



RESEARCH ARTICLE

# Interactions of planting dates and mulching practices on growth and yield of garlic (*Allium sativum* L.) in central India

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## Abstract

Garlic (*Allium sativum* L.) is a globally important spice crop valued for its culinary, medicinal and nutraceutical properties, with India being a major producer. Crop growth, yield and quality are highly influenced by planting time and mulching practices, which regulate soil moisture, temperature and weed suppression. This study aimed to evaluate the effects of different planting dates and mulching treatments on garlic growth, pest and disease incidence, yield and quality under central Indian conditions. A field experiment was conducted during the 2020–21 rabi season at central India, Jabalpur (MP), to evaluate the effects of planting dates and mulching on growth, pest and disease incidence, yield and quality of garlic (*Allium sativum* L., variety G-50). The trial was laid out in a factorial randomised block design with three planting dates (15 November, 1 December, 16 December) and three mulching treatments (plastic mulch, paddy straw mulch and no mulch). Growth, bulb morphometry, Stemphylium blight, thrips infestation, yield and quality parameters were recorded at different day intervals. Results revealed highly significant interaction effects of planting date and mulch on all growth, yield and quality traits. Early planting (15 November) combined with plastic mulch consistently produced superior vegetative growth, larger bulbs, higher clove weight, maximum total and marketable yield (90.10 q/ha and 80.45 kg/plot) and improved quality traits (TSS 39.58 °B; dry matter 42.16 %) while minimising pest and disease incidence. Conversely, late planting without mulch (16 December, no mulch) resulted in the poorest performance. The study concludes that timely planting coupled with appropriate mulching, particularly plastic mulch, is a highly effective agronomic strategy to enhance garlic growth, yield and quality under central Indian conditions.

**Keywords:** *Allium sativum*; bulb morphometry; mulching; plastic mulch; stemphylium blight; yield

## Introduction

Garlic (*Allium sativum* L.) is one of the most recognised bulbous spice crops (family *Amaryllidaceae*,  $2n=16$ ) for its nutritional and economic value (1). Grown widely across different regions of the world, including tropical and subtropical climates, among which India is a major producer, with production of 3.37 million tonnes (mt) annually (2). Globally, Asia dominates garlic cultivation, accounting for close to 90 % of total production, with China alone contributing more than 25 % of this share. Garlic is esteemed not only as a culinary ingredient but also for its remarkable medicinal and nutraceutical properties (3). The crop is mainly cultivated for its diverse culinary applications and is valued for its characteristic flavour and aroma that enhance the taste and palatability of various dishes; additionally, its well-documented antimicrobial, anti-inflammatory, anticancer and cardiovascular properties have further strengthened its market demand at both national and international levels (4). Garlic pastes combined with lime juice are traditionally used to treat mouth ulcers and sore throat and can also be incorporated into toothpaste to help prevent dental caries

(5, 6). Additionally, garlic has been identified as a potential therapeutic food that may aid in managing COVID-19 infection (7). In India, garlic holds a prominent place among different spice crops, with Madhya Pradesh accounting for 29 % of the total cultivated area and 31 % of the national production. Ratlam, Ujjain, Mandsaur, Neemuch and Indore are the major garlic-producing districts of Madhya Pradesh. Crop productivity and its quality are highly dependent on the timing of planting, as it is a thermosensitive and photosensitive crop (8). The selection of an appropriate planting time is critical for vegetative growth and quality of clove, with optimal environmental conditions (9). Deviations from the recommended planting time, either early or late, can significantly reduce bulb size and quality.

This decline ultimately lowers market value, highlighting the need for region-specific planting schedules to maximise economic returns. Mulching is an important agronomic practice that plays a major role in garlic productivity by covering the soil surface with organic or inorganic materials to achieve multiple benefits (10). It helps in covering the soil surface, which conserves soil moisture, regulates soil temperature, suppresses weed growth

and improves soil physical, chemical or biological properties, with a direct impact on garlic production (11). Mulching contributes to faster plant development by suppressing weed growth and minimising the risk of soil-borne contamination in the farm. The main objective of this study was to assess the effect of different planting dates or mulches on growth, pest or disease incidence and yield of garlic under Central Indian conditions, Jabalpur region, where no weed control measures are adopted.

## Materials and Methods

### Agro-climatic and soil conditions of the experimental site

During the cropping season from October to March, weekly meteorological data were recorded at JNKV, Jabalpur, showing temperatures ranging from 4.8–38.8 °C, high morning humidity (47–91 %), lower evening humidity (11–58 %) and rainfall mainly in November (5.2 mm) and May (39 mm), reflecting a humid subtropical climate influencing crop growth and yield (Table S1). Soil samples (0–20 cm depth) collected from the experimental field revealed light black, well-drained soil suitable for vegetable cultivation, with a pH of 7.5. The soil was nutritionally adequate, with available potash (321 kg/ha), available phosphorus (25.9 kg/ha), organic carbon (0.89 %) and available nitrogen (261 kg/ha) (Table S2).

