*International Journal of Plant & Soil Science*

***Volume 37, Issue 9, Page 77-87, 2025; Article no.IJPSS.136242***
***ISSN: 2320-7035***

# Evaluating the Impact of Fertigation Levels and Mulching on Growth and Yield of Garlic (*Allium sativum* L.)

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***Authors' contributions***

*This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.*

***Article Information***

DOI: https://doi.org/10.9734/ijpss/2025/v37i95687

**Open Peer Review History:**
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://pr.sdiarticle5.com/review-history/136242

***Original Research Article***

***Received: 23/03/2025***
***Published: 22/08/2025***

## ABSTRACT

Polyethylene mulch can be utilized for several purposes: altering soil temperature to promote faster early-season growth and earlier harvesting, reducing weed proliferation, preventing nutrient losses due to leaching and minimizing soil water loss by decreasing evaporation from the soil surface. The objective of this research is to assess the impact of different fertigation levels and mulch or the various growth parameters of garlic. An experiment was conducted to assess the impact of different fertigation levels and mulch or the various growth parameters of garlic at the Experimental farm of the Department of Soil Science and Water Management, Dr. Y.S Parmar University of Horticulture and Forestry, Solan (HP) during the year 2018-2019. The experiment was laid out in a randomized block design with eight treatments and three replications. The treatments consisted of 3 fertigation levels 60, 80 and 100 per cent recommended dose of fertilizer through water soluble fertilizer and

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***Cite as:** Rattan, Varsha, and R.S Spehia. 2025. "Evaluating the Impact of Fertigation Levels and Mulching on Growth and Yield of Garlic (Allium Sativum L.)". International Journal of Plant & Soil Science 37 (9):77-87. https://doi.org/10.9734/ijpss/2025/v37i95687.*

surface irrigation with 100 per cent with recommended dose of fertilizer. There were 2 mulching levels of black and silver plastic mulch of 30-micron thickness and no mulch. The findings demonstrated compelling outcomes, illustrating that the diverse fertigation levels and mulch practices had pronounced effects on the growth characteristics of the garlic. Of all the treatments, the combination of fertigation at 100 per cent RDF with mulch yielded the most favorable results followed by 80 per cent RDF with mulch. The increase in yield attributes might have been due to the optimal availability and uptake of nutrients, which enhanced photosynthesis, promoted leaf expansion, and resulted in a higher accumulation of reserved food.

*Keywords: Fertilizers; fertigation; crop; mulch; garlic; growth.*

## 1. INTRODUCTION

Drip fertigation is a highly input-efficient method to minimize irrigation losses, better fertilizer application and adverse environmental impact on crop production. Both water and nutrient uptake were enhanced by the plants and realized maximum dry matter production and yield through drip fertigation. Mulching is one of the most promising practices among different methods of moisture conservation. Mulching helps to reduce the evaporation losses from soil, preventing the soil particles from direct contact of raindrops which helps to control the soil erosion and check run-off losses (Kumar et al., 2024a; Kumar et al., 2024b). Garlic (*Allium sativum*) holds great commercial significance as a bulb crop in India, ranking second only to onions within the Alliaceae family. With its origin in Central Asia and the Mediterranean region, it is considered one of the oldest known vegetable crops. Studies have highlighted allicin, a component found in garlic, as effective in treating seed-borne pathogens in carrots and tomato plants, making it a valuable asset in organic farming (Gruhlke *et al*, 2016). The global demand for garlic is increasing, both in India and internationally. In India, major garlic-producing states include Maharashtra, Madhya Pradesh, Karnataka, Gujarat, Rajasthan, Assam and Uttar Pradesh. While garlic is grown across the country, long-day garlic is specifically cultivated in temperate regions such as Jammu and Kashmir, Himachal Pradesh, and Uttarakhand, making it highly desirable in the market. Himachal Pradesh, particularly the Sirmaur district, is a major contributor to garlic production, with 6.51 thousand hectares devoted to its cultivation and a harvest of 12.70 thousand metric tons (Anonymous, 2021). In recent years, garlic has increasingly been processed into various products, including garlic extract, garlic essential oil, garlic powder allicin and black garlic, all of which have demonstrated significant economic benefits. Garlic is rich in organic sulfur compounds, saponins, flavonoids, polyphenols, and other bioactive ingredients, which contribute to its medicinal properties. These properties include anti-inflammatory effects, sterilization, lowering blood pressure and lipids, antioxidation activity, and prevention of cardiovascular disease and diabetes (Song et al., 2024; Tesfaye & Bayih, 2024).

