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Effect of deficit irrigation on growth parameters and water use efficiency on garlic

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Abstract

A field experiment in a randomized block design with three replications was conducted during the rabi season of 2021-22 at Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra, to investigate the “Effect of deficit irrigation on growth parameters and water use efficiency on garlic”. The experiment included 27 treatment combinations applied at different growth stages of garlic: vegetative stage, bulb initiation, and bulb development stage. The garlic crop was subjected to different levels of water stress: no water stress (0.00S), 30% water stress (0.30S), and 60% water stress (0.60S). The soil in the experimental plot was clay with a field capacity of 39.01%, permanent wilting point of 19.08%, and bulk density of 1.28 g cm⁻³. Treatment T₁ (no water stress) recorded the highest plant height, number of tillers, and garlic yield, while the lowest values were observed in the high water stress treatment (T₂₇). Water use efficiency was lowest in the no water stress treatment (T₁) at 0.015 t/ha/mm, whereas the highest water use efficiency was observed in high water stress treatments such as T₉ and T₁₈, which recorded 0.027 t ha⁻¹ mm⁻¹.

Keywords: Deficit irrigation, plant height, number of tillers, garlic yield, water use efficiency

1. Introduction

Garlic (*Allium sativum* L.) production has a long and diverse history. Originating in Central Asia over 5,000 years ago, it was revered by ancient civilizations like the Egyptians and Romans for its culinary and medicinal value. Garlic (*Allium sativum* L.) is an essential and widely cultivated crop that holds immense agricultural, culinary, and medicinal significance. This pungent and flavorful bulbous plant belongs to the Allium genus, which includes other popular members like onions, shallots, and leeks. Garlic cultivation thrives in well-drained, loamy or sandy loam soils that offer good aeration and drainage. These soils should be rich in organic matter, with a pH level ranging from slightly acidic to neutral (pH 6-7). Adequate soil moisture is essential during the growing season, but garlic is susceptible to waterlogged conditions, so excessive moisture should be avoided to prevent bulb rot. Additionally, garlic benefits from soil that is free from weeds and has good fertility, with appropriate levels of essential nutrients like phosphorus and potassium. Proper soil preparation, including the addition of organic matter and balanced fertilization, can contribute to successful garlic cultivation. Garlic (*Allium sativum*) is a bulbous plant with a unique crop physiology. It belongs to the Alliaceae family and is characterized by its underground bulb composed of multiple cloves. Garlic is a perennial plant, but it is typically grown as an annual crop. It has a relatively short growing season and is classified as a cool-season crop. Garlic's physiological characteristics, such as its ability to form bulbs and store energy in them, make it a valuable crop for culinary and medicinal purposes (Suresh Kumawat *et al.* 2023). Adequate soil moisture is essential during the growing season, but garlic is susceptible to waterlogged conditions, so excessive moisture should be avoided to prevent bulb rot. Additionally, garlic benefits from soil that is free from weeds and has good fertility, with appropriate levels of essential nutrients like phosphorus and potassium. Proper soil preparation, including the addition of organic matter and balanced fertilization, can contribute to successful garlic cultivation. The utilizable quantity of water in India faces significant limitations due to its uneven distribution across both time and space. The country grapples with the recurring challenges of frequent floods and droughts in various regions. These climatic extremes pose a considerable threat, exacerbated by the burgeoning population and the demands

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of a rapidly developing nation. Moreover, the looming specter of climate change further compounds the strain on available water resources, potentially leading to heightened conflicts among different user groups. Unfortunately, public awareness regarding the overall scarcity and economic value of water remains relatively low, resulting in widespread wastage and inefficient utilization.

Another critical issue is the inequitable distribution of water resources and the lack of unified perspectives in planning and managing these resources. India boasts the world's largest irrigation system, yet its irrigation efficiency has seldom exceeded 40%. Given the escalating costs associated with developing additional water resources, it becomes imperative to harness available water more efficiently. While addressing food security remains a top priority for many nations, including India, the challenge extends beyond merely providing food for the growing population. It also entails conserving water for various other essential uses. To achieve this delicate balance, there is a pressing need to develop and disseminate innovative water-saving technologies and management practices. Capacity-building efforts must empower farming communities to adopt new approaches in irrigated agriculture. This holistic approach aims to meet the security, income, and nutritional needs of the projected population in 2050, where food production will need to nearly double. Deficit irrigation emerges as a valuable technique in this context. This method involves intentionally irrigating crops with less water than their full requirement. By subjecting the crop to a certain level of water stress at specific stages or throughout the growing season, deficit irrigation aims to maximize crop yield per unit of water applied. Numerous researchers have delved into the study of deficit irrigation, particularly its impact on specific crops like garlic (Rajesh Gupta *et al.* 2017, Taha N. M. *et al.* 2019, and Rajesh Gupta *et al.* 2020) [1, 3, 2]. Their findings contribute to the growing body of knowledge on how this water-saving technique can be effectively employed to address the dual challenge of ensuring food security and conserving water resources in a country like India. These efforts represent a crucial step towards sustainable and efficient water management in the face of increasing demands and climate-related uncertainties.

The specific water needs of any crop are contingent upon a multitude of factors. Crop-related factors, such as the crop variety, growth stage, duration, plant population, and the length of the growing season, all come into play. Additionally, soil-related factors, including its texture, structure, depth, and topographical features, influence water requirements. Climatic factors like temperature, relative humidity, and wind speed further impact the amount of water necessary for optimal crop growth. Moreover, crop management practices, such as tillage, fertilization, and weed control, also affect the overall water

demand. This involves making informed decisions about when and how much to irrigate. The sophistication of irrigation decision-making processes can range from relying on personal experience and intuition to using advanced computer-aided instruments that consider soil moisture levels and atmospheric parameters (Rajesh Gupta *et al.* 2020) [3].