### Experiment field preparation and crop establishment

The experiment was conducted at the Vegetable Research Farm, JNKV Jabalpur, during 2020–2021, using garlic variety G-50. The trial was laid out in a factorial randomised block design (FRBD) with three replications, nine treatment combinations and a total of 27 plots. Each plot measured 2.0 × 1.95 m, with plant spacing of 15 × 15 cm, 260 plants per plot and interplot or inter-replication distance of 0.5 m and 1 m. The treatments comprised three dates of planting, 15<sup>th</sup> November (D<sub>1</sub>), 1<sup>st</sup> December (D<sub>2</sub>) and 16<sup>th</sup> December (D<sub>3</sub>), combined with three mulching conditions, i.e., no mulch (M<sub>0</sub>), plastic mulch (M<sub>1</sub>) and paddy straw mulch (M<sub>2</sub>), resulting in nine treatment combinations. Field preparation included ploughing, levelling and application of 50 t farm yard manure and nitrogen, phosphorus, potassium fertilisers, with garlic cloves (8–10 mm) treated with thiram and planted at 15 × 15 cm spacing. Plastic and paddy straw mulches were applied.

### Measurement of growth attributes of garlic under different planting dates and mulching treatments

Observations on garlic were recorded based on morphological traits, yield attributes and bulb quality. For data collection, five plants were randomly selected and tagged from each plot. Morphological parameters measured included plant height (cm), number of leaves per plant, leaf length (cm) and width (cm), pseudostem length (cm) and diameter (cm), recorded at 30, 60 and 90 days after planting (DAP) using a measuring scale or vernier calliper, with mean values computed from the five sampled plants. Bulb characteristics, including polar and equatorial diameters (cm), were measured using vernier calipers and the average of five bulbs per plot was taken to represent each treatment.

### Evaluation of stemphylium blight and thrips infestation

The incidence of Stemphylium blight on garlic was assessed using a 0–9 scale based on the proportion of leaf area covered by pustules (12) (Table 1). Five plants at the bulb developmental stage were

randomly selected from each plot and scored at fortnightly intervals. Concurrently, the thrips population was monitored by counting nymphs and adults on the top five leaves of five randomly selected plants per replication at 30, 60 and 90 days after planting (DAP), with mean thrips per plant calculated to represent infestation levels. Percent disease incidence (PDI) was calculated using the formula:

$$\text{PDI (\%)} =$$

$$\left( \frac{\text{Sum of ratings}}{\text{Maximum possible score}} \times \text{Number of leaves}$$

**Table 1.** % disease incidence Scale for evaluating Stemphylium blight in Garlic

Grade	% area covered (leaf)
0	Absolutely free from infection
1	Small-sized lesions on the leaf covering <1 % area
2	Small-sized lesions on the leaf covering <2–5 % area
3	Small-sized lesions on the leaf covering <6–10 % area
4	Small-sized lesions on the leaf covering <11–15 % area
5	Small-sized lesions on the leaf covering <16–25 % area
6	26–40 % area covering
7	41–60 % area covering
8	61–75 % area covering
9	>75 % area covered with spots, most of the leaves dried

$$\text{examined} \times 100 \quad (\text{Eqn. 1})$$

### Assessment of yield and quality parameters in garlic under different planting dates and mulching treatments

The yield and quality parameters of garlic were recorded by sampling five plants randomly from each plot. Yield parameters included bulb weight, number of cloves per bulb and the weight of ten cloves, with mean values calculated for each measurement. Total yield per plot was determined by weighing all harvested bulbs, while marketable yield (%) was calculated by separating rotted, undersized and sprouted bulbs from the total yield using the formula.

$$\text{Marketable yield (\%)} =$$

$$\left( \frac{\text{Marketable yield (kg/plot)}}{\text{Total yield (kg/plot)}} \times 100 \right) \quad (\text{Eqn. 2})$$

The total yield was extrapolated to q/ha after curing the bulbs for 15 days. Quality parameters included total soluble solids (TSS, °Brix) measured using a hand refractometer and dry matter content, estimated by taking ten fresh bulbs from each plot at harvest, air-drying and then oven-drying at 65 ± 2 °C for 45–48 hr until constant weight, with dry matter content calculated as.

$$\text{Dry matter content (\%)} =$$

$$\left( \frac{\text{Weight of cloves after drying}}{\text{Weight of cloves before drying}} \times 100 \right) \quad (\text{Eqn. 3})$$

### Statistical analysis

The data recorded on growth, yield and quality parameters were subjected to statistical analysis using analysis of variance (ANOVA). Data were analysed using R software and treatment effects in the Factorial RBD were subjected to two-way ANOVA and means were separated using critical difference (CD) tests at a 5 % level of significance. The ANOVA was performed by partitioning the total variation into components due to replications, treatments, planting dates, mulching materials and their interaction effects. The mean sum of squares for each source of variation was computed by dividing the sum of squares by its respective degrees of freedom and the calculated 'F' values were compared with the tabulated 'F'

values at the 5% probability level to determine significance.

