01 plants m⁻² at 30 DAS and 19.36 plants m⁻² at harvest, while flat bed sowing recorded 19.07 and 13.01 plants m⁻², respectively.

Among spacing treatments, raised bed with broadcasting (B2S1) recorded the highest plant population (32.38 plants m⁻² at 30 DAS and 29.07 plants m⁻² at harvest), whereas flat bed with 60×30 cm spacing (B1S4) recorded the lowest population (13.30 and 12.80 plants m⁻²).

Fresh and dry weight at 30 DAS were significantly higher under raised bed sowing (113.91 g and 16.87 g) compared to flat bed sowing (89.93 g and 14.93 g). Among spacing treatments, 30×30 cm spacing recorded the highest fresh weight (114.91 g) and dry weight (16.97 g). The interaction effect showed that raised bed with broadcasting (B2S1) produced the maximum fresh weight (136.02 g) and dry weight (18.63 g).

The number of pods per plant at 90 DAS was higher under raised bed sowing (17.65) compared to flat bed sowing (17.19). Among spacing treatments, 30×30 cm spacing recorded the highest number of pods (18.63), while broadcasting recorded the lowest (17.01). The maximum number of pods (21.18) was observed under raised bed with 60×30 cm spacing (B2S4).

Days to 50% flowering were significantly influenced by treatments. Raised bed sowing resulted in earlier flowering (36.80 days) compared to flat bed sowing (40.16 days). Among spacing treatments, 30×30 cm spacing recorded minimum days to flowering (39.21 days), while broadcasting resulted in delayed flowering (40.69 days). Overall, the study concluded that raised bed sowing combined with appropriate spacing improved growth and yield attributes of urdbean under Malwa region conditions.

Keywords: Attributes, growth, influence, Malwa, spacing, sowing and urdbean

Introduction

Urdbean (*Vigna mungo* L. Hepper), commonly known as black gram, is an important pulse crop belonging to the family Leguminosae (Fabaceae), subfamily Papilionaceae, and genus *Vigna*, Nair *et al.*, (2024) [25]. It is one of the major grain legumes cultivated in the Indian subcontinent and has been grown in India since ancient times. Urdbean plays a significant role in Indian agriculture due to its adaptability to diverse agro-climatic conditions, short duration, and ability to improve soil fertility through biological nitrogen fixation Giri *et al.*, (2024) [13]. Expansion in Urdbean cultivation and utilization has contributed to food security and enhanced income for small and marginal farmers.

Urdbean is a diploid, self-pollinated C₃ plant with a chromosome number of 2n = 22 (Bhattacharjee, 2024) [5]. It is an annual herbaceous crop possessing a well-developed tap root

system with lateral roots bearing nitrogen-fixing nodules (Singh, 2013) [31]. The crop exhibits a dicotyledonous growth habit with erect, semi-erect, or spreading plant types depending on the variety. Urdbean grows well under tropical and subtropical climatic conditions (Hedayetullah and Zaman, 2018) [19]. The crop requires warm weather, with optimum temperatures ranging between 25 and 35°C, and performs best under moderate rainfall of 600-1000 mm. It is sensitive to frost and prolonged waterlogging. Urdbean can be successfully cultivated on a wide range of soils, including loamy, clay loam, and black cotton soils, provided proper drainage is available Sahni *et al.*, (2016) [29]. A soil pH range of 6.0 to 7.5 is considered ideal for optimum growth and development.

Nutritionally, Urdbean is a rich source of plant protein, containing about 24-26% protein, 55-60% carbohydrates, 1-1.5% fat, 3-4% minerals, and 4-5% crude fiber Kole *et al.*, (2002) [24]. It is particularly rich in the essential amino acid lysine, which complements cereal-based diets. Urdbean is also a good source of vitamins such as thiamine, riboflavin, and niacin, making it an important component of human nutrition, especially in vegetarian diets.