Despite its potential to boost farmer’s economic conditions, garlic faces challenges due to its dependence on rainfall, which affects both yield and quality. The crop's shallow root system makes it highly sensitive to moisture stress, especially during key stages of bulb formation and growth, thereby necessitating consistent and frequent irrigation (Pelter *et al.*, 2004). To address this issue, modern micro-irrigation techniques like drip irrigation have been adopted, ensuring timely and efficient water application, resulting in increased yield and economic production, especially in regions with low rainfall or water scarcity. Drip irrigation can save 12-84 per cent of irrigation water and enhance productivity by 10-55 per cent, depending on soil types and climatic conditions (Pramanik *et al.*, 2016). Additionally, this irrigation technique facilitates fertigation, which involves delivering dissolved fertilizer directly to the plant's root zone, thereby optimizing the use of both water and fertilizers.

Polyethylene mulch can be utilized for several purposes: altering soil temperature to promote faster early-season growth and earlier harvesting, reducing weed proliferation, preventing nutrient losses due to leaching and minimizing soil water loss by decreasing evaporation from the soil surface. Fertigation, combined with mulching, serves as an additional strategy to enhance soil health and plant growth. This approach maximizes nutrient delivery and moisture retention while also preventing weed growth and maintaining optimal soil conditions. To enhance crop yields per unit area, support food security and protect soil and water from environmental pollution, effective water and fertilizer management via fertigation, combined with mulching, is crucial (Kumar *et al*., 2016). Consequently, it is vital to examine the impact of precision farming practices such as drip irrigation, fertigation and polyethylene mulching on the growth and yield of garlic crops. Considering these aspects, a research study was conducted to identify effective methods for overcoming challenges in garlic cultivation and for supporting sustainable agricultural practices. Hence the objective of this research work is to assess the impact of different fertigation levels and mulch or the various growth parameters of garlic.

## 2. MATERIALS AND METHODS

During the 2018-2019 academic year, a study was undertaken at the experimental farm of the Department of Soil Science and Water Management at Dr. Yashwant Singh Parmar University of Horticulture and Forestry, located in Nauni to assess the growth characteristics of garlic (cv. 'Solan Selection') under varying fertigation and mulch treatments. The region experienced annual rainfall between 1100 and 1300 mm, primarily occurring during the monsoon season from June to September. The experiment followed a randomized block design with three replications, using plot sizes of 3×2 m and a spacing of 20×10 cm. There were eight treatments in total, which were as follows.

The general view of the experiment showing different treatments is given in Fig. 1. Drip irrigation was employed on a bi-weekly basis in all treatments except for $F_4M_0$ and $F_4M_1$, where irrigation of 4 cm depth was applied at 15-day intervals. The total amount of irrigation water applied under drip irrigation at 100% ETc (Crop Evapotranspiration) from October 2018 to April 2019 was 23.6 cm. Fertilizers were applied through the fertigation tank in 24 equal splits at a weekly interval, using water-soluble fertilizer 19:19:19, supplemented with urea to meet the NPK requirements of different treatments. The levels of fertigation were controlled by adjusting the opening and closing of valves at appropriate points.

For mulching, a 30-micron thick plastic mulch of black and silver colours was used. The black portion of the mulch was placed downwards in contact with the soil, while the silver portion faced upwards.

Various plant attributes like plant height, number of leaves per plant, neck thickness, bulb diameter, number of cloves per plant, biological yield and dry matter content were assessed and recorded during the experiment. Ten randomly selected plants were counted and measured for height using a measuring tape, from the base to the tip of the uppermost leaf. The average height in centimetres was calculated from these measurements. The measurement of these plants was taken from the base attachment of the bulb with the foliage in centimetres to calculate neck thickness using a digital vernier calliper. The bulb diameter of 10 randomly selected garlic bulbs was also calculated using a digital vernier calliper as shown in Fig. 2.