2. Material and Methods

During the rabi season, a trial was conducted at Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra, to investigate the effect of deficit irrigation on garlic growth parameters and water use efficiency. The following materials and methods were employed throughout the experiment.

2.1 Irrigation systems

The experiment was laid out with twenty seven treatments with three replications. Irrigation was applied through drip irrigation system. It helps to apply the water directly to near the root zone and also helps to avoid the deep percolation and leakage loss through the plot. The following pipe network was used in the drip irrigation system.

- **Filtration System-** Sand Filter and screen Filter

- **Pipe Network-**

Main line- 75mm

Submain-32mm

Lateral- Inline lateral

Spacing of dripper – 40 cm

Dripper Discharge- 4 Lph

2.2 Experimental details

2.2.1 Treatment details

The field experiment will be laid out in randomized block design (RBD), with three replication and twenty seven treatments with combination quantity of water stress during different growth stages. The treatment combination presented in Table 1.

2.1.2 Crop Growth Stages

Garlic crop has three growth stages to be considered for whole experiment. The following are the stages with its period, Vegetative Stage- up to 50 days

Bulb Initiation Stage- Between 50-75 days

Bulb enlargement Stage- 75 days to harvest

2.1.3 Water stress effect

Garlic crop will give the different water stress on the growth stages of crop throughout crop period of garlic. The following stress will be considered

No Stress i.e. 0.00S

30% Stress i.e. 0.30S

60% Stress i.e. 0.60S

Table 1: The treatments combination are given below

1.	T ₁	VS -No stress (0.00S), BI-No stress (0.00S), BD-No stress (0.00S)
2.	T ₂	VS -No stress (0.00S), BI-No stress (0.00S), BD-Moderate stress (0.30S)
3.	T ₃	VS -No stress (0.00S), BI-No stress (0.00S), BD-High stress (0.60S)
4.	T ₄	VS -No stress (0.00S), BI-Moderate stress (0.30S), BD-No stress (0.00S)
5.	T ₅	VS -No stress (0.00S), BI-Moderate stress (0.30S), BD- Moderate stress (0.30S)
6.	T ₆	VS -No stress (0.00S), BI-Moderate stress (0.30S), BD- High stress (0.60S)
7.	T ₇	VS -No stress (0.00S), BI-High stress (0.60S), BD-No stress (0.00S)
8.	T ₈	VS - No stress (0.00S), BI- High stress (0.60S), BD- Moderate stress (0.30S)
9.	T ₉	VS - No stress (0.00S), BI- High stress (0.60S), BD- High stress (0.60S)
10.	T ₁₀	VS -Moderate stress (0.30S), BI-No stress (0.00S), BD-No stress (0.00S)
11.	T ₁₁	VS -Moderate stress (0.30S), BI-No stress (0.00S), BD- Moderate stress (0.30S)
12.	T ₁₂	VS -Moderate stress (0.30S), BI-No stress (0.00S), BD- High stress (0.60S)

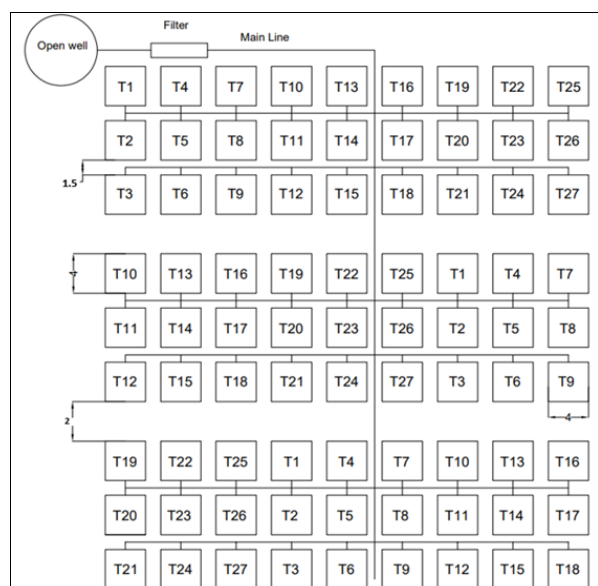
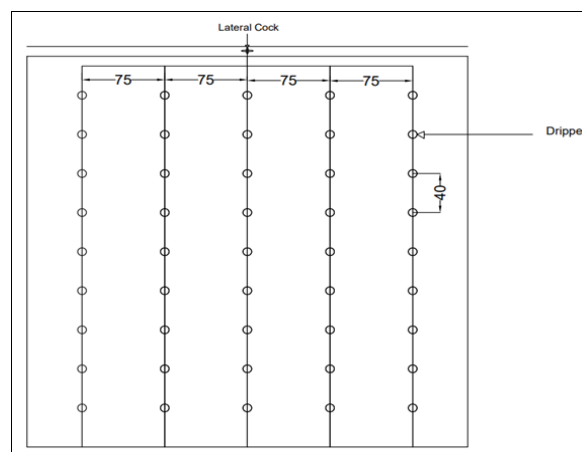
13.	T ₁₃	VS-Moderate stress (0.30S), BI- Moderate stress (0.30S), BD-No stress (0.00S)
14.	T ₁₄	VS-Moderate stress (0.30S), BI- Moderate stress (0.30S), BD- Moderate stress (0.30S)
15.	T ₁₅	VS-Moderate stress (0.30S), BI- Moderate stress (0.30S), BD- High stress (0.60S)
16.	T ₁₆	VS-Moderate stress (0.30S), BI- High stress (0.60S), BD-No stress (0.00S)
17.	T ₁₇	VS-Moderate stress (0.30S), BI- High stress (0.60S), BD- Moderate stress (0.30S)
18.	T ₁₈	VS-Moderate stress (0.30S), BI- High stress (0.60S), BD- High stress (0.60S)
19.	T ₁₉	VS-High stress (0.60S), BI-No stress (0.00S), BD-No stress (0.00S)
20.	T ₂₀	VS- High stress (0.60S), BI-No stress (0.00S), BD- Moderate stress (0.30S)
21.	T ₂₁	VS- High stress (0.60S), BI-No stress (0.00S), BD- High stress (0.60S)
22.	T ₂₂	VS- High stress (0.60S), BI- Moderate stress (0.30S), BD-No stress (0.00S)
23.	T ₂₃	VS- High stress (0.60S), BI- Moderate stress (0.30S), BD- Moderate stress (0.30S)
24.	T ₂₄	VS- High stress (0.60S), BI- Moderate stress (0.30S), BD- High stress (0.60S)
25.	T ₂₅	VS- High stress (0.60S), BI- High stress (0.60S), BD-No stress (0.00S)
26.	T ₂₆	VS- High stress (0.60S), BI- High stress (0.60S), BD- Moderate stress (0.30S)
27.	T ₂₇	VS- High stress (0.60S), BI- High stress (0.60S), BD- High stress (0.60S)