Urdbean is widely used in traditional Indian cuisine. The split seeds are consumed as dal, while the flour is extensively used in the preparation of idli, dosa, vada, papad, and other fermented food products. In addition to its use as food, Urdbean residues serve as valuable fodder for livestock, and the crop contributes to soil health by enhancing organic matter and nitrogen content. India is the largest producer and consumer of Urdbean globally. Major Urdbean-growing states include Madhya Pradesh, Uttar Pradesh, Maharashtra, Rajasthan, Andhra Pradesh, Karnataka, and Tamil Nadu. In Maharashtra, Urdbean is predominantly cultivated in the Vidarbha and Marathwada regions, where climatic conditions and soil types are favorable Nair *et al.*, (2024) [25]. Adoption of suitable agronomic practices such as ridge and furrow and Broad Bed Furrow (BBF) methods helps in moisture conservation and improves crop performance under rainfed conditions.

Plant spacing plays a crucial role in determining the growth and yield of Urdbean, as it influences light penetration, air circulation, nutrient uptake, and moisture utilization Kole *et al.*, (2002) [24]. Optimum plant geometry ensures better crop growth, reduces competition among plants, and enhances yield potential while minimizing the need for excessive inputs. The findings of this study will help farmers identify suitable sowing methods and optimum spacing to improve productivity, resource-use efficiency, and profitability of urdbean cultivation in the region.

Materials and Methods

The present investigation titled “Influence of Sowing Methods and Plant Spacing on Urdbean (*Vigna mungo* L.) in the Malwa Region (M.P.). The present experiment was conducted at Crop Research Cafeteria, under Mandsaur University, Mandsaur (Madhya Pradesh). Mandsaur (Madhya Pradesh) which is situated at latitude 24°04'36.61"N, longitude 75°04'9.46"E and at an altitude of 442.16 meters above the mean sea level. The experiment involved two main plot treatments: B₁ for flat bed sowing and B₂ for raised bed sowing. There were four sub-plot treatments based on spacing: S₁ for broadcasting, S₂ for 30×30 cm spacing, S₃ for 45×30 cm spacing, and S₄ for 60×30 cm spacing. The treatment combinations were as follows: T₁: Flat bed + Broadcasting (B₁S₁), T₂: Flat bed + 30×30 cm spacing (B₁S₂), T₃: Flat bed + 45×30 cm spacing (B₁S₃), T₄: Flat bed + 60×30 cm spacing (B₁S₄), T₅: Raised bed + Broadcasting (B₂S₁), T₆: Raised bed + 30×30 cm spacing (B₂S₂), T₇: Raised bed +

45×30 cm spacing (B₂S₃) and T₈: Raised bed + 60×30 cm spacing (B₂S₄). 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 Urdbean 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.

Results and Discussion

1. Plant population

Data pertaining to plant population at 30 Days After Sowing (DAS) and at harvest, 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's) on the plant population in Urdbean (*Vigna mungo* L.). These factors significantly affected the plant population at both 30 DAS and harvest, with distinct trends observed throughout the growing stages.

Main Effect of Sowing Methods

In general, the raised bed method (B₂) showed a consistently higher plant population both at 30 DAS and at harvest compared to the flat bed method (B₁). Urdbean sown under raised beds (B₂) had a plant population of 25.01 plants per square meter at 30 DAS, which reduced to 19.36 plants per square meter at harvest. In contrast, Urdbean sown under flat beds (B₁) had 19.07 plants per square meter at 30 DAS, with at harvest further decrease to 13.01 plants per square meter at harvest. Previous studies are well justified with the present findings as made by (Mehta and Bharat, 2017; Asewar *et al.*, 2017 and Keisham *et al.*, 2021) [1, 2, 23].