## Results

### Interaction effect of planting dates and mulching on growth and bulb morphometry of garlic

Interaction effects were found to be highly significant for all measured growth traits. The combination of 15<sup>th</sup> November planting with plastic mulch (D<sub>1</sub>M<sub>1</sub>) consistently produced superior growth performance across all parameters. This treatment resulted in the maximum plant height (34.82–68.09 cm), number of leaves per plant (5.53–9.75), leaf length (26.79–49.11 cm), leaf width (0.85–2.37 cm), pseudostem length (2.34–4.89 cm) and pseudostem diameter (0.57–0.84 cm). In contrast, the combination of 16<sup>th</sup> December planting without mulch (D<sub>3</sub>M<sub>0</sub>) recorded the minimum values for all traits, with plant height ranging from 19.63 to 56.47 cm, number of leaves from 2.74 to 7.55, leaf length from 21.62 to 40.87 cm, leaf width from 0.67 to 1.66 cm, pseudostem length from 1.97 to 3.58 cm and pseudostem diameter from 0.41 to 0.74 cm. These results clearly demonstrate that early planting combined with plastic mulch significantly enhances vegetative growth compared to late planting under no-mulch conditions. All the above data are presented in the supplementary file (Tables S3–S8). Interaction effects exerted a highly significant influence on garlic bulb dimensions. The treatment combination of 15<sup>th</sup> November planting with plastic mulch (D<sub>1</sub>M<sub>1</sub>) consistently produced superior bulb development, recording the maximum polar diameter (2.95 cm) and equatorial diameter (4.39 cm) (Fig. 1). Conversely, the combination of 16<sup>th</sup> December planting without mulch (D<sub>3</sub>M<sub>0</sub>) resulted in the smallest bulbs, with the lowest polar (2.55 cm) and equatorial (3.96 cm) diameters indicating a pronounced negative effect of delayed planting under non-mulched conditions on bulb growth (Fig. 1).

### Pest and disease incidence as affected by planting date × mulch interaction

Garlic planted on 15<sup>th</sup> November recorded the lowest incidence of Stemphylium blight, with disease index values of 3.52 %, 4.79 % and 5.90 % at 30, 60 and 90 days after planting, respectively. The highest disease incidence (5.26 %, 6.69 %) and 9.04 % was observed in the 16<sup>th</sup> December planting. Among mulches, plastic mulch showed the lowest disease index (3.36 %, 4.66 % and 6.24 %), significantly better than other treatments, while no mulch resulted in the highest incidence (5.61 %, 6.80 % and 8.51 %). The combination of 15<sup>th</sup> November planting with plastic mulch gave the minimum disease index (2.47 %, 3.89 % and 4.80 %), whereas the highest incidence (6.43 %, 7.80 % and 10.39 %) was recorded in the 16<sup>th</sup> December planting without mulch (Table 2). Thrips incidence was significantly affected by planting dates and mulching treatments. Garlic planted on 15<sup>th</sup> November showed the lowest thrips population (8.96, 10.85 and 13.03 thrips per plant at 30, 60 and 90 DAP, respectively), while the highest incidence (12.76 thrips per plant) was recorded on 16<sup>th</sup> December at 60 DAP. Plastic mulch resulted in the minimum thrips count (8.32, 10.09 and 11.08 thrips per plant), which was significantly better than other treatments, whereas no mulch recorded the highest incidence (11.50, 13.56 and 13.92 thrips per plant). The combination of 15<sup>th</sup> November planting with plastic mulch showed the least infestation (7.84, 9.23 and 11.54 thrips per plant), while the highest population (13.56 thrips per plant) was observed under the 16<sup>th</sup> December planting without mulch at 60 DAP (Table 3).

### Effect of planting date and mulching on garlic bulb traits and yield

Interaction effects between planting date and mulch application were found to be highly significant for all bulb and yield parameters, clearly demonstrating the combined influence of these factors on garlic productivity. The treatment combination of 15<sup>th</sup> November planting with plastic mulch (D<sub>1</sub>M<sub>1</sub>) consistently outperformed all other combinations, producing the highest fresh bulb weight (29.79 g), maximum number of cloves per bulb (21.87) and the heaviest average weight of 10 cloves (7.46 g) (Fig. 2–4). This superior growth translated into the highest per-plot yield (4.32 kg),