Table 2: Experimental Details

Sr. No.	Particulars	Specification
1.	Crop	Garlic
2.	Scientific name	<i>Allium sativum L.</i>
3.	Variety	Phule Baswant
4.	Experimental design	Randomized Block Design
5.	Number of replications	Three
6.	Number of treatments	Twenty seven
7.	Number of plots	81
8.	Plot size	4.0 X 4.0 m
9.	Inter space between replications per plots	2 m
10.	Season	Rabi 2021
11.	Crop spacing	15 X10 (row to row X plant to plant)
12.	Seed rate	400-500 kg/ha
13.	Recommended fertilizer dose	100:50:50 (N:P:K) with FYM before sowing
14.	Date of sowing	19 Dec. 2021
15.	Date of harvesting	26 April 2022

2.1.4 Experimental layout

The experiment was laid out with twenty seven treatments with three replication with randomized block design. The total treatments were Eighty one (81) in whole field of size 48m x 49m. The each plot size was 4m x 4m and the each plot was separated by buffer with size of 1.5m. The spacing between two replications was 2m. The each plot was irrigated by drip irrigation system with five lateral was spaced at 75cm on plot and connected to submain through lateral cock. The detail layout shown in the given Fig.1 and Fig.2.

**Fig 1:** Experimental Layout**Fig 2:** Layout of single plot with lateral network

2.2 Methodology

2.2.1 Determination of moisture content

Soil moisture content reading was taken prior to every at regular interval at 15cm, and 30cm depth from the respective plot of each treatment. The soil samples were collected from only one replication from the plot. The moisture content of soil sample is to be determined by gravimetric method. The collected soil samples were weighed by weighing balance and then put in hot air oven for the period of 24 hrs. of 110°C temperature. The following formula used for determination of moisture content

$$\text{Moisture content(\%)} = \frac{W1 - W2}{W2} \times 100$$

Where,

W1- Weight soil sample before drying

W2 – Weight of soil sample after drying

2.2.2 Bulk density determination

The bulk density of soil layers at an interval of 15cm depth was determined by the method prescribed by miller and Donahue (1990) with the help of core sampler method. The bulk density of each layer of 15cm were estimated once and considered same for experimental period. The bulk density was expressed in Mg m⁻³. The relevant data are presented in result and discussion section.

$$BD_i = \frac{\text{Wt.of soil sapmle,gm}}{\text{Volume of core samoler,m}^3}$$

Where

BD_i = Bulk density of *i*th layer of soil.

2.3 Water Use Efficiency

The field water use efficiency is ratio of yield and total water requirement. Field water use efficiency is to be determine by following formula

$$\text{Field water use efficiency(t – ha/mm)} = \frac{\text{Yield(tonne)}}{\text{water requirment(mm)}}$$

2.4 Yield Attributing Character

Plant height and number of tiller of garlic crop was measured at regular 30 days interval in each treatment by using the measuring scale. Randomly five plants selected from each treatment and these plants were used for the study of plant height observation from start to end observation.

2.4 Yield Attributing Character

Plant height and number of tiller of garlic crop was measured at regular 30 days interval in each treatment by using the measuring scale. Randomly five plants selected from each treatment and these plants were used for the study of plant height observation from start to end observation entire growing season. The plant height measured at 30 DAS, 60 DAS, 90 DAS, and at harvest. Yield of garlic after the harvest were recorded from the each treatment. Garlic yield and growth attributing characters were statistically analyzed by using randomized block design software.

2.5 Scheduling of Irrigation

2.5.1 Application of irrigation water

The scheduling of irrigation was based on field of soil water content of respective treatments. As treatments were based on applying water as per moisture stress, measured amount of water was applied in each treatment by measuring soil moisture in the root zone depth. The soil moisture measurements were made for each 0.15 m layer in the soil profile to depth of root zone depleted. The depletion never allowed more than 50% of available soil water suggested by FAO-56 for garlic. The irrigation was done to replenish the soil profile to field capacity in case of no water stress condition. The irrigation was scheduled at every growth stage of garlic crop. The quantities of water applied according to the stress were given to each treatment. The depth of water applied during each irrigation was calculated according to the following formula.

$$d = \frac{FC - Mbi}{100} \times BDi \times Di$$

Where,

d- Net depth of Irrigation, cm

FC-Field Capacity, %

Mbi-Moisture content before irrigation, %

BD- Bulk density gm cm⁻³

Di- depth of root zone,cm

The soil moisture contents at 33KPa and 1500 Kpa were worked out for different layers of experimentation with pressure plate apparatus available with parent department. The relevant data are presented in result and discussion section. The actual irrigation depth (*I_t*) relative to each treatment was calculated as.

$$I_t = d_t - (d_t \times K_s)$$

Where

I_t = Actual irrigation depth of respective treatment at *t*th day, (mm);

K_s = Target stress coefficient relative to each treatment

(0, 0.3 and 0.6 for no, moderate and high stress respectively)

2.5.2 Time of operation

The volume of water applied per plot was computed by using equation.

$$V_t = I_t \times A$$

Where,

V_t = Volume of water to be applied/ plotin lit on *t*th day.