Main Effect of Spacing

Among the different sowing method × spacing combinations, significant variations in plant populations were observed. Under the raised bed method (B₂), the combination with broadcasting (S₁) resulted in the highest plant population at 30 DAS (32.38 plants per square meter), and this remained relatively high at harvest with 29.07 plants per square meter. In contrast, the combination of flat bed method (B₁) and 60×30 cm spacing (S₄) resulted in the lowest plant population at both stages (13.30 plants per square meter at 30 DAS, decreasing to 12.80 plants per square meter at harvest). It suggests that the plant spacing may not be ideal for maximizing plant establishment in the flat bed method, particularly at a larger distance between plants. The present study is incorporated with the findings of Ghormade *et al.*, (2011) [12]; Ghasemi *et al.*, (2017) [11] and Rathnayaka *et al.*, (2018) [28] and Kaysha *et al.*, (2018) [22] in Urdbean.

Interaction Effects of Sowing Method and Spacing

The interaction between the sowing method and spacing treatments also revealed significant results. The highest plant population at both 30 DAS and harvest was observed under the raised bed + broadcasting (B₂S₁) treatment, with 32.38 plants per square meter at 30 DAS, decreasing slightly to 29.07 at harvest. Similarly, the flat bed + 45×30 cm spacing (B₁S₃) combination resulted in a good plant population, with 20.59 plants per square meter at 30 DAS, which slightly increased to 19.30 plants per square meter at harvest. On the other hand, the flat bed + 60×30 cm spacing (B₁S₄) combination resulted in the smallest plant population at both stages, with only 13.30 plants per square

meter at 30 DAS and 12.80 plants per square meter at harvest. This highlights the importance of selecting appropriate sowing methods and spacing combinations to maximize plant population and ensure optimal crop performance. Similar observations were reported by the findings of Ghasemi *et al.*, (2017) ^[11], El-Sayed *et al.*, (2020) ^[8]; and Zyada *et al.*, (2021) ^[33].

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

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

Main Effect of Sowing Methods

Urdbean plants grown on raised beds (B_2) had a higher fresh weight (113.91 g) and dry weight (16.87 g) compared to those grown on flat beds (B_1), which had a fresh weight of 89.93 g and a dry weight of 14.93 g.

Our results substantiate the findings of past studies conducted by Qureshi *et al.*, (2018) ^[27] and Joseph *et al.*, (2019) ^[20].

Main Effect of Spacing

Among the subplot treatments, the plants grown with 30×30 cm spacing (S_2) had the highest fresh weight of (114.91 g) and the highest dry weight of (16.97 g) followed by 60×30 cm spacing (S_4) showed a fresh weight of (105.21g) and a dry weight of (16.01g) and broadcasting (S_1) resulted in a fresh weight of (100.63 g) and a dry weight of (15.81 g). The 45×30 cm spacing (S_3) had the lowest fresh weight at (88.87 g) and dry weight at (14.50 g).

The evidence we present echoes the results reported by (Asewar *et al.*, 2017 and Singh *et al.*, 2018) ^[2, 30] and Aseefa *et al.*, in Urdbean.

Interaction Effects of Sowing Method and Spacing

The combination of B_2S_1 (Raised bed + Broadcasting) produced the highest fresh weight (136.02 g) and dry weight (18.63 g) followed by B_2S_2 (Raised bed + 30×30 cm spacing) resulted in a fresh weight of (124.53g) and a dry weight of (18.29g) and B_2S_3 (Raised bed + 45×30 cm spacing) resulted in a fresh weight of (123.39 g) and a dry weight of (18.22g). 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 results obtained here are in contrast with the conclusions of (Adhikari and Ramana 2019 and Gulser, 2019) ^[1, 16] and Habde *et al.*, (2025) ^[18] in Urdbean.

3. Number of Pods at 90 days after sowing (DAS)

Data pertaining to the number of pods at 90 Days After Sowing (DAS), as presented in the (Table-3), indicate the main effects of different sowing methods (flat bed and raised bed) and spacing treatments (broadcasting and various row spacing) on the number of pods in Urdbean. These factors significantly affected the number of pods at 90 DAS, with distinct trends observed throughout the growing stages. The current study aligns with previous reports by (Dhakad *et al.*, 2017 and Singh *et al.*, 2021).