**Table 1. Treatment details**

| Treatments | Treatment code | Treatment Combination |
|---|---|---|
| $T_1$ | $F_1M_0$ | Fertigation at 100% recommended dose of fertilizer through water soluble fertilizer (RDF) |
| $T_2$ | $F_2M_0$ | Fertigation at 80% recommended dose of fertilizer through water soluble fertilizer |
| $T_3$ | $F_3M_0$ | Fertigation at 60% recommended dose of fertilizer through water soluble fertilizer |
| $T_4$ | $F_4M_0$ | Surface irrigation at 100% recommended dose of fertilizer |
| $T_5$ | $F_1M_1$ | Fertigation at 100% recommended dose of fertilizer through water soluble fertilizer+ polyethylene mulch |
| $T_6$ | $F_2M_1$ | Fertigation at 80% recommended dose of fertilizer through water soluble fertilizer + polyethylene mulch |
| $T_7$ | $F_3M_1$ | Fertigation at 60% recommended dose of fertilizer through water soluble fertilizer + polyethylene mulch |
| $T_8$ | $F_4M_1$ | Surface irrigation at 100% recommended dose of fertilizer through water soluble fertilizer + polyethylene mulch |

**Fig. 1. Drip irrigation technique**

**Fig. 2. Digital vernier caliper**

After harvesting the garlic, the bulbs were separated from the dried foliage. Each bulb was then weighed using a digital weighing balance and the values were converted into quintal per hectare (q $ha^{-1}$) for each treatment. In each replication, 100 grams of garlic cloves were weighed to estimate the dry matter content. The cloves were then dried in an oven at 65±5°C until a constant weight was attained, indicating the complete removal of moisture content. The dry matter content (%) was then computed as follows:

$$Dry\ matter\ content\ (\%)\ = \frac{Dry\ weight\ (g)}{Fresh\ weight\ (g)} \times 100$$

The data obtained were statistically analyzed by using MS-Excel and OPSTAT software. The mean values of data were subjected to analysis of variance as described by Panse and Sukhatme (2000) using Randomized Block Design (Factorial).

## 3. RESULTS AND DISCUSSION

The Tables (2 & 3) showed the effect of different fertigation levels and mulch on the growth parameters and yield.

**Plant Height:** Among all the fertigation levels in Table 2, the maximum mean value of plant height (80.45 cm) was recorded under treatment

$F_1$ (fertigation at 100% recommended dose of fertilizer), while the minimum mean value of plant height (66.43 cm) was observed under $F_4$ (surface irrigation with 100% recommended dose of fertilizer). The effect of fertigation on plant height was found to be significant. The higher mean plant height (75.17 cm) was noticed under mulch as compared to unmulched treatments and was significant over unmulched treatments. Amongst all the interactions maximum plant height (81.70 cm) was recorded under $F_1M_1$ (fertigation at 100% recommended dose of fertilizer through water soluble fertilizer + polyethylene mulch), while, the minimum plant height (65.00 cm) was reported under $F_4M_0$ (surface irrigation with 100% recommended dose of fertilizer). The interaction effect between fertigation and mulch was non-significant.

The increase in the plant height might be due to the better and timely availability of nutrients and their utilization by plants. An adequate supply of nutrients combined with optimal water availability enabled the crops to absorb a maximum amount of nutrients, thereby minimizing leaching and volatilization losses and enhancing nutrient use efficiency. These results were in consonance with those of Ganesaraja *et al*. (2009), Der *et al.* (2018) and Gupta *et al.* (2018). The increase in plant height under mulch might be due to the reduction of evapotranspiration and maintaining the moisture level and temperature of the soil. The results are in agreement with the findings of Hassan *et a*l. (1995), Singh and Ahmed (2008) and Ahshrafuzzaman *et al*. (2011).

**Number of Leaves Per Plant:** In Table 2, the treatment $F_1$, which involved fertigation at 100 per cent of the recommended fertilizer dose, recorded the highest average number of leaves at 9.50. Meanwhile, treatment $F_3$, where fertigation was applied at just 60 per cent of the recommended dose, showed the lowest average of 7.68 leaves. The results indicated that fertigation levels significantly influenced the number of leaves produced. Between mulched and unmulched conditions, the higher mean number of leaves (8.92) were noticed under mulched conditions and the effect of mulch was statistically significant over unmulched treatments. Among the various interactions between fertigation and mulch, the maximum number of leaves (10.33) were observed under $F_1M_1$ (fertigation at 100% recommended dose of fertilizer through water-soluble fertilizer + polyethylene mulch), while, minimum number of leaves (7.67) were recorded $F_3M_0$ (fertigation at 60% recommended dose of fertilizer through water-soluble fertilizer). Under treatment $F_4M_1$ (surface irrigation with 100% recommended dose of fertilizer + polyethylene mulch) the number of leaves was 9.00, whereas, under $F_4M_0$ (surface irrigation with 100% recommended dose of fertilizer) the mean number of leaves was 8.33. The statistical analysis revealed that the interaction between fertigation and mulch had a non-significant effect.