A= total area of plolt, m² (4×4, m²)

Time of operation on *t*th day (*T_t*) in hrs was calculated by following formula

$$T_t = \frac{\text{Volume of water to be applied/plot ,lit}}{\text{Discharge of dripper (4lph)×number of drippers}}$$

3. Result and Discussion

The texture class of the soil in experimental plot was clay. The soil was medium alkaline in reaction (pH 8.36) with electrical conductivity 0.40 dS m⁻¹. The depth of soil was 1.8 m. The average field capacity and permanent wilting point 39.8% and 19% respectively, with bulk density as 1.28 gm cm⁻³.

3.1 Biometric observation

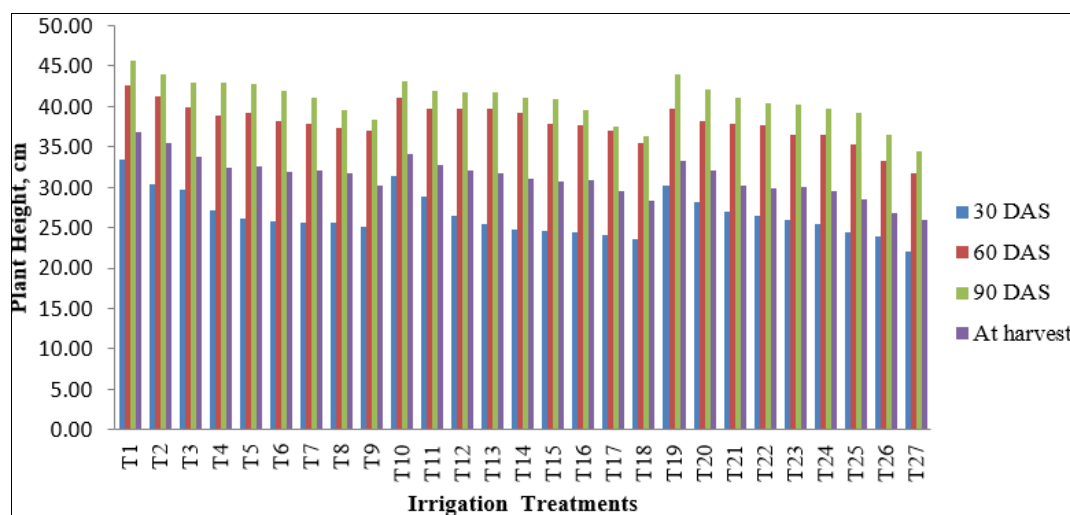
The influence of deficit irrigation on average plant growth parameter such as plant height, number of tiller, yield details are given.

3.1.1 Plant height

Plant heights were recorded for each irrigation treatment at 30, 60, and 90 days after sowing (DAS), as well as at harvest. Plant height increased progressively with crop age until maturity, reaching its maximum at the bulb development stage, i.e., 90 DAS. Significant differences in plant height were observed among treatments subjected to varying levels of stress at different growth stages. The maximum plant height was recorded in the no water stress treatment (*T₁*) at 30, 60, 90 DAS, and at harvest, while the lowest plant height was observed in the high water stress treatment (*T₂₇*). Plant heights for different treatments are presented in Table 6 and illustrated graphically in Fig. 3.

Table 3: Periodical plant height (cm) in garlic influenced by different treatments

