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Effect of different levels of NPK fertigation on growth, yield and quality of garlic (*Allium sativum* L.) var. AAS-2 under Northern Dry Zone of Karnataka

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Abstract
A filed experiment was carried out at KRCCH, Arabhavi, UHS, Bagalkot during *rabi* 2024-25 to study the effect of different levels of NPK fertigation on growth, yield, quality and economics of garlic (*Allium sativum* L.) var. AAS-2 under Northern Dry Zone of Karnatak. The experiment was laid out in a Randomized Complete Block Design (RCBD) with six treatment combinations with different levels RDF, *viz*. 50%, 75%, 100%, 125%, 150% applied through fertigation using completely water-soluble fertilizers in split doses along with a conventional method of manual application. The result of experiment revealed that application of 100 per cent RDF (T_4) through fertigation recorded significantly maximum plant height (61.78 cm), number of leaves per plant (8.95), leaf length (48.81 cm), leaf breath (1.59 mm), collar diameter (7.08 mm), weight of the bulb (13.95 g/plant), bulb diameter (31.22 mm), number of cloves per bulb (23.75), bulb yield (7.58 t/ha), net return (3,37,328.85 Rs./ha) and return per rupee of expenditure (2.10) compared to other treatments along with a higher value for the quality parameter like sulphur content of 0.38 per cent. Application of 100 per cent RDF through fertigation results in a decrease in physiological weight loss per cent, sprouting per cent and rotting per cent, thereby improving the keeping quality of garlic bulb. Hence, it can be concluded that the application of 100 per cent of recommended dose of fertilizer (125:62.5:62.5 kg/ha) through fertigation in garlic proved to be most effective in enhancing growth, yield, quality and profitability under the Northern Dry Zone of Karnataka.

Keywords: Garlic, fertigation, yield, net return and return per rupee of expenditure.

Introduction
Garlic (*Allium sativum* L.) is an important bulbous spice crop belonging to the family Alliaceae, known for its unique aroma, medicinal properties and high economic value (Singh *et al*., 2023) [32]. It is believed to have originated in Central Asia with secondary centre of diversity in the Mediterranean region. The crops has been cultivated since ancient times and is mainly grown as a cool-season crop during the rabi season, requiring moderate temperatures for vegetative growth and slightly warmer conditions for bulb formation (Dhall *et al*., 2023) [6].

Water scarcity is one of the major limiting factors affecting garlic production in several regions. In many areas, surface irrigation is commonly used; however, it often leads to poor water use efficiency, deep percolation losses and ono uniform water distribution. For shallow-rooted crops like garlic, the inability to provide precise and small quantities of water under surface irrigation can adversely affect crop performance (Pawar *et al.*, 1998) [22].

Garlic roots are generally confined to the top 30 cm of the soil layer, making the crop highly susceptible to moisture stress (Rajesh *et al.*, 2018) [25]. Adequate soil moisture throughout the growth period is essential, while excessive watering during maturity may cause bulb rot and reduce market quality. Drip irrigation serves as a suitable technique, providing frequent and unform water application according to the crops shallow root system. The adoption of drip irrigation has been found to enhance yield by 25-30 per cent and reduce irrigation water use by 40-60 per cent (Sankar *et al.*, 2008) [29].

Likewise, the application of fertilizers through fertigation using water soluble fertilizers improves nutrient use efficiency, minimizes nutrient losses and enhances yield and quality by

30-35 per cent (Sivanappan, 1979) [33]. It ensures a unform, timely and site-specific nutrient supply directly to the root zone, resulting in better utilization of water, nutrient, energy and labour (Tripathi *et al*., 2010) [34]. Considering these facts, the present study was carried out to evaluate the influence of different levels of fertigation on the growth, yield, quality and economics of garlic (*Allium sativum* L.) var. AAS-2 under Northern Dry Zone of Karnataka with the objective of evaluating its growth, yield and quality response to varied fertigation treatments. The experimental procedures and key findings are summarized and discussed below.