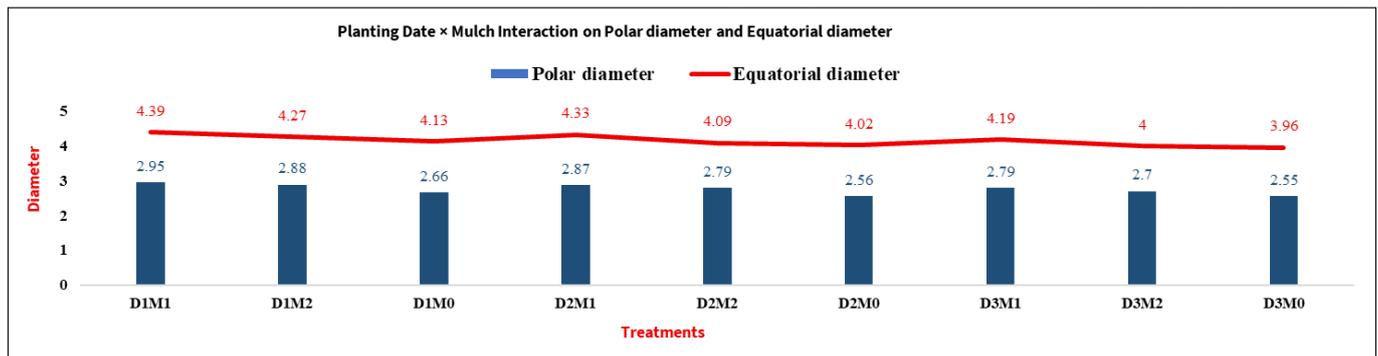


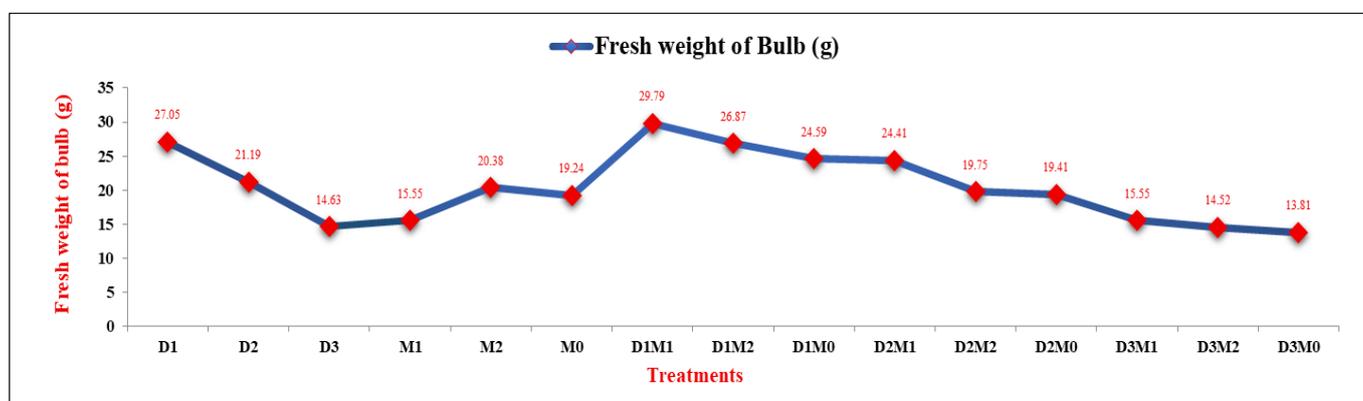
Fig. 1. Interaction effect of planting dates and mulching on polar diameter and equatorial diameter.

Table 2. % disease incidence of Stemphylium blight as affected by planting date and mulching