Sr. No.	Treatments	30 DAS	60 DAS	90 DAS	At harvest
T ₁	VS (0.00S), BI (0.00S), BD (0.00S)	33.37 ^a	41.18 ^a	45.57 ^a	36.80 ^a
T ₂	VS (0.00S), BI (0.00S), BD (0.30S)	29.64 ^b	41.23 ^a	43.87 ^a	35.43 ^a
T ₃	VS (0.00S), BI (0.00S), BD (0.60S)	25.91 ^c	39.81 ^a	42.91 ^b	33.70 ^b
T ₄	VS (0.00S), BI (0.30S), BD (0.00S)	27.14 ^c	38.90 ^a	42.93 ^b	32.33 ^c
T ₅	VS (0.00S), BI (0.30S), BD (0.30S)	26.17 ^c	40.89 ^a	42.80 ^b	32.50 ^c
T ₆	VS (0.00S), BI (0.30S), BD (0.60S)	25.79 ^c	41.00 ^a	41.93 ^b	31.90 ^c
T ₇	VS (0.00S), BI (0.60S), BD (0.00S)	28.44 ^b	41.31 ^a	41.10 ^c	32.00 ^c
T ₈	VS (0.00S), BI (0.60S), BD (0.30S)	26.43 ^c	38.93 ^a	39.60	31.63 ^c
T ₉	VS (0.00S), BI (0.60S), BD (0.60S)	25.08 ^c	38.63 ^a	38.27	30.23
T ₁₀	VS (0.30S), BI (0.00S), BD (0.00S)	31.30 ^a	41.01 ^a	43.97 ^a	34.17 ^b
T ₁₁	VS (0.30S), BI (0.00S), BD (0.30S)	24.34	39.73 ^a	41.87 ^b	32.77 ^c
T ₁₂	VS (0.30S), BI (0.00S), BD (0.60S)	25.06 ^c	39.77 ^a	41.70 ^c	32.03 ^c
T ₁₃	VS (0.30S), BI (0.30S), BD (0.00S)	25.49 ^c	39.75 ^a	41.67 ^c	31.63 ^c
T ₁₄	VS (0.30S), BI (0.30S), BD (0.30S)	24.77 ^c	39.99 ^a	41.03 ^c	31.00 ^c
T ₁₅	VS (0.30S), BI (0.30S), BD (0.60S)	30.39 ^a	40.48 ^a	40.80 ^c	30.77
T ₁₆	VS (0.30S), BI (0.60S), BD (0.00S)	25.40 ^c	38.44 ^a	39.60	30.83
T ₁₇	VS (0.30S), BI (0.60S), BD (0.30S)	26.82 ^c	40.15 ^a	37.50	29.53
T ₁₈	VS (0.30S), BI (0.60S), BD (0.60S)	26.45 ^c	38.57 ^a	36.30	28.27
T ₁₉	VS (0.60S), BI (0.00S), BD (0.00S)	30.23 ^a	39.77 ^a	43.10 ^a	33.27 ^b
T ₂₀	VS (0.60S), BI (0.00S), BD (0.30S)	24.89 ^c	37.32 ^c	42.10 ^b	32.00 ^c
T ₂₁	VS (0.60S), BI (0.00S), BD (0.60S)	25.25 ^c	38.91 ^b	41.04 ^c	30.27
T ₂₂	VS (0.60S), BI (0.30S), BD (0.00S)	26.39 ^c	35.65 ^c	40.40 ^c	29.80
T ₂₃	VS (0.60S), BI (0.30S), BD (0.30S)	25.96 ^c	37.87 ^c	40.17 ^c	30.10
T ₂₄	VS (0.60S), BI (0.30S), BD (0.60S)	28.15 ^b	40.30 ^a	39.67	29.47
T ₂₅	VS (0.60S), BI (0.60S), BD (0.00S)	26.24 ^c	38.01 ^c	39.20	28.50
T ₂₆	VS (0.60S), BI (0.60S), BD (0.30S)	25.61 ^c	38.43 ^a	36.47	26.80
T ₂₇	VS (0.60S), BI (0.60S), BD (0.60S)	22.10	34.40 ^c	34.47	25.90
	General Mean	26.77	39.27	41.87	31.49
	SE±	1.20	1.12	0.74	0.85
	CD@5%	3.4	3.19	2.10	2.41

**Fig 3:** Periodical plant height (cm) in garlic influenced by different treatments

3.1.2 Number of tiller

The tillers were recorded for each irrigation treatment at 30, 60, 90 DAS and at harvest. The number of tillers increased progressively with the advancement in the crop age till crop maturity and registered maximum at bulb development stage i.e. 90 DAS. The treatments subjected to different amount of stress

during different crop growth stage were differed significantly in tillers. The maximum number of tillers recorded in no water stress treatment (T₁) at 30, 60, 90, and at harvest; whereas lowest plant height recorded in high water stress treatment (T₂₇). The number of tillers different treatments were recorded, presented in given Table 7 and graphically shown in Fig 4.

Table 4: Periodical number of tillers in garlic influenced by different treatments

Sr. No.	Treatments	30 DAS	60 DAS	90 DAS	At harvest
T ₁	VS (0.00S), BI (0.00S), BD (0.00S)	4.7 ^a	8.1 ^a	9.2 ^a	8.4 ^a
T ₂	VS (0.00S), BI (0.00S), BD (0.30S)	4.5 ^a	7.9 ^a	8.9 ^a	8.2 ^a
T ₃	VS (0.00S), BI (0.00S), BD (0.60S)	4.5 ^a	7.6 ^c	8.8 ^b	8.0 ^a
T ₄	VS (0.00S), BI (0.30S), BD (0.00S)	4.4 ^a	7.6 ^c	8.7 ^b	7.8
T ₅	VS (0.00S), BI (0.30S), BD (0.30S)	4.4 ^a	7.5 ^c	8.7 ^b	7.7
T ₆	VS (0.00S), BI (0.30S), BD (0.60S)	4.4 ^a	7.3	8.3	7.5
T ₇	VS (0.00S), BI (0.60S), BD (0.00S)	4.1 ^b	7.1	8.1	7.4
T ₈	VS (0.00S), BI (0.60S), BD (0.30S)	3.9 ^c	6.6	7.6	7.2
T ₉	VS (0.00S), BI (0.60S), BD (0.60S)	3.7	6.1	7.2	6.8
T ₁₀	VS (0.30S), BI (0.00S), BD (0.00S)	4.5 ^a	7.7 ^b	8.9 ^a	8.1 ^b
T ₁₁	VS (0.30S), BI (0.00S), BD (0.30S)	4.5 ^a	7.9 ^a	8.4 ^c	7.7
T ₁₂	VS (0.30S), BI (0.00S), BD (0.60S)	4.5 ^a	7.7 ^b	8.2	7.5
T ₁₃	VS (0.30S), BI (0.30S), BD (0.00S)	4.3 ^b	7.3	7.9	7.6
T ₁₄	VS (0.30S), BI (0.30S), BD (0.30S)	4.3 ^b	7.5	7.8	7.4
T ₁₅	VS (0.30S), BI (0.30S), BD (0.60S)	4.1 ^b	7.3	7.5	7.4
T ₁₆	VS (0.30S), BI (0.60S), BD (0.00S)	3.9 ^c	6.6	7.4	7.2
T ₁₇	VS (0.30S), BI (0.60S), BD (0.30S)	3.7	6.1	7.3	6.9
T ₁₈	VS (0.30S), BI (0.60S), BD (0.60S)	3.5	5.9	6.8	6.7
T ₁₉	VS (0.60S), BI (0.00S), BD (0.00S)	4.3 ^b	7.7 ^b	8.8 ^b	7.8
T ₂₀	VS (0.60S), BI (0.00S), BD (0.30S)	4.2 ^b	7.5 ^c	8.1	7.3
T ₂₁	VS (0.60S), BI (0.00S), BD (0.60S)	4.2 ^b	7.3	8.1	7.1
T ₂₂	VS (0.60S), BI (0.30S), BD (0.00S)	4.1 ^b	7.2	8.0	6.9
T ₂₃	VS (0.60S), BI (0.30S), BD (0.30S)	4.0 ^b	7.2	7.9	6.7
T ₂₄	VS (0.60S), BI (0.30S), BD (0.60S)	3.7	7.0	7.8	6.5
T ₂₅	VS (0.60S), BI (0.60S), BD (0.00S)	3.7	6.7	6.9	6.3
T ₂₆	VS (0.60S), BI (0.60S), BD (0.30S)	3.4	6.1	6.6	6.1
T ₂₇	VS (0.60S), BI (0.60S), BD (0.60S)	3.2	5.7	6.2	5.9
	General Mean	4.1	7.1	7.9	7.3
	SE±	0.11	0.08	0.11	0.10
	CD@5%	0.30	0.24	0.30	0.27