Main Effect of Sowing Methods

In general, the raised bed method (B_2) resulted in a higher number 17.65 of pods at 90 DAS compared to the flat bed method (B_1) had 17.19 pods at 90 DAS.

Main Effect of Spacing

Among the different spacing treatments, significant variations in the number of pods were observed. The 30×30 cm spacing (S_2)

treatment led to the highest number of pods at 90 DAS, with a measurement of 18.63, followed by the 30×30 cm spacing, followed by (S_3) treatment, which resulted in 18.50 pods. In contrast, the broadcasting treatment (S_1) resulted in the lowest number of pods at 90 DAS, with 17.01 pods. In line with the current experiment, the findings suggest as per (Ghasemi *et al.*, 2017 ^[11] and Kaur *et al.*, (2025) ^[21] in Urdbean.

Interaction Effects of Sowing Method and Spacing

The interaction between the sowing method and spacing treatments revealed significant differences in the number of pods. The highest number of pods was observed under the treatment $T_8 (B_2S_4)$ raised bed + 60×30 cm spacing combination, with 21.18 pods, followed by treatment $T_5 (B_2S_1)$ raised bed + broadcasting with 19.05 pods, and treatment $T_2 B_1S_2$ (Flat bed + 30×30 cm spacing) (B_1S_2) with 18.82 pods. However, the minimum number of pods was recorded under the treatment B_2S_2 (Raised bed + 30×30 cm spacing) with 12.44 pods at 90 DAS.

The results obtained here are in contrast with the conclusions of (Adhikari and Ramana 2019 and Gulser, 2019) ^[1, 16].

4. Days to 50% flowering

Data pertaining to the number of pods at 90 Days after Sowing (DAS), as presented in the (Table -4), indicate the main effects of different sowing methods (flat bed and raised bed) and spacing treatments (broadcasting and various row spacing) on days to 50% flowering in Urdbean. These factors significantly affected the days to 50% flowering, with distinct trends observed throughout the growing stages. This suggests that the raised bed method may provide a more favorable environment for plant growth and development, leading to earlier flowering. The findings presented here contradict the results reported by (Eseigbe *et al.*, 2024; Essilfie *et al.*, 2024) ^[9, 10] and Kaur *et al.*, (2025) ^[21] in Urdbean.

Main Effect of Sowing Methods

In general, the raised bed method (B_2) resulted in minimum days taken for flowering (36.80) days compared to the flat bed method (B_1) which observed (40.16) at 90 days. The findings presented here contradict the results reported by (Eseigbe *et al.*, 2024; Essilfie *et al.*, 2024; Taksalkar *et al.*, 2024) ^[9, 10, 32] in Urdbean.

Main Effect of Spacing

Among the different spacing treatments, significant variations were observed for days to 50% flowering. The 30×30 cm spacing (S_2) treatment led to the minimum days to 50% flowering at 90 DAS, with 39.21 days, followed by treatment (S_3) 45×30 cm spacing, which observed (40.00) days. In contrast, the treatment (S_1) broadcasting treatment resulted maximum (40.69) days.

In contrast, the treatment (S_1) broadcasting treatment resulted maximum (40.66) days. This suggests that closer spacing may optimize flowering time, possibly by enhancing plant interaction or reducing competition for resources like nutrients and sunlight. Some previously studies also in line with our study as per (Gu *et al.*, 2024 & Chavan *et al.*, 2025) ^[15, 6] and Bansal *et al.*, 2024 ^[4] in Urdbean.

Interaction Effects of Sowing Method and Spacing

The interaction between the sowing method and spacing treatments revealed significant differences in the days to 50% flowering. The minimum days was observed under the treatment $T_8 (B_2S_4)$ Raised bed + 60×30 cm spacing combination, with

(39.05) days, followed by treatment T₄ (B₁S₄) Flat bed +60×30 cm spacing with (39.17) days, and treatment T₆ (B₂S₂) Raised bed + 30×30 cm spacing with (39.33) days. However, the maximum days to 50% flowering was recorded under the treatment T₃ (B₂S₂) flat bed +45×30 cm spacing with (40.69) days.