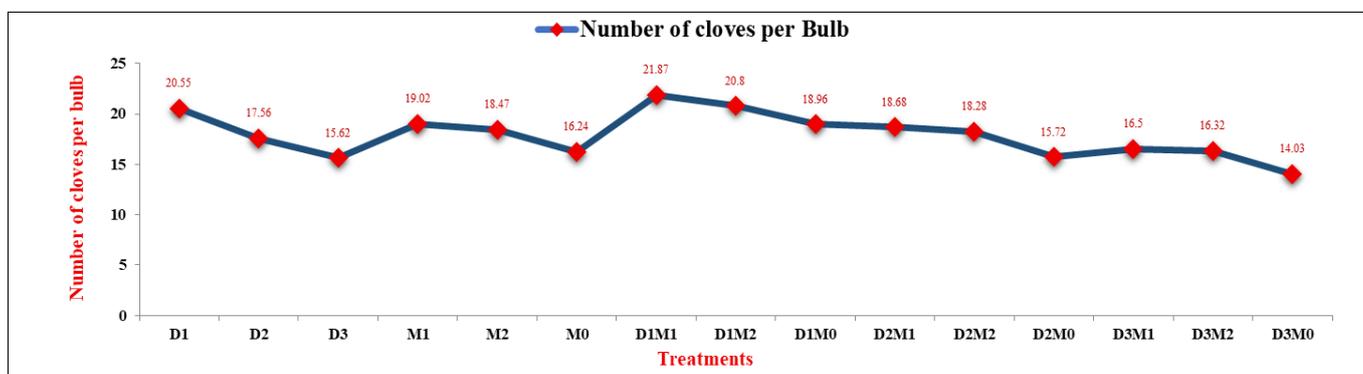
Planting date	Mulching											
	30 DAP				60 DAP				90 Days			
	(M <sub>1</sub> ) Plastic Mulch	(M <sub>2</sub> ) Paddy Straw	(M <sub>0</sub> ) No Mulch	Mean Dates	(M <sub>1</sub> ) Plastic Mulch	(M <sub>2</sub> ) Paddy Straw	(M <sub>0</sub> ) No Mulch	Mean dates	(M <sub>1</sub> ) Plastic Mulch	(M <sub>2</sub> ) Paddy Straw	(M <sub>0</sub> ) No Mulch	Mean Dates
D <sub>1</sub> (15 <sup>th</sup> November)	2.47	3.35	4.73	3.52	3.89	4.65	5.84	5.90	4.80	5.98	6.92	5.90
D <sub>2</sub> (1 <sup>st</sup> December)	3.47	4.58	5.69	4.58	4.41	5.61	6.76	7.13	6.08	7.08	8.23	7.13
D <sub>3</sub> (16 <sup>th</sup> December)	4.13	5.21	6.43	5.26	5.69	6.59	7.80	9.04	7.84	8.90	10.39	9.04
Mean Mulch	3.36	4.38	5.61		4.66	5.62	6.80		6.24	7.32	8.51	
Factor	SE(m)±			C.D. at 5 % level	SE(m)±			C.D. at 5 % level	SE(m)±			C.D. at 5 % level
Planting dates	0.06			0.20	0.06			0.19	0.03			0.11
Mulch	0.06			0.20	0.06			0.20	0.03			0.11
Planting date × mulch	0.11			0.35	0.11			0.33	0.06			0.19

**Table 3.** Thrips incidence as affected by planting date and mulching

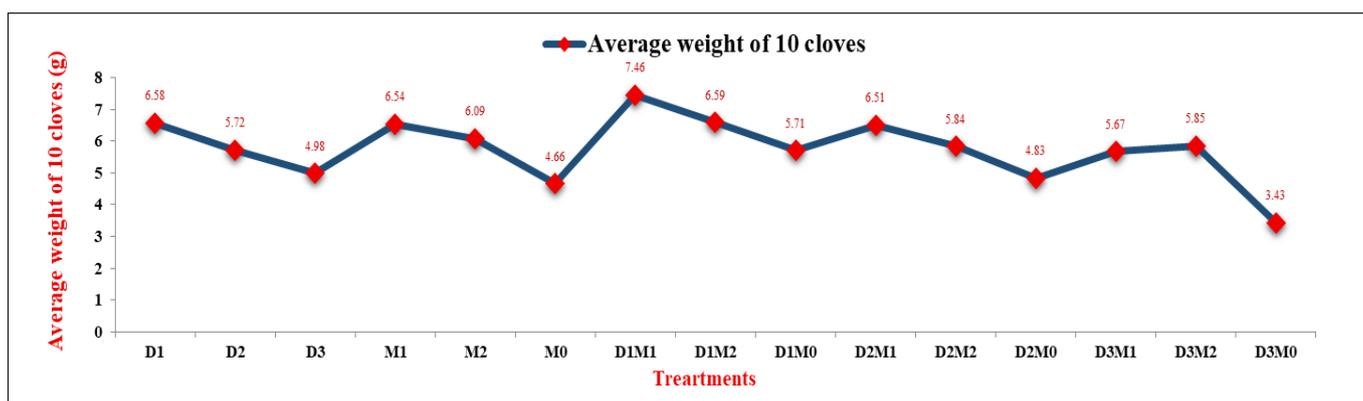
Planting date	Mulching											
	30 DAP				60 DAP				90 Days			
	(M <sub>1</sub> ) Plastic Mulch	(M <sub>2</sub> ) Paddy Straw	(M <sub>0</sub> ) No Mulch	Mean dates	(M <sub>1</sub> ) Plastic Mulch	(M <sub>2</sub> ) Paddy Straw	(M <sub>0</sub> ) No Mulch	Mean dates	(M <sub>1</sub> ) Plastic Mulch	(M <sub>2</sub> ) Paddy Straw	(M <sub>0</sub> ) No Mulch	Mean dates
<b>D<sub>1</sub> (15<sup>th</sup> November)</b>	7.84	8.60	10.43	8.96	9.23	10.70	12.62	10.85	11.54	13.07	14.50	13.03
<b>D<sub>2</sub> (1<sup>st</sup> December)</b>	8.36	9.65	11.56	9.85	10.26	12.44	14.11	12.27	10.59	12.70	14.18	12.49
<b>D<sub>3</sub> (16<sup>th</sup> December)</b>	8.76	10.84	12.51	10.70	10.80	13.56	13.53	12.76	11.11	12.25	13.08	12.01
<b>Mean Mulch</b>	8.32	9.69	11.50		10.09	12.22	13.56		11.08	12.67	13.92	
<b>Factor</b>	<b>SE(m)±</b>		<b>C.D. at 5 % level</b>		<b>SE(m)±</b>		<b>C.D. at 5 % level</b>		<b>SE(m)±</b>		<b>C.D. at 5 % level</b>	
<b>Planting dates</b>	0.06		0.20		0.05		0.17		0.07		0.21	
<b>Mulch</b>	0.06		0.20		0.05		0.17		0.07		0.21	
<b>Planting date × mulch</b>	0.10		0.32		0.10		0.32		0.12		0.36	