Materials and Methods

The field experiment was conducted during *rabi* 2024-25 at the Department of PSMA field research block in KRCCH, Arabhavi, UHS, Bagalkot, Karnataka, India. Garlic variety AAS-2 was selected for the experiment and planted in October-2024 with a spacing 15 cm x 7.5 cm. The experiment consists of six treatments and 4 replications laid out in a randomized complete block design (RCBD). Fertigation was initiated fifteen days after sowing and applied in ten equal splits at seven-day interval, while irrigation was stopped fifteen days before harvesting in all treatments. A basal dose of 25 tonnes per hectare of well decomposed farmyard manure was incorporated in the soil before sowing. The check plot was irrigated through drip irrigation and fertilizers were applied manually at 100 per cent recommended dose with two split applications. Water soluble fertilizers including Urea, MAP (12:61:0), SoP (0:0:50) were used in fertigation process, administered at weekly intervals. The observation on growth and yield parameters were recorded following standard procedures. The statistical analysis of the data was carried out by using standard statistical method of analysis of variance as per Panse and Sukhatme (1985) [21]. The treatments details are as follows:

T_1: RDF (125:62.5:62.5 kg/ha) was given through conventional method of fertilizer application
T_2: 50% RDF (62.5:31.25:31.25 kg/ha) through fertigation
T_3: 75% RDF (93.75:46.87:46.87 kg/ha) through fertigation
T_4: 100% RDF (125:62.5:62.5 kg/ha) through fertigation
T_5: 125% RDF (156.25:78.12:78.12 kg/ha) through fertigation
T_6: 150% RDF (187.5:93.75:93.75 kg/ha) through fertigation

Results and Discussion

Growth parameters

The result of the present investigation revealed that growth parameters such as plant height, number of leaves per plant, leaf length, leaf breadth and collar diameter of garlic were influenced significantly by different levels of fertigation treatments (Table 1). The maximum plant height (61.78 cm), number of leaves per plant (8.95), leaf length (48.81 cm) and leaf breadth (1.59 mm) were recorded with application of 100 per cent RDF through fertigation (T_4). This treatment was found to be on par with application of 75 per cent RDF through fertigation (T_3), which recorded 59.64 cm, 8.38, 47.53 cm, 1.40 mm, respectively.

Table 1: Effect of different levels of fertigation on growth parameters of garlic (*Allium sativum* L.) var. AAS-2.

Treatment	Plant height (cm)	Number of leaves per plant	Leaf length (cm)	Leaf breadth (mm)	Collar diameter (mm)
T_1 - RDF (125:62.5:62.5 kg/ha) through soil application - without fertigation	53.57	7.95	44.37	1.31	5.58
T_2 - 50% RDF (62.5:31.25:31.25 kg/ha) through fertigation	49.22	7.13	42.15	1.19	4.97
T_3 - 75% RDF (93.75:46.87:46.87 kg/ha) through fertigation	59.64	8.38	47.53	1.40	6.10
T_4 - 100% RDF (125:62.5:62.5 kg/ha) through fertigation	61.78	8.95	48.81	1.59	7.08
T_5 - 125% RDF (156.25:78.12:78.12) through fertigation	55.14	7.95	44.72	1.34	5.88
T_6 - 150% RDF (187.5:93.75:93.75 kg/ha) through fertigation	53.03	8.05	43.41	1.32	5.76
Mean	55.40	8.07	45.44	1.36	5.89
S.Em±	0.96	0.32	1.35	0.06	0.26
C.D @ 5%	2.90	0.97	4.06	0.17	0.79
CV (%)	12.48	17.97	15.93	18.37	13.91

Significantly lower plant height (49.22 cm), number of leaves per plant (7.13), leaf length (42.15 cm) and leaf breadth (1.19 mm) were observed in 50 per cent RDF through fertigation (T_2).

A significant difference was also observed in collar diameter between the different fertigation treatments. The Highest collar diameter (7.08 mm) was recorded in T_4 (100% RDF through fertigation), followed by 75 per cent RDF through fertigation with 6.10 mm. While lower collar diameter (4.97 mm) was observed in T_2 (50 per cent RDF through fertigation).