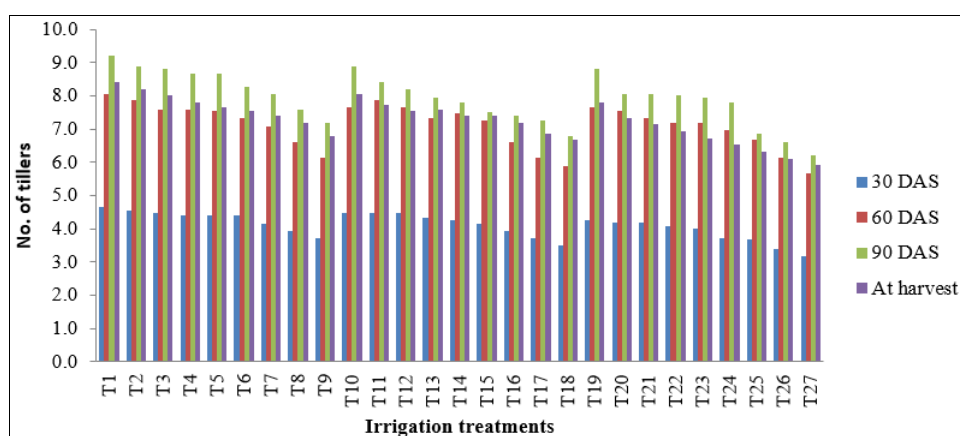
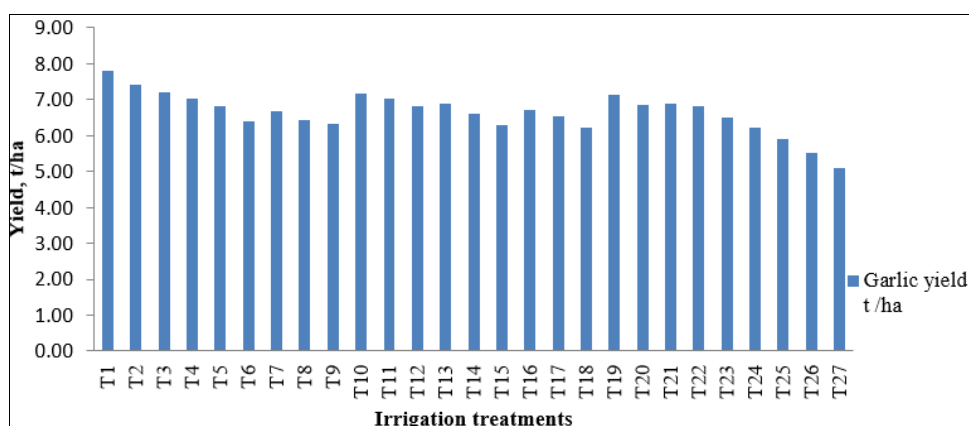
**Fig 4.** Periodical Number of tillers in garlic influenced by different treatments**Fig 5:** Garlic yield influenced by different irrigation treatments