The increase in the number of leaves might have been due to the enhanced availability of nitrogen (N) and phosphorus (P), which were crucial for the synthesis of proteins and carbohydrates. This effect might have developed gradually during the growth phases, ultimately leading to a higher leaf production (Neary *et al*. 1995). Furthermore, keeping the crop foliage dry might have led to a decrease in pest presence on the leaves, resulting in a higher leaf count per plant. These results were similar to those given by Nayak *et al.* (2018), Antony and Singandhupe (2004) and Kapoor *et al*. (2017). The highest number of leaves in the mulch treatments may be attributed to the microclimate created by the mulch, which provides favorable conditions for the production of a greater number of leaves in the plants. The findings were similar to those of Ahshrafuzzaman *et al.* (2011), Gessesew and Gebreslassie (2017) and Yimer (2020).

**Neck Thickness:** In Table 2, within all the fertigation levels, the highest mean neck thickness of 0.85 cm was recorded under treatment $F_1$ (fertigation at 100% of the recommended fertilizer dose), while the lowest mean neck thickness of 0.70 cm was observed in treatment $F_3$ (fertigation at 60% of the recommended dose). The effect of fertigation on neck thickness was found to be significant. In mulched conditions, the mean neck thickness was higher at 0.78 cm compared to unmulch treatments, indicating a significant effect of mulch on neck thickness. Among all interaction treatments, the maximum neck thickness of 0.85 cm was noted in $F_1M_1$ (fertigation at 100% of the recommended dose using water-soluble fertilizer with polyethylene mulch), while the minimum neck thickness of 0.69 cm was recorded in $F_3M_0$ (fertigation at 60% of the recommended dose using water-soluble fertilizer). The treatment $F_4M_1$ (surface irrigation with 100% recommended fertilizer and polyethylene mulch) resulted in a neck thickness of 0.76 cm, whereas $F_4M_0$ (surface irrigation with 100% recommended fertilizer) reported 0.74 cm. However, the interaction between fertigation and mulch was found to be non-significant.

**Table 2. Effect of different fertigation levels and mulch on the growth parameters**

| M / F | Plant height (cm) | | | Number of leaves/plant | | | Neck thickness (cm) | | | Bulb diameter (cm) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **$M_0$** | **$M_1$** | **Mean** | **$M_0$** | **$M_1$** | **Mean** | **$M_0$** | **$M_1$** | **Mean** | **$M_0$** | **$M_1$** | **Mean** |
| $F_1$ | 79.20 | 81.70 | 80.45 | 8.67 | 10.33 | 9.50 | 0.84 | 0.85 | 0.85 | 5.32 | 5.47 | 5.39 |
| $F_2$ | 75.27 | 79.37 | 77.32 | 8.33 | 8.67 | 8.50 | 0.78 | 0.80 | 0.79 | 5.13 | 5.31 | 5.22 |
| $F_3$ | 69.60 | 71.73 | 70.67 | 7.67 | 7.69 | 7.68 | 0.69 | 0.72 | 0.70 | 4.33 | 4.53 | 4.43 |
| $F_4$ | 65.00 | 67.87 | 66.43 | 8.33 | 9.00 | 8.67 | 0.74 | 0.76 | 0.75 | 5.02 | 4.92 | 4.97 |
| Mean | 72.27 | 75.17 | | 8.25 | 8.92 | | 0.76 | 0 .78 | | 4.95 | 5.06 | |
| CD $_{(0.05)}$ | | | | | | | | | | | | |
| F | 3.35 | | | 0.82 | | | 0.03 | | | 0.14 | | |
| M | 3.35 | | | 0.58 | | | 0.02 | | | 0.09 | | |
| F×M | NS | | | NS | | | NS | | | NS | | |

**Table 3. Effect of different fertigation levels and mulch on the growth and yield attributes**

| M / F | No. of cloves | | | Dry matter content (%) | | | Biological yield (q ha$^{-1}$) | | |
|---|---|---|---|---|---|---|---|---|---|
| | **$M_0$** | **$M_1$** | **Mean** | **$M_0$** | **$M_1$** | **Mean** | **$M_0$** | **$M_1$** | **Mean** |
| $F_1$ | 14.87 | 15.17 | 15.02 | 39.75 | 41.22 | 40.48 | 218.33 | 273.33 | 245.83 |
| $F_2$ | 14.03 | 14.53 | 14.28 | 38.36 | 38.93 | 38.64 | 191.66 | 210.00 | 200.83 |
| $F_3$ | 12.13 | 12.53 | 12.33 | 35.42 | 35.78 | 35.60 | 133.33 | 166.11 | 149.72 |
| $F_4$ | 11.87 | 13.13 | 12.50 | 38.23 | 38.65 | 38.44 | 147.22 | 181.66 | 164.44 |
| Mean | 13.23 | 13.84 | | 37.94 | 38.65 | | 218.33 | 273.33 | |
| CD $_{(0.05)}$ | | | | | | | | | |
| F | 0.61 | | | 0.39 | | | 11.12 | | |
| M | 0.43 | | | 0.23 | | | 7.86 | | |
| F×M | NS | | | 0.46 | | | 15.73 | | |