The significant higher plant height, number of leaves per plant, leaf length, leaf breadth and collar diameter recorded under 100 per cent RDF through fertigation might be attributed to balanced nutrient availability, efficient water and nutrient utilization and improved vegetative growth resulting from enhanced photosynthetic activity. These findings are in close agreement with those reported by Kumari *et al*. (2022) [15] in garlic, Kebede (2003) [13] in onion, Prabhakar *et al*. (2011) [24] in *rabi* onion, and Pooja *et al*. (2018) [23] in onion, Howard *et al*. (2000) [11]. Similarly, Mishra *et al*., (2005) [17] reported that, drip irrigation and fertigation at regular intervals provides a uniform moisture regime and nutrient supply, thereby enhancing root activity, nutrient availability and translocation of assimilates, which collectively promote better vegetative growth and maintain optimum soil moisture and temperature.

Yield parameters

In the present study (Table 2), fertigation with recommended dose of fertilizer (100% RDF through fertigation) resulted in higher yield and yield attributing parameters like weight of the bulb, number of cloves per bulb, bulb diameter and bub yield per hectare. The maximum weight of the bulb (13.95 g/plant) was recorded in T_4 (100% RDF through fertigation) which was found to be on par with T_3 (75% RDF through fertigation) having 12.05 g/plant, while the minimum weight of the bulb (9.58 g/plant) was recorded in T_2 (50% RDF through fertigation) with 50 per cent RDF through fertigation. Similarly, the maximum bulb diameter (31.22 mm), number of cloves per bulb (23.75) and bulb yield (7.58 t/ha) were recorded in T_4 (100% RDF through fertigation) followed by T_3 (28.55 mm, 20.75 and 6.05 t/ha, respectively). The lowest values for these parameters were obtained in T_2 (23.66 mm, 14.75 and 4.09 t/ha, respectively) with 50 per cent RDF through fertigation. The improvement in

yield and yield components under 100 per cent RDF through fertigation might be attributed to enhanced plant height, number of leaves per plant and collar diameter, which provide a greater photosynthetic surface area leading to higher carbohydrate synthesis and efficient translocation of assimilates to the bulbs. This in turn contributed to large bulb size and higher yield. These findings are in agreement with results reported by Chopade *et al*. (1998) [4], Rumpel *et al*. (2004) [27], Bhakare and Fatkal (2008) [3], Abdissa *et al*. (2011) [1], Ramana *et al*. (2014) [26], Gupta *et al*. (2016) [10], Dingre *et al*. (2016) [7], Kaur *et al*. (2019) [12] and laxmi *et al*. (2019) [16].

Table 2: Effect of different levels of fertigation on yield parameters of garlic (*Allium sativum* L.) var. AAS-2.

Treatment	Weight of the bulb (g)	Bulb diameter (mm)	Number of cloves per bulb	Bulb yield (t/ha)
T_1 - RDF (125:62.5:62.5 kg/ha) through soil application - without fertigation	10.90	27.07	19.50	5.99
T_2 - 50% RDF (62.5:31.25:31.25 kg/ha) through fertigation	9.58	23.66	14.75	4.09
T_3 - 75% RDF (93.75:46.87:46.87 kg/ha) through fertigation	12.05	28.55	20.75	6.05
T_4 - 100% RDF (125:62.5:62.5 kg/ha) through fertigation	13.95	31.22	23.75	7.58
T_5 - 125% RDF (156.25:78.12:78.12) through fertigation	11.30	27.44	18.75	5.95
T_6 - 150% RDF (187.5:93.75:93.75 kg/ha) through fertigation	10.00	27.25	18.25	5.36
Mean	11.30	27.52	19.29	5.84
S.Em±	0.65	0.89	0.60	0.16
C.D @ 5%	1.97	2.68	1.81	0.48
CV (%)	17.57	16.45	16.22	15.50

Table 3: Effect of different levels of fertigation on sulphur content in garlic (*Allium sativum* L.) var. AAS-2 at harvest.