**Fig. 2.** Interaction effect of planting dates and mulching on fresh weight of bulb.



**Fig. 3.** Interaction effect of planting dates and mulching on the number of cloves per bulb.



**Fig. 4.** Interaction effect of planting dates and mulching on the average weight of 10 cloves.

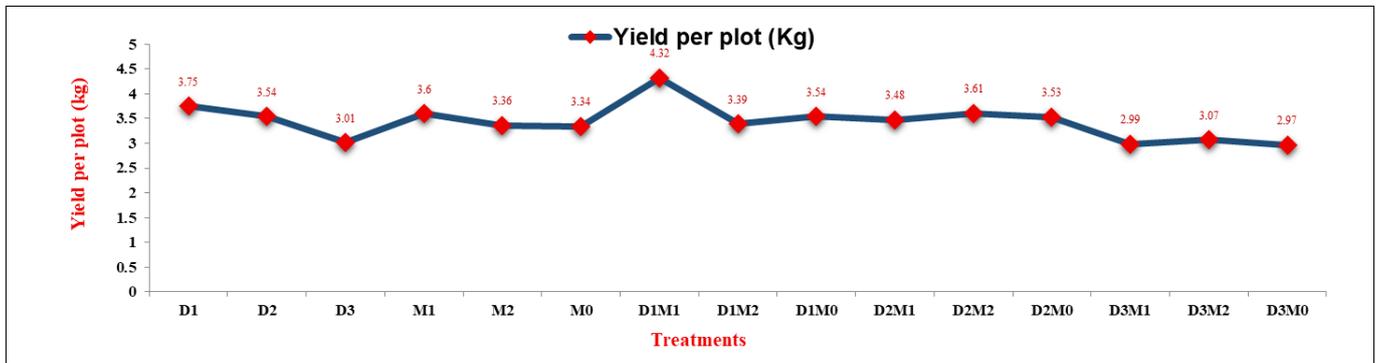


Fig. 5. Interaction effect of planting dates and mulching on yield per plot.

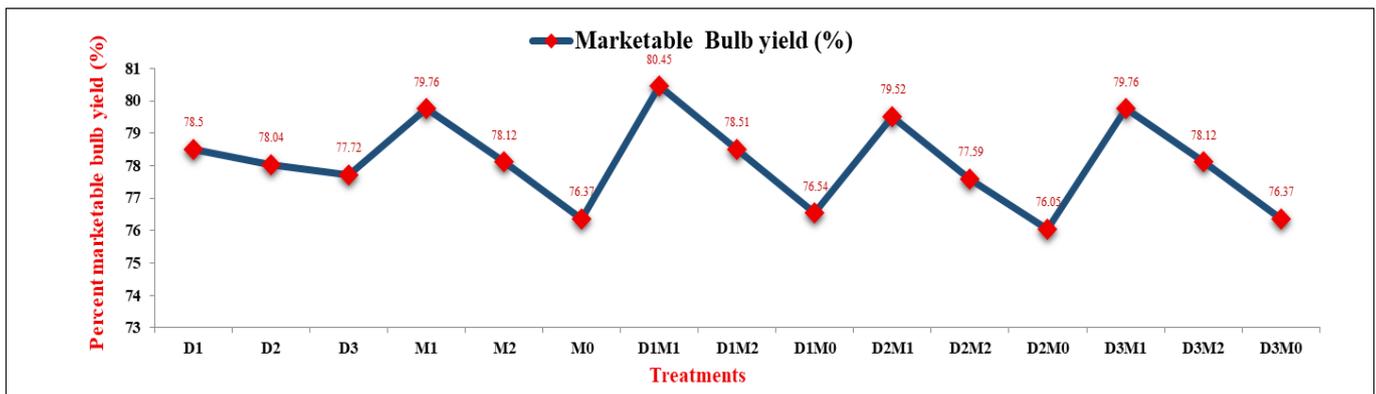


Fig. 6. Interaction effect of planting dates and mulching on marketable bulb yield.