The increase in neck thickness recorded across various fertigation levels might have been due to the application of fertilizers in more readily available forms, leading to greater availability of essential nutrients in the soil solution. This enhanced nutrient accessibility likely facilitated improved translocation of assimilates from the source to the sink. Similar findings have been reported by Kumar *et al.* (2016) and Gupta *et al.* (2018). The increased neck thickness may be due to the vigorous plant and bulb growth. Similar findings were given by Jamil *et al*. (2005) and Yimer (2020).

**Bulb Diameter:** Analysis of the data given in Table 2 showed that among the different fertigation levels, the largest mean garlic bulb diameter (5.39 cm) was recorded under treatment $F_1$ (fertigation at 100% of the recommended fertilizer dose), while the smallest mean bulb diameter (4.43 cm) was observed under treatment $F_3$ (fertigation at 60% of the recommended fertilizer dose). The effect of fertigation on bulb diameter was found to be significant. Bulbs under mulched conditions had a higher mean diameter (5.06 cm) compared to unmulch treatments, with the difference being statistically significant. In the interaction between fertigation and mulch, the largest bulb diameter (5.47 cm) was recorded under $F_1M_1$ (100% fertigation with a water-soluble fertilizer and polyethylene mulch), while the smallest (4.33 cm) was observed under $F_3M_0$ (60% fertigation without mulch). The bulb diameter under $F_4M_1$ (surface irrigation with 100% fertigation and mulch) was 4.92 cm, while under $F_4M_0$ (surface irrigation with 100% fertigation without mulch), it was 5.02 cm. However, the interaction between fertigation and mulch was found to be non-significant.

The diameter of the garlic bulb is a key factor in classifying it into different grades such as A, B, C and D. An increase in bulb diameter might be due to the adequate fulfillment of the crop's nutritional requirements and proper water intake during various stages of growth. This helped in the accumulation of photosynthates in the bulb's storage organ, leading to an increase in bulb size. These findings were consistent with those of Sankar *et al*. (2008) and Gupta *et al*. (2018). The use of mulch might have also contributed to increased bulb diameter by promoting enhanced vegetative growth. Mulch helps maintain optimal soil moisture and temperature, which might have facilitated the translocation of more assimilates into bulb formation, thereby boosting its size. These results aligned with the studies of Jamil *et al*. (2005) and Ashrafuzzaman *et al*. (2011).

**Number of Cloves:** The data summarised in Table 3 showed that $F_1$ (fertigation at 100% recommended dose of fertilizer) recorded maximum mean number of cloves per bulb (15.02), while, minimum mean number of cloves (12.33) was recorded under $F_3$ (fertigation at 60% recommended dose of fertilizer), thus showing a significant effect of fertigation on the number of cloves. Under mulched treatments, the mean of number of cloves (13.84) was more as compared to un-mulched treatments and, the effect of mulch on number of cloves per bulb was recorded to be significant. In comparison to all the interaction treatments, the treatment $F_1M_1$ (fertigation at 100% recommended dose of fertilizer through water soluble fertilizer with mulch + polyethylene mulch) recorded a maximum number of cloves (15.17), whereas, the treatment $F_4M_0$ (surface irrigation with 100% recommended dose of fertilizer) recorded a minimum number of cloves (11.87), while, under $F_4M_1$ (surface irrigation with 100% recommended dose of fertilizer + polyethylene mulch) 13.13 number cloves were obtained. The interaction between fertigation and mulch was found out to be non-significant.

The increase in the number of cloves might have been influenced by fertigation, which facilitated the transportation of soluble nutrients essential for plant growth and development. These results were consistent with those of Vasanthi *et al*. (2017), Selvaperumal and Muthuchamy (2017) and Der *et al*. (2018). The maximum number of cloves was observed under mulching conditions, as mulching helped maintain soil temperature and moisture, thereby promoting nutrient transfer to the plant through the active root zone. This, in turn, improved growth and increased the number of cloves. Similar findings were reported by Uddin (1997), Haque *et al*. (2003), Jamil et al. (2005) and Najafabadi *et al*. (2012).