Table 5: Garlic yield (t ha⁻¹) influenced by different treatment

Sr. No.	Treatments	2021-22
T ₁	VS (0.00S), BI (0.00S), BD (0.00S)	7.80 ^a
T ₂	VS (0.00S), BI (0.00S), BD (0.30S)	7.40 ^a
T ₃	VS (0.00S), BI (0.00S), BD (0.60S)	7.20 ^b
T ₄	VS (0.00S), BI (0.30S), BD (0.00S)	7.03 ^b
T ₅	VS (0.00S), BI (0.30S), BD (0.30S)	6.80 ^c
T ₆	VS (0.00S), BI (0.30S), BD (0.60S)	6.40 ^c
T ₇	VS (0.00S), BI(0.60S), BD (0.00S)	6.67 ^c
T ₈	VS (0.00S), BI (0.60S), BD (0.30S)	6.43 ^c
T ₉	VS (0.00S), BI (0.60S), BD (0.60S)	6.32
T ₁₀	VS (0.30S), BI (0.00S), BD (0.00S)	7.18 ^b
T ₁₁	VS (0.30S), BI (0.00S), BD (0.30S)	7.01 ^b
T ₁₂	VS (0.30S), BI (0.00S), BD (0.60S)	6.80 ^c
T ₁₃	VS (0.30S), BI (0.30S), BD (0.00S)	6.90 ^b
T ₁₄	VS (0.30S), BI (0.30S), BD (0.30S)	6.60 ^c
T ₁₅	VS (0.30S), BI (0.30S), BD (0.60S)	6.30
T ₁₆	VS (0.30S), BI (0.60S), BD (0.00S)	6.71 ^c
T ₁₇	VS (0.30S), BI (0.60S), BD (0.30S)	6.54 ^c
T ₁₈	VS (0.30S), BI (0.60S), BD (0.60S)	6.23
T ₁₉	VS (0.60S), BI (0.00S), BD (0.00S)	7.15
T ₂₀	VS (0.60S), BI (0.00S), BD (0.30S)	6.85
T ₂₁	VS (0.60S), BI (0.00S), BD (0.60S)	6.90
T ₂₂	VS (0.60S), BI (0.30S), BD (0.00S)	6.80
T ₂₃	VS (0.60S), BI (0.30S), BD (0.30S)	6.50
T ₂₄	VS (0.60S), BI (0.30S), BD (0.60S)	6.20
T ₂₅	VS (0.60S), BI (0.60S), BD (0.00S)	5.90
T ₂₆	VS (0.60S), BI (0.60S), BD (0.30S)	5.50
T ₂₇	VS (0.60S), BI (0.60S), BD (0.60S)	5.10
	General Mean	6.66
	SE±	0.18
	CD@5%	0.50

Table 6: Number of irrigation and total depth of irrigation water applied in (mm) for different treatments

Treatments	Number of irrigation			Total depth of water applied in mm				
	Vegetative stage	Bulb initiation stage	Bulb development stage	Vegetative stage	Bulb initiation stage	Bulb development stage	Total	% water saving over T ₁
T ₁	3	3	5	57.96	153.04	294.69	505.68	--
T ₂	3	3	5	58.72	154.57	209.96	423.24	16.30
T ₃	3	3	5	61.09	160.89	119.30	341.29	32.51
T ₄	3	3	5	56.97	105.20	280.52	442.69	12.46
T ₅	3	3	5	57.48	106.23	207.56	371.27	26.58
T ₆	3	3	5	58.32	107.64	121.91	287.88	43.07
T ₇	3	3	5	59.66	62.85	294.79	417.30	17.48
T ₈	3	3	5	58.27	61.74	213.97	333.99	33.95
T ₉	3	3	5	55.52	58.97	118.34	232.83	53.96
T ₁₀	3	3	5	41.36	156.45	299.74	497.56	1.67
T ₁₁	3	3	5	40.17	151.38	199.14	390.70	22.74
T ₁₂	3	3	5	40.29	151.98	120.13	312.40	38.22
T ₁₃	3	3	5	40.88	109.01	292.81	442.70	10.14
T ₁₄	3	3	5	41.41	110.70	216.28	368.38	27.74
T ₁₅	3	3	5	41.13	126.88	123.41	291.42	42.37
T ₁₆	3	3	5	39.96	106.40	120.28	415.70	17.79
T ₁₇	3	3	5	40.93	62.33	216.25	319.25	36.83
T ₁₈	3	3	5	42.18	64.30	127.98	234.46	53.64
T ₁₉	3	3	5	23.91	160.07	291.64	475.62	5.89
T ₂₀	3	3	5	23.52	156.51	212.06	392.10	22.46
T ₂₁	3	3	5	23.88	158.69	118.34	300.92	40.49
T ₂₂	3	3	5	23.97	111.98	311.45	447.40	11.53
T ₂₃	3	3	5	22.70	106.34	201.38	330.42	34.66
T ₂₄	3	3	5	22.15	103.95	117.53	243.63	51.82
T ₂₅	3	3	5	23.12	61.98	301.60	386.71	23.53
T ₂₆	3	3	5	22.43	60.39	208.04	290.85	42.48
T ₂₇	3	3	5	25.08	66.96	127.85	219.89	56.52

3.1.3 Garlic yield

The irrigation treatments had appreciably influenced garlic

yield. Since, the garlic is 4- 5 months crop and require good quantity of water for its full growth and maturity, showed

significant effect of different water stress applied during different growth stages was observed in both the seasons. The garlic yield observed during season are given in Table 5 and graphically shown in Fig. 5. The garlic yield ranged from 7.8 t ha⁻¹ to 5.10 t ha⁻¹ However, the higher yield observed in T₁ and lower yield observed in T₂₇ in both season.

3.2 Irrigation Water Applied

Irrigations were scheduled at regular intervals throughout the entire growing period of the garlic. The total depth of irrigation water applied during the growth period is shown in Table 6. The no water stress treatment (T₁) received the highest irrigation depth, while the highly stressed treatment (T₂₇) received the lowest. For the season, the total depth of irrigation water applied to treatment T₁ was 505.68 mm. In contrast, treatment T₁₄, which experienced 30% water stress throughout the growth period, received a total of 368.38 mm. Treatment T₂₇ had the lowest total depth of water applied during the season, at 219.89 mm. The number of irrigations applied during the vegetative stage, bulb initiation stage, and bulb development stage were 3, 3, and 5, respectively. The bulb development stage, which lasted 65-70 days, had the highest water requirement, followed by the bulb initiation stage and the vegetative stage. For all treatments, irrigation water applied during the bulb development stage was 1.5 to 1.9 times greater than that applied during the other stages.