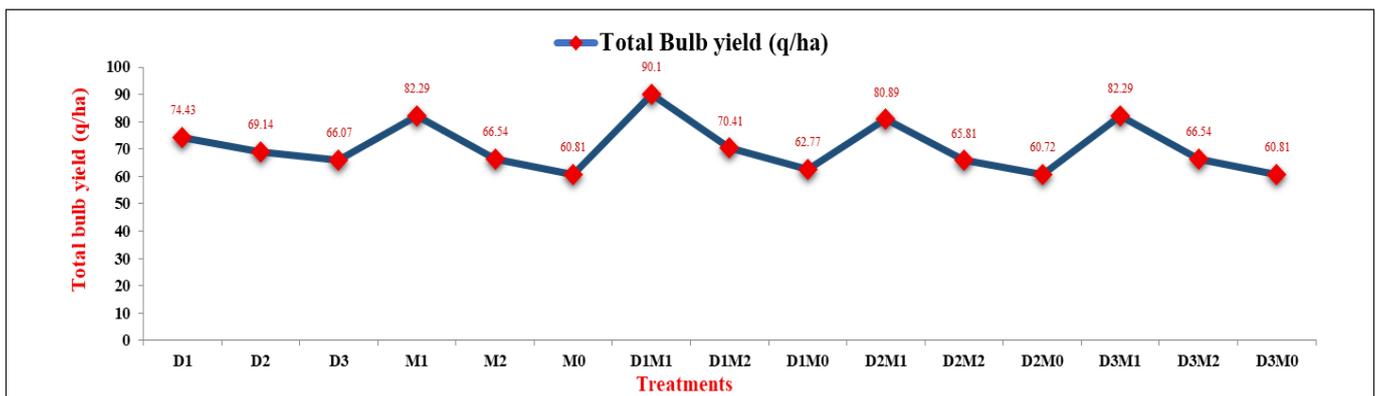


Fig. 7. Interaction effect of planting dates and mulching on total bulb yield.

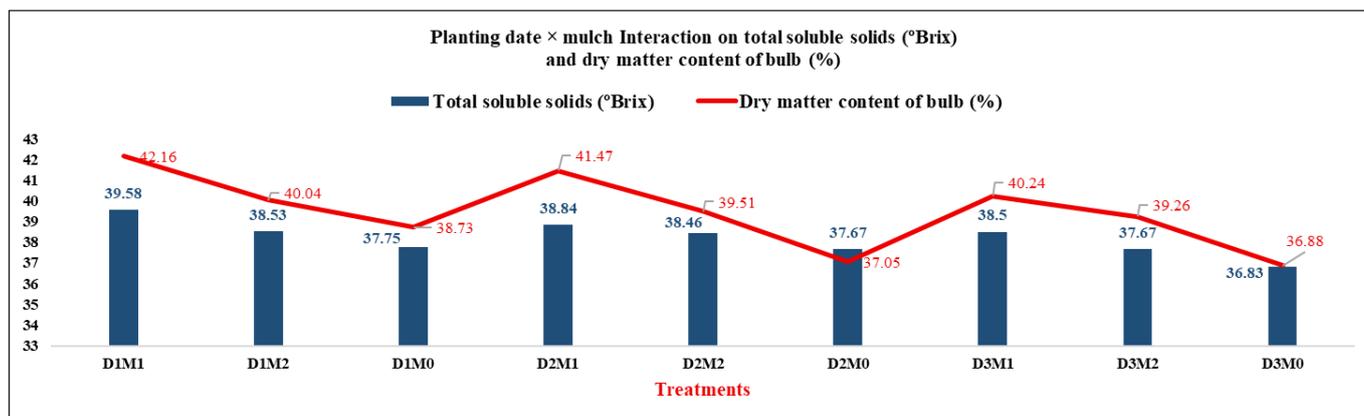
maximum marketable yield (80.45 %) and the greatest total yield (90.10 q/ha) (Fig. 5–7).

Conversely, the combination of 16<sup>th</sup> December planting without mulch (D3M0) consistently recorded the poorest performance, with the lowest fresh bulb weight (13.71 g), minimum number of cloves per bulb (4.04), smallest average clove weight (3.43 g), lowest per-plot yield (2.97 kg) and the least marketable yield (76.05 kg) and total yield (60.81 q/ha). Interaction effects of planting date and mulching were found to be highly significant for TSS (°Brix) and dry matter content of garlic bulbs. The highest TSS (39.58 °B) was recorded under 15<sup>th</sup> November planting with plastic mulch (D1M1), which was significantly superior to all other treatment combinations (Fig. 8). The lowest TSS (36.83 °B) was observed under late planting without mulch (D3M0) (Fig. 8). Similarly, mulching treatments significantly influenced dry matter content, with plastic mulch (M1) recording the highest bulb dry matter content (41.29 %) (Fig. 8), which was significantly superior to other mulching treatments. The lowest dry matter content (37.55 %) was noted under no mulch (M0). The interaction effect further revealed that the combination of 15<sup>th</sup> November planting with plastic mulch

(D1M1) resulted in the maximum dry matter content (42.16 %), whereas the minimum value (36.88 %) was observed under 16<sup>th</sup> December planting with no mulch (D3M0) (Fig. 8). These findings highlight that timely planting combined with plastic mulch application is critical for achieving optimal bulb development, higher clove weight and maximizing garlic yield potential.