**Dry Matter Content:** Among the various fertigation levels shown in Table 3, the highest average dry matter content (40.48%) was recorded under treatment $F_1$ (fertigation at 100% recommended dose of fertilizer), while the lowest mean dry matter content (35.60%) was observed under $F_3$ (fertigation at 60% recommended dose of fertilizer). This indicates that fertigation had a significant effect on dry matter content. The average dry matter content was higher under mulched conditions (38.65%) compared to unmulched conditions (37.94%), highlighting the significant impact of mulch on dry matter content. When comparing the interaction treatments, the highest dry matter content (41.22%) was observed under treatment $F_1M_1$ (fertigation at 100% recommended dose of fertilizer through water-soluble fertilizer with polyethylene mulch), while the lowest dry matter content (35.42%) was recorded under treatment $F_3M_0$ (fertigation at 60% recommended dose of fertilizer through water-soluble fertilizer without mulch). Treatment $F_4M_1$ (surface irrigation with 100% recommended dose of fertilizer and polyethylene mulch) resulted in a higher dry matter content (38.65%), while treatment $F_4M_0$ (surface irrigation with 100% recommended dose of fertilizer) showed a dry matter content of 38.23%. The interaction between fertigation and mulch was found to be statistically significant.

An increase in nutrient levels might have ensured an adequate supply of nutrients to the crop, which might have enhanced vegetative growth and promoted the development of green foliage. This, in turn, might have maximized photosynthesis and resulted in greater dry matter accumulation in the bulb. These findings were in agreement with the studies of Abraham *et al*. (2018) and Der *et al*. (2018). The highest dry matter content observed under mulch might have been due to improved plant development from increased moisture levels and reduced weed growth. This reduction in weed proliferation might have minimized competition for light, water and nutrients, ultimately leading to an increase in dry matter content in the bulbs. These results were also consistent with those of Jamil *et al*. (2005) and Yimer (2020).

**Biological Yield:** As shown in Table 3, the highest mean biological yield of 245.83 q $ha^{-1}$ was recorded under treatment $F_1$, where fertigation was applied at 100 per cent of the recommended fertilizer dose. This yield was statistically significantly higher than those observed in all other treatments. In contrast, the lowest mean biological yield (149.72 q $ha^{-1}$) was observed under $F_3$ (fertigation at 60% recommended dose of fertilizer). Mulched conditions resulted in a higher mean yield (273.33 q $ha^{-1}$) compared to unmulched conditions (218.33 q $ha^{-1}$), with the mulch treatment showing a significant improvement over the unmulch treatment. The best interaction between fertigation and mulch was observed under treatment $F_1M_1$ (fertigation at 100% recommended dose of fertilizer through water-soluble fertilizer with polyethylene mulch), which produced the highest biological yield (273.33 q $ha^{-1}$). The lowest yield (133.33 q $ha^{-1}$) was recorded under treatment $F_3M_0$ (fertigation at 60% recommended dose of fertilizer without mulch). Under treatment $F_4M_1$ (surface irrigation with 100% recommended dose of fertilizer and polyethylene mulch), the biological yield was 181.66 q $ha^{-1}$, while in treatment $F_4M_0$ (surface irrigation with 100% recommended dose of fertilizer), the biological yield was 147.22 q $ha^{-1}$. The interaction between fertigation and mulch showed significant effects.

The increase in yield attributes might have been due to the optimal availability and uptake of nutrients, which enhanced photosynthesis, promoted leaf expansion, and resulted in a higher accumulation of reserved food. These reserves were then translocated to various plant parts, ultimately maximizing the yield. These findings were in agreement with those of Meenakshi *et al*. (2008), Maind *et al*. (2018), Gupta *et al*. (2018) and Der *et al*. (2018). The increase in biological yield under mulching conditions might have been attributed to the conservation of soil moisture and improved vegetative growth, which enhanced the traits contributing to yield. Similar results were reported by Islam et al. (2007), Singh et al. (2009) and Yimer (2020).

## 4. CONCLUSIONS

Fertigation emerged as a highly effective technique for enhancing plant growth, yielding improvements across key growth characteristics. Mulching also made a significant contribution to plant growth and yield of garlic. The combination of fertigation and mulching produced exceptional results, particularly in dry matter content and biological yield.

Therefore, the integration of 100 per cent fertigation along with polyethylene mulch proved to be the most robust and effective method for boosting plant growth and maximizing yield and may also enhanced sustainable farming methods, leading to a significant increase in productivity in modern agriculture.

## DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that generative AI technologies such as Large Language Models have been used during the writing and editing of this manuscript. Specifically, ChatGPT-4 (OpenAI) and Grammarly were employed. ChatGPT-4 was used for rephrasing, content enhancement and summarization of technical content, while Grammarly was used for grammar checking.

**Details of the AI usage are given below:**

1. Language refinement
2. Summarization
3. Content refinement

## ACKNOWLEDGEMENT

The author sincerely thanks Department of Soil Science and Water Management, DR Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan H.P, for carrying out the study.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

## REFERENCES

Abraham, R. K., Sarathi, M. P., & Manna, D. C. (2018). Yield performance and profitability of bitter gourd cultivation as influenced by drip irrigation, fertigation and plastic mulching. *International Journal of Current Microbiology and Applied Sciences, 6*, 638–645.

Anonymous. (2021). *Indian Horticulture Database*. National Horticultural Board, Ministry of Agriculture, Government of India. http://www.nhb.gov.in

Antony, E., & Singandhupe, R. B. (2004). Impact of drip and surface irrigation on growth, yield and WUE of capsicum (*Capsicum annuum* L.). *Agricultural Water Management, 65*, 121–132.

Ashrafuzzaman, Md., Ismail, M. R., Shahidullah, S. M., & Halim, M. A. (2011). Effect of plastic mulch and yield on chilli (*Capsicum annuum* L.). *Brazilian Archives of Biology and Technology, 54*, 321–330.

Der, H. N., Dabhi, A. B., Barad, B. B., & Gohil, P. J. (2018). Scheduling of drip irrigation and fertigation in rabi garlic (*Allium sativum* L.). *International Journal of Chemical Studies, 6*, 1002–1005.

Ganesaraja, V., Rani, S., Kavitha, M. P., & Paulpandi, V. K. (2009). Effect of drip irrigation regimes and fertilizer application methods on growth, yield and nutrient uptake of baby corn. *Journal of Maharashtra Agricultural Universities, 34*, 92–93.

Gessesew, W. S., & Gebreslassie, T. Y. (2017). Garlic (*Allium sativum* L.) growth parameters as affected by different mulching with irrigation under Fiche condition, Ethiopia. *Preprints, 1*, 2–7.

Gruhlke, M. C. H., Nicco, C., Batteux, F., & Slusarenko, A. (2016). The effects of allicin, a reactive sulfur species from garlic, on a selection of mammalian cell lines. *Antioxidants (Basel), 6*, 3–16.

Gupta, R., Hardaha, M. K., & Mishra, K. P. (2018). Effect of different fertigation levels on growth and yield of garlic (*Allium sativum* L.) cv. G-282. *Plant Archives, 18*, 893–896.

Haque, M. S., Islam, R., Karim, M. A., & Khan, A. H. (2003). Effects of natural and synthetic mulches on garlic (*Allium sativum* L.). *Asian Journal of Plant Sciences, 2*, 90–96.

Hassan, S. A., Abidin, R. Z., & Ramlan, M. F. (1995). Growth and yield of chilli (*Capsicum annuum* L.) in response to mulching and potassium fertilization. *Journal of Tropical Agriculture Science, 18*, 113–117.

Islam, A. K., Hossain, M. M., Khanam, F., Majumder, U. K., Rahman, M. M., & Rahman, M. S. (2007). Effect of mulching and fertilization on growth and yield of garlic at Dinajpur in Bangladesh. *Asian Journal of Plant Sciences, 6*, 98–101.

Jamil, M. K., Munir, M., Qasim, M. S., & Baloch, J. (2005). Effect of different types of mulches and their duration on the growth and yield of garlic (*Allium sativum* L.). *International Journal of Agriculture and Biology, 7*, 588–591.

Kapoor, R., Sandal, S. K., Sharma, S. K., Kumar, A., & Saroch, K. (2017). Effect of varying drip irrigation levels and NPK fertigation on soil water dynamics, productivity and water use efficiency of cauliflower (*Brassica oleracea* var. *botrytis*) in wet temperate zone of Himachal Pradesh. *Indian Journal of Soil Conservation, 42*, 249–254.

Kumar, S. P., Geetha, P., Kutty, M. C. N., Kutty, C. N., & Kumar, P. T. (2016). Fertigation—the key component of precision farming. *Journal of Tropical Agriculture, 54*, 103–114.

Kumar, S., Seenappa, C., Madam, V., & Anand, M. R. (2024a). Influence of different levels of drip fertigation and mulching on growth, yield, water productivity and nutrient uptake of pigeonpea (*Cajanus cajan* L.). *Legume Research: An International Journal, 47*(8).