In contrast, treatment T₅ with raised bed + broadcasting (B₂S₁) 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 (Pereyra *et al.*, 2024; Dos Santos *et al.*, 2024) ^[26, 7].

Table 1: Plant Population at 30 DAS of Urdbean (1 Meter Square in Plot)

		Main Plot				
S. No.	Treatments	Sowing method	Plant Population at 30 DAS (1 meter square in plot)		At harvest	
1	B ₁	Flat bed	19.07		13.01	
2	B ₂	Raised bed	25.01		19.36	
		Sub plot treatments				
1	S ₁	Broadcasting	25.50		22.50	
2	S ₂	30×30cm	23.16		20.00	
3	S ₃	45×30cm	21.83		17.16	
4	S ₄	60×30cm	17.50		16.16	
S. No.	Treatments	Treatment combination	Plant Population at 30 DAS (1 meter square in plot)		At harvest	
1.	T ₁	B ₁ S ₁ (Flat bed+Broadcasting)	18.66		16.00	
2.	T ₂	B ₁ S ₂ (Flat bed +30×30 cm spacing)	23.33		18.00	
3.	T ₃	B ₁ S ₃ (Flat bed +45×30 cm spacing)	20.66		19.30	
4.	T ₄	B ₁ S ₄ (Flat bed +60×30 cm spacing)	13.30		12.80	
5.	T ₅	B ₂ S ₁ (Raised bed + Broadcasting)	32.38		29.07	
6.	T ₆	B ₂ S ₂ (Raised bed + 30×30 cm spacing)	20.33		16.33	
7.	T ₇	B ₂ S ₃ (Raised bed + 45×30 cm spacing)	25.66		20.59	
8.	T ₈	B ₂ S ₄ (Raised bed + 60×30 cm spacing)	21.66		19.333	
		Factors	C.D.	SE(m) ±	C.D.	SE(m) ±
		Factor A (Sowing methods)	2.15	1.08	2.05	1.02
		Factor B (Spacing)	2.11	1.05	2.12	3.50
		Factor (A×B)	2.25	1.12	2.20	1.12

Table 2: Plant Population at 30 DAS of Urdbean (5 tagged plants per plot)

		Main Plot		
S. No.	Treatments	Sowing method	Plant population at 30 DAS (5 tagged plants per plot)	
1	B ₁	Flat bed	53.02	
2	B ₂	Raised bed	53.47	
		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 population at 30 DAS (5 tagged plants per plot)	
1.	T ₁	B ₁ S ₁ (Flat bed+Broadcasting)	53.79	
2.	T ₂	B ₁ S ₂ (Flat bed +30×30 cm spacing)	48.13	
3.	T ₃	B ₁ S ₃ (Flat bed +45×30 cm spacing)	55.50	
4.	T ₄	B ₁ S ₄ (Flat bed +60×30 cm spacing)	56.45	
5.	T ₅	B ₂ S ₁ (Raised bed + Broadcasting)	46.59	
6.	T ₆	B ₂ S ₂ (Raised bed + 30×30 cm spacing)	58.59	
7.	T ₇	B ₂ S ₃ (Raised bed + 45×30 cm spacing)	60.78	
8.	T ₈	B ₂ S ₄ (Raised bed + 60×30 cm spacing)	46.33	
		Factors	C.D.	SE(m) ±
		Factor A (Sowing methods)	2.45	1.25
		Factor B (Spacing)	2.12	1.05
		Factor (A×B)	1.65	0.72

Table 3: Number of Pods at 90 DAS of Urdbean (5 tagged plants per plot)