## Discussion

The results of the present investigation clearly demonstrate that planting date and mulching had a significant influence on the vegetative growth, bulb development, yield and quality parameters of garlic. The G-50 variety produced compact, creamy white bulbs (3.5–4.0 cm, 35–40 cloves) and was harvested 4-5 months after planting. Regular observations of morphological traits revealed a distinct pattern of growth, with plant height increasing steadily up to 60 DAP, reaching physiological maturity and then gradually declining at later stages due to senescence. Leaf production continued until 90 DAP, after which leaf senescence became prominent beyond 100 days, resulting in a sharp decline in leaf count. These growth dynamics were strongly influenced by



**Fig. 8.** Interaction effect of planting dates and mulching on total soluble solids and dry matter content of the bulb.

environmental factors such as soil temperature, humidity and nutrient availability, which played a crucial role in determining the physiological performance of garlic. Early planting, especially around 15<sup>th</sup> November, promoted more vigorous vegetative growth, reflected in greater plant height, higher leaf number and larger leaf dimensions. This enhanced growth under early planting is likely due to an extended vegetative period with more favourable temperature and photoperiod conditions that support prolonged cell division and photosynthetic activity before bulb initiation. Research has demonstrated that earlier sowings increased vegetative growth and canopy development, leading to higher accumulation of dry matter and improved growth parameters compared with delayed planting dates in garlic (13–17)

Early planting in garlic was shown to be highly advantageous for achieving optimum vegetative growth and bulb development (18). Similarly, research indicates that planting in the 3<sup>rd</sup> week of October with a spacing of 15 × 15 cm resulted in the highest bulb yield (70.93 q/ha) along with superior bulb quality, highlighting the importance of both appropriate planting time and spacing for maximising garlic productivity (19). The increase in foliage under early planting enhanced photosynthetic capacity, leading to greater production of carbohydrates and other metabolites, which in turn contributed to the formation of larger and heavier bulbs. In contrast, late planting (16<sup>th</sup> December) was associated with reduced vegetative growth, lower leaf area and consequently, limited photosynthetic activity, resulting in smaller bulbs and lower yield. The enhanced photosynthetically active leaf area in early planting also improved solar radiation interception and dry matter accumulation in bulbs, thus improving their quality attributes. This clearly reflects the positive synergistic effect of early planting and mulching in enhancing bulb expansion. Mulching is a traditional practice used to retain soil water, suppress unwanted vegetation, regulate soil temperature and create a favourable environment for plant growth (11). Mulching had a pronounced effect on crop performance, with plastic mulch (white polyethene) recording the tallest plants (64.92 cm), the maximum number of leaves (9.59) and the highest values for leaf width, pseudostem length, diameter, bulb polar and equatorial diameters. These results align with the findings in tomato and bitter melon (20–22). Research found that 0.008 mm biodegradable mulch matched polyethene mulch in garlic yield and quality, improved soil health and degraded in sync with crop growth, offering a sustainable alternative to conventional polyethene mulch (23). The combination of early planting and plastic mulch (D<sub>1</sub>M<sub>1</sub>) showed the lowest infestation of *Stemphylium* blight and thrips incidence, likely

due to healthier, more vigorous plants and favourable microclimatic conditions that limited pathogen and thrips development. The beneficial effects of mulching may be attributed to better soil moisture conservation, moderated soil temperature and reduced weed competition, creating a favourable microclimate for root activity and nutrient uptake. Research reported that mulching markedly enhanced garlic vegetative growth and bulb size (24, 25).

## Conclusion

The present study demonstrates that both early planting and mulching significantly enhance the vegetative growth, bulb yield and quality attributes of garlic. Early planting, particularly around mid-November, promotes vigorous vegetative growth, increased leaf area and thicker pseudostems, which enhance photosynthetic efficiency and carbohydrate accumulation, ultimately leading to larger and heavier bulbs. Mulching, especially with plastic (white polyethylene), further enhances plant growth by conserving soil moisture, moderating temperature and reducing weed competition, thereby creating a favourable microclimate for root and nutrient development. Overall, the combined use of early planting and mulching represents an effective agronomic strategy to maximize garlic productivity and bulb quality.

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## Authors' contributions

N<sup>1</sup> contributed to formal analysis, investigation, methodology, writing, original draft preparation. BRP contributed to conceptualization of research. AS did the supervision, writing, review and editing. RN contributed to formal analysis, writing, original draft preparation. VBH did the writing, review and editing. SKS did the writing, review and editing. N<sup>2</sup> did the analysis and edited the manuscript. R contributed the methodology, writing, review and editing. All authors read and approved the final

manuscript. [N<sup>1</sup> stands for Nishant and N<sup>2</sup> stands for Nirankar].

## Compliance with ethical standards

**Conflict of interest:** Authors do not have any conflict of interests to declare.

**Ethical issues:** None

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