3.3 Water use efficiency

The values of Water Use Efficiency (WUE) influenced by different irrigation treatments are presented in Table 7 and illustrated graphically in Fig. 6. The WUE ranged from 0.014 to 0.027 t ha⁻¹ mm⁻¹. The maximum WUE of 0.027 t ha⁻¹ mm⁻¹ was recorded in treatments T₉ and T₁₈, while the minimum WUE of 0.014 t ha⁻¹ mm⁻¹ was observed in treatment T₁₀. (Zanjad A.B *et*

al., 2021) [4].

Table 7: Water use efficiency in different treatments

Treatments	Water use efficiency		
	Yield t/ha	Water used, mm	WUE t/ha-mm
T ₁	7.80	505.68	0.015
T ₂	7.40	423.24	0.017
T ₃	7.20	341.29	0.021
T ₄	7.03	442.69	0.016
T ₅	6.80	371.27	0.018
T ₆	6.40	287.88	0.022
T ₇	6.67	417.30	0.016
T ₈	6.43	333.99	0.019
T ₉	6.32	232.83	0.027
T ₁₀	7.18	497.56	0.014
T ₁₁	7.01	390.70	0.018
T ₁₂	6.80	312.40	0.022
T ₁₃	6.90	442.70	0.016
T ₁₄	6.60	368.38	0.018
T ₁₅	6.30	291.42	0.022
T ₁₆	6.71	415.70	0.016
T ₁₇	6.54	319.25	0.020
T ₁₈	6.23	234.46	0.027
T ₁₉	7.15	475.62	0.015
T ₂₀	6.85	392.10	0.017
T ₂₁	6.90	300.92	0.023
T ₂₂	6.80	447.40	0.015
T ₂₃	6.50	330.42	0.020
T ₂₄	6.20	243.63	0.025
T ₂₅	5.90	386.71	0.015
T ₂₆	5.50	290.85	0.019
T ₂₇	5.10	219.89	0.023

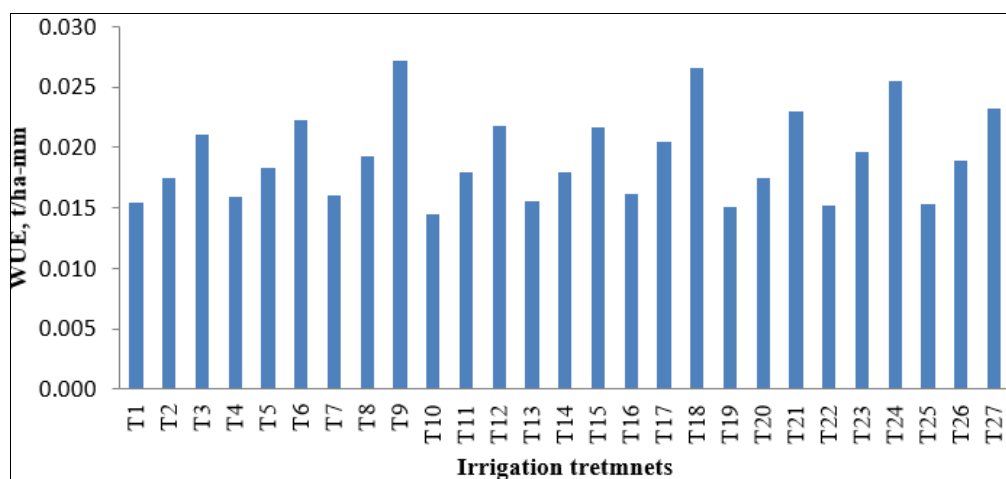


Fig 6: Water use efficiency influenced by different irrigation treatments

4. Conclusion

The research concludes that deficit irrigation has a positive effect on garlic, particularly in terms of growth parameters such as plant height, number of tillers, and yield. The maximum plant height and number of tillers were observed in the no water stress treatment, which also produced the highest garlic yield. Conversely, the lowest plant height, number of tillers, and garlic yield were recorded in the high water stress treatment. Additionally, the lowest water use efficiency was observed in the no water stress treatment, while the highest water use efficiency was found in the treatments subjected to high water stress.

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6. References

1. Gupta R, Mishra KP, Hardaha MK. Response of garlic (*Allium sativum* L.) cv. G-282 to different irrigation levels under drip irrigation system. *Int J Pure Appl Biosci.* 2017;5(6):1334-1340.
2. Taha NM, Abd-Elrahman SH, Hashem FA. Improving yield and quality of garlic (*Allium sativum* L.) under water stress conditions. *Middle East J Agric Res.* 2019;8(1):330-346.
3. Gupta R, Hardaha MK, Mishra KP. Response of garlic (*Allium sativum* L.) to drip fertigation in the Malwa region of Madhya Pradesh. *J Pharmacogn Phytochem.* 2020;9(2):2252-2255.
4. Zanjad AB, Pimpale AR, Ghawade SM, Wadatkar SB. Water use efficiency and cost economics of onion under different fertilizer levels in surface and drip irrigation. *Int J Agric Sci.* 2021;13(9):10876-10879.
5. Ahmed M, Derbala A, Abd El-Kader N. Effect of irrigation frequency and potassium source on the productivity, quality, and storability of garlic. *Misr J Agric Eng.* 2009;26(3):1245-1262.
6. Ayele BG, Asseffa S, Tuhar AW. Effect of deficit irrigation under furrow irrigation techniques on garlic (*Allium sativum* L.) productivity at central highland Ethiopia. *Water Energy Nexus.* 2023;6:32-45.
7. Chala M, Quraishi S. Effect of deficit irrigation on yield and water productivity of garlic (*Allium sativum* L.) under drip irrigation and mulching at Wolaita Soddo, Ethiopia. *Int J Life Sci.* 2015;4(4):232-239.