Treatment	Sulphur content (%)
T_1 - RDF (125:62.5:62.5 kg/ha) through soil application - without fertigation	0.29
T_2 - 50% of RDF (62.5:31.25:31.25 kg/ha) through fertigation	0.23
T_3 - 75% of RDF (93.75:46.87:46.87 kg/ha) through fertigation	0.34
T_4 - 100% of RDF (125:62.5:62.5 kg/ha) through fertigation	0.38
T_5 - 125% of RDF (156.25:78.12:78.12) through fertigation	0.32
T_6 - 150% of RDF (187.5:93.75:93.75 kg/ha) through fertigation	0.25
Mean	0.30
S.Em±	0.02
C.D @ 5%	0.05
CV (%)	15.53

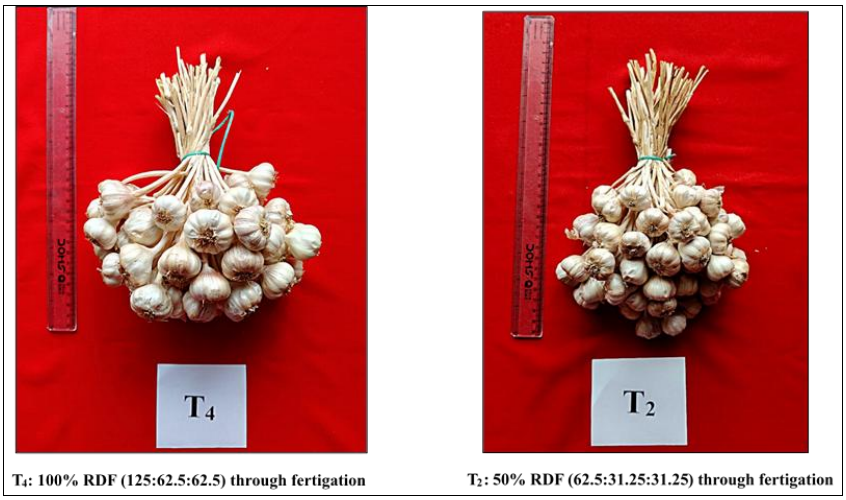

Fig 1: Comparison of best performing fertigation level at 100 per cent RDF through fertigation (T_4) with fertigation level at 50 per cent RDF through fertigation (T_2)

Quality parameters

The data on fertigation studies (Table 3) revealed that, the treatment T_4 (100% RDF through fertigation) had a significant influence on the sulphur content (0.38%), which was found to be on par with T_3 (75% RDF through fertigation) having 0.34 per cent sulphur content. The lowest values of sulphur content (0.23%) were recorded in T_2 (50% RDF through fertigation). The increase in sulphur content at optimal fertigation levels may be attributed to improved sulphur uptake and assimilation, which supports the synthesis of sulphur containing compounds responsible for pungency, flavour and overall bulb quality. Similarly, observation were reported by Forney *et al*. (2010) [9] in onion (*Allium cepa* L.), where sulphur fertilization significantly enhanced bulb sulphur concentration, pungency (pyruvic acid content) and overall traits under field conditions. Comparable findings were also reported by Nasreen and Huql, 2024 [20].

Physical parameters

The physical parameter such as physiological loss in weight,

sprouting, rotting and marketable bulb of garlic at 90 days of storage after harvest were significantly influenced by different levels of fertigation (Table 4). Significantly lower physiological weight loss (11.93%) was recorded in T_4 (100% RDF through fertigation) with no sprouting or rotting observed. In contrast, the highest physiological weight loss (16.155), along with slight sprouting (0.54%) and rotting (0.32%) were observed in T_2 (50% RDF through fertigation).

The highest marketable bulb (88.08%) was also recorded in T_4 (100% RDF through fertigation), which was on par with T_3 (75% RDF through fertigation) showing 86.73 per cent marketable bulb, while the lowest values (82.99%) were observed in T_2 (50% RDF through fertigation). This may be due to the additive effect of potassium and phosphorous, which helps mitigate the adverse effects of excessive nitrogen by reducing the rate of respiration and maintaining the bulb hydration during storage. Similar findings were also reported with Kumara *et al.* (2025) [14], Muluneh *et al*. (2018) [18]. Singh and Dankhar, (1991) [31] and Nandi *et al*. (2002) [19].

Table 4: Effect of different levels of fertigation on physiological loss in weight, sprouting, rooting and marketable bulb per cent of garlic (*Allium sativum* L.) var. AAS-2 at 90 days after storage.