Kumar, S., Singh, S. S., Patel, V. K., Singh, V. K., Patle, U., Kumar, H., & Pandre, E. (2024b). Growth and yield attributes of garlic as influenced by application of organic manure, synthetic fertilizers and liquid manure in Bundelkhand region of India. *Asian Journal of Soil Science and Plant Nutrition, 10*(1), 347–353.

Maind, M. M., Yadload, S. S., Bhalerao, R. V., & Thalkari, G. N. (2018). Effect of irrigation and fertilizer levels on growth and yield of chilli (*Capsicum annuum* L.). *International Journal of Current Microbiology and Applied Sciences, 6*, 1192–1199.

Meenakshi, N., Vadivel, E., Veeraraghavathatham, D., & Kavitha, M. (2008). Dry matter accumulation and leaf chlorophyll content of bitter gourd (*Momordica charantia* L.) as influenced by fertigation. *The Asian Journal of Horticulture, 3*, 307–309.

Najafabadi, B. M., Peyvast, G., Asil, M. H., Olfati, J. A., & Rabiee, M. (2012). Mulching effects on the yield and quality of garlic as second crop in rice fields. *International Journal of Plant Production, 6*, 279–290.

Nayak, H., Sahoo, D., Swain, S. C., Jena, B., Paramjita, D., & Bisoyi, B. S. (2018). Influence of fertigation doses and mulching on yield attributing characters and post-harvest shelf life of pointed gourd (*Trichosanthes dioica* Roxb.). *International Journal of Current Microbiology and Applied Sciences, 7*, 3212–3220.

Neary, P. E., Starlie, C. A., & Paterson, J. W. (1995). Fertilization requirements for drip-irrigated bell peppers grown on loamy sand soils. In *Proceedings of Fifth International Microirrigation Congress* (pp. 187–193). Florida.

Panse, V. G., & Sukhatme, P. V. (2000). *Statistical methods for agricultural workers*. ICAR, New Delhi.

Pelter, G. Q., Mittelstadt, R., Leib, B. G., & Redulla, C. A. (2004). Effect of water stress at specific growth stages on onion bulb yield and quality. *Agricultural Water Management, 68*, 107–115.

Pramanik, S., Lai, S., Ray, R., & Patra, S. K. (2016). Effect of drip fertigation on yield, water use efficiency, and nutrients availability in banana in West Bengal, India. *Communication in Soil Science and Plant Analysis, 47*, 13–14.

Sankar, V., Lawande, K. E., & Tripathi, P. C. (2008). Effect of micro irrigation practices on growth and yield of garlic (*Allium sativum* L.) var. G.41. *Journal of Spices and Aromatic Crops, 17*, 230–234.

Selvaperumal, A., & Muthuchamy, I. (2017). Effect of drip fertigation and plastic mulching on the plant growth and yield attributes of chilli (*Capsicum annuum* L.). *International Journal of Agricultural Science and Research, 7*, 135–142.

Singh, N., & Ahmed, Z. (2008). Effect of mulching on potato production in high altitude cold arid zone of Ladakh. *Potato Journal, 35*, 118–121.

Singh, R., Kumar, S., Nangare, D. D., & Meena, M. S. (2009). Drip irrigation and black polyethylene mulch influence on growth, yield and water-use efficiency of tomato. *African Journal of Agricultural Research, 4*, 1427–1430.

Song, J., Jia, H., Wang, Y., Zhang, X., Yang, W., Zhang, T., ... & Wang, H. (2024). Evaluation of the effects of degradable mulching film on the growth, yield and economic benefit of garlic. *Agronomy, 15*(1), 93.

Tesfaye, E. L., & Bayih, T. (2024). Impact of NPS rates on growth and yield of garlic (*Allium sativum* L.) varieties in greenhouse. *Heliyon, 10*(21).

Uddin, M. A. (1997). Effect of mulching and fertilizer management practices on the growth and yield of garlic (MSc thesis). Department of Horticulture, Bangladesh Agricultural University, Mymensingh, Bangladesh, pp. 110–130.

Vasanthi, B. G., Srinivasappa, K. N., Manjunath, B., & Padmavathi, M. (2017). Effect of fertigation levels and schedules on growth, yield and economic returns of tomato (*Solanum lycopersicum* L.). *International Research Journal of Agricultural Economics and Statistics, 8*, 320–324.

Yimer, O. (2020). Different mulch material on growth, performance and yield of garlic: A review. *International Journal of the Science of Food and Agriculture, 4*, 38–42.



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