		Main Plot	
S. No.	Treatments	Sowing method	Number of pods at 90 DAS (5 tagged plants per plot)
1	B ₁	Flat bed	17.19
2	B ₂	Raised bed	17.65
Sub plot treatments			
1	S ₁	Broadcasting	17.01
2	S ₂	30×30cm	18.63
3	S ₃	45×30cm	18.49
4	S ₄	60×30cm	15.76

S.No.	Treatments	Treatment combination	Number of pods at 90 DAS (5 tagged plants per plot)	
1.	T ₁	B ₁ S ₁ (Flat bed+Broadcasting)	15.13	
2.	T ₂	B ₁ S ₂ (Flat bed +30×30 cm spacing)	18.82	
3.	T ₃	B ₁ S ₃ (Flat bed +45×30 cm spacing)	18.73	
4.	T ₄	B ₁ S ₄ (Flat bed +60×30 cm spacing)	16.13	
5.	T ₅	B ₂ S ₁ (Raised bed + Broadcasting)	19.05	
6.	T ₆	B ₂ S ₂ (Raised bed + 30×30 cm spacing)	12.44	
7.	T ₇	B ₂ S ₃ (Raised bed + 45×30 cm spacing)	18.26	
8.	T ₈	B ₂ S ₄ (Raised bed + 60×30 cm spacing)	21.18	
		Factors	C.D.	SE(m) ±
		Factor A (Sowing methods)	1.80	0.92
		Factor B (Spacing)	2.40	1.21
		Factor (A×B)	2.05	1.05

Table 4: Days to 50% flowering at 90 DAS of Urdbean (5 tagged plants per plot)

		Main Plot		
S. No.	Treatments	Sowing method	Days to 50% flowering at 90 DAS (5 tagged plants per plot)	
1	B ₁	Flat bed	40.16	
2	B ₂	Raised bed	36.80	
		Sub plot treatments		
1	S ₁	Broadcasting	40.69	
2	S ₂	30×30cm	39.21	
3	S ₃	45×30cm	40.00	
4	S ₄	60×30cm	40.33	
S. No.	Treatments	Treatment combination	Days to 50% flowering at 90 DAS (5 tagged plants per plot)	
1.	T ₁	B ₁ S ₁ (Flat bed+Broad casting)	40.33	
2.	T ₂	B ₁ S ₂ (Flat bed +30×30 cm spacing)	40.65	
3.	T ₃	B ₁ S ₃ (Flat bed +45×30 cm spacing)	40.69	
4.	T ₄	B ₁ S ₄ (Flat bed +60×30 cm spacing)	39.17	
5.	T ₅	B ₂ S ₁ (Raised bed + Broadcasting)	41.00	
6.	T ₆	B ₂ S ₂ (Raised bed + 30×30 cm spacing)	39.33	
7.	T ₇	B ₂ S ₃ (Raised bed + 45×30 cm spacing)	40.00	
8.	T ₈	B ₂ S ₄ (Raised bed + 60×30 cm spacing)	39.05	
		Factors	C.D.	SE(m) ±
		Factor A (Sowing methods)	2.25	1.18
		Factor B (Spacing)	2.05	1.03
		Factor (A×B)	1.75	0.87

Conclusion

The raised bed method (B₂) consistently resulted in a higher plant population compared to the flat bed method (B₁). The best combination for plant population was raised bed + broadcasting (B₂S₁), while flat bed with wider spacing (60×30 cm) showed the lowest. Urdbeans grown on raised beds (B₂) had higher fresh and dry weights than those on flat beds (B₁). The raised bed + broadcasting (B₂S₁) combination produced the highest biomass, while raised bed + 60×30 cm spacing (B₂S₄) had the lowest. Raised beds (B₂) led to more pods compared to flat beds (B₁). The highest pod count was found in the raised bed + 60×30 cm spacing (B₂S₄), while broadcasting (S₁) had the lowest. The raised bed method (B₂) resulted in earlier flowering. Raised bed + 60×30 cm spacing (B₂S₄) flowered the earliest, while broadcasting (S₁) took the longest.

Author's Contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Competing Interest

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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