Treatment	Physiological loss in weight	Sprouting	Rooting	Marketable bulb
	Per cent			
T_1 - RDF (125:62.5:62.5 kg/ha) through soil application - without fertigation	14.05	0.00	0.00	85.95
T_2 - 50% RDF (62.5:31.25:31.25 kg/ha) through fertigation	16.15	0.54	0.32	82.99
T_3 - 75% RDF (93.75:46.87:46.87 kg/ha) through fertigation	13.75	0.00	0.00	86.73
T_4 - 100% RDF (125:62.5:62.5 kg/ha) through fertigation	11.93	0.00	0.00	88.08
T_5 - 125% RDF (156.25:78.12:78.12) through fertigation	13.98	0.00	0.00	85.75
T_6 - 150% RDF (187.5:93.75:93.75 kg/ha) through fertigation	14.25	0.00	0.00	86.02
Mean	14.02	0.09	0.05	85.92
S.Em±	0.46	0.14	0.08	0.46
C.D @ 5%	1.39	NS	NS	1.39
CV (%)	18.59	-	-	14.07

NS - Non-significant

Table 5: Effect of different levels of fertigation on economics in garlic (*Allium sativum* L.) var. AAS-2

Treatment	Bulb yield (t/ha)	Total cost of Cultivation (Rs/ha)	Gross return (Rs/ha)	Net return (Rs/ha)	Return per rupee of expenditure
T_1 - RDF (125:62.5:62.5 kg/ha) Conventional method	5.99	297409.50	509150.00	211740.47	1.71
T_2 - 50% of RDF (62.5:31.25:31.25 kg/ha) through fertigation	4.09	283213.70	347650.00	64436.27	1.22
T_3 - 75% of RDF (93.75:46.87:46.87 kg/ha) through fertigation	6.03	295287.70	512550.00	217262.28	1.73
T_4 - 100% of RDF (125:62.5:62.5 kg/ha) through fertigation	7.58	306971.20	644300.00	337328.85	2.10
T_5 - 125% of RDF (156.25:78.12:78.12) through fertigation	5.95	315749.50	505750.00	190000.46	1.60
T_6 - 150% of RDF (187.5:93.75:93.75 kg/ha) through fertigation	5.36	325845.20	455600.00	129754.79	1.39

Note: Cost of garlic bulb (2024-25) - Rs. 85 per kg

Economics

Economics parameters such as cost of cultivation per hectare, gross returns per hectare, net returns per hectare and returns per rupee of expenditure (Table 5).

Among all the treatments, treatment T_6 (150% of RDF through fertigation) recorded the highest cost of cultivation per hectare (Rs. 3,25,845.20) followed by T_5 (125% of RDF through fertigation), while lowest cost of cultivation (Rs. 2,83,213.70/ha) was observed in T_2 (50% RDF through fertigation). However, the highest gross return per hectare (Rs. 6,44,300.00) was obtained from T_4 (100% of RDF through fertigation) followed by T_3 (75% of RDF through fertigation), whereas T_2 (50% of RDF through fertigation) recorded lowest gross return (Rs. 3,47,650.00/ha). The maximum net returns per hectare (Rs. 3,37,328.85) and return per rupee of expenditure (2.10) were also achieved in T_4 (100% of RDF) followed by T_3 (75% of RDF), while the lowest net return (Rs. 64,436.27/ha) and return per rupees of expenditure (1.22) were recorded in T_2 (50% of RDF). The result clearly indicates that optimizing nutrient management through fertigation is a viable and profitable strategy for garlic cultivation. It not only enhances bulb yield and quality but also ensures higher profitability and better resource use efficiency by increasing return per rupee of investment. Similar finding were reported by Behera *et al*. (2014) [2] in mint, Shigvan *et al.* (2023) [30], Vaidehi *et al*. (2017) [35] and Sanjit and Patra (2015) [28] observed similar.

Conclusion

Based on results obtained, it can be concluded that, among the different fertigation treatments evaluated, the application of 100 per cent RDF through fertigation produced the best performance in term of growth, yield, yield attributes and economic returns. Therefore, it may be inferred that drip irrigation combined with fertigation at seven days interval significantly enhances garlic plant growth, yield and yield attributes, particularly when 100 per cent RDF applied through fertigation compared to other treatments.

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