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Response of garlic (*Allium sativum* L.) to drip fertigation in Malwa region of Madhya Pradesh

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Abstract
The field experiments were conducted during rabi seasons 2014-15 and 2015-16 to standardize the drip fertigation system for garlic cv. G-282 in Malwa Region of Madhya Pradesh. The experiment laid out in a FRBD consists of three levels of irrigation water i.e., IW/CPE ratio 0.60 (I1), 0.80 (I2), 1.00 (I3) and three levels of RDF i.e., 60% (F1), 80% (F2), and 100% (F3) and one control plot treatment with three replications. Different drip fertigation treatments significantly affected ($P< 0.05$) the plant height, polar and equatorial diameter, marketable bulb yield and gross bulb yield of garlic. Among different irrigation and fertigation levels tested, treatment I3F3 recorded highest plant height (74.19 cm), polar diameter (5.41 cm), equatorial diameter (5.08 cm), marketable bulb yield (147.33 q/ha) and gross bulb yield (161.07 q/ha). The maximum WUE was recorded in treatment I1F3 (7.09 q/ha-cm) whereas maximum water FUE was recorded in treatment I3F3 (64.43 kg/kg). The drip fertigation treatment I3F3 gave the highest B:C ratio of 5.60.

Keywords: Fertigation, garlic irrigation, WUE, FUE, B:C ratio

Introduction
Garlic (*Allium sativum* L.) is considered as one of the important bulb crop which belongs to the family Alliaceae. It is the second important bulb crop grown after onion and world area coverage by garlic increased from 1142.22 thousand ha in 2003 to 1422.41 thousand ha in 2011 with an average productivity of 12 and 16.71 t/ha, respectively [1]. In India, garlic is cultivated in 280.95 thousand ha with a production of 1617.34 thousand MT with an average yield of 5.76 t/ha [2]. It is grown in large quantities in the states of Madhya Pradesh, Gujarat, Orissa, Rajasthan, Karnataka, Tamil Nadu, Maharashtra and Bihar. Madhya Pradesh is leader state in the production of seed spices and the largest producer of garlic in India and occupies the area of over 81.17 thousand ha with a production of 424.50 thousand MT [2]. Garlic is a very shallow rooted bulb crop and very sensitive to moisture stress conditions particularly during bulb initiation and development. Irrigation is one of the most crucial inputs for garlic crop. The shortage of irrigation at bulb development, which usually coincides with early summer season affect the yield drastically. Climate change predictions of increase in temperature and decrease in rainfall may enhance water scarcity. Thus, increasing efficiency in irrigation is only option. In last few decades, emphasis has been given in enhancing the productivity of irrigation water. Therefore, efficient use of water by irrigation is becoming increasingly important, and alternative water application method such as micro-irrigation methods may contribute substantially to attain the twin objectives of higher productivity and optimum use of water.

In garlic, flood irrigation is widely practiced in India, which results in inefficient use of irrigation water due to losses in deep percolation, distribution and evaporation. The drip fertigation technology is the key intervention in water and fertilizer saving which enhanced the crop productivity. Fertigation is the most efficient method of fertilizer application, as it ensures application of the fertilizers directly to the plant roots [3]. In fertigation, fertilizer application is made in small and frequent doses that fit within scheduled irrigation intervals matching the plant water use to avoid leaching. Crop yield under fertigation have shot up to potentials never before imagined [4, 5]. Drip fertigation enables, the application of water soluble fertilizers and other chemicals along with application of water uniformly and more efficiently in the root zone of crop. However, as against approximately 80 percent of the irrigated land in Israel under fertigation, there is negligible share of fertigation in India. A tremendous effort has been made by various researchers towards the evaluation of micro-irrigation systems on growth and yield of garlic in which either irrigation water or fertilizer requirements for garlic crop was standardized. All the findings reported are site specific and greatly influenced by climatic conditions and soil properties.

Applicability and success of drip irrigation changes with soil type, climate and management of system of irrigation and hence it has to be tested for region specific [6]. Therefore, the present study was conducted to standardization of drip fertigation system for garlic crop in Malwa region of Madhya Pradesh.

Materials and Methods

The field experiments were conducted during the two consecutive rabi seasons 2014-15 and 2015-16 at farmer's field in Dhariyakhedi village of Mandsaur district of Madhya Pradesh. The area is situated in western part of Madhya Pradesh which falls under agro-climatic zone of Malwa plateau. It lies between the parallels of 23°45'50" and 25°2'55" north latitudes and between the meridians of 74°42'30" and 75°50'20" east longitudes with an average elevation of 436 meters. Mandsaur belongs to sub-tropical climate having a mean temperature range of minimum 5 ^{0}C and maximum 44^{0}C in winter and summer, respectively. The average annual rainfall in the district is 786.6 mm. The topography of the experimental site was uniform and leveled and the soil is clayey in texture with 45 cm depth. The total plot size of experimental site was 35 m X 25 m with individual plot area of 15 m X 1.2 m. The garlic cloves (cv. G-282) were dibbled at 15 cm X 10 cm spacing on broad bed furrow (BBF) of 120 cm top width with 45 cm furrow maintaining 15 cm height. Each BBF having two drip laterals with in-built emitters with 50 cm spacing between two consecutive emitters at a discharge rate of 4.1 lph. The uniformity coefficient was calculated as 96.80% at pressure of 1.0 kg/cm^2. Irrigation water was applied according to daily crop evapotranspiration. In this study, a fixed irrigation interval of three days was adopted and amount of water applied was estimated based on previous two days evapotranspiration. The irrigation was stopped 15 days before harvesting in all treatments.

The experiment consists of three levels of irrigation water i.e., IW/CPE ratio 0.60 (I1), 0.80 (I2), 1.00 (I3) and three levels of recommended doses of fertilizer i.e., 60% (F1), 80% (F2), and 100% (F3) for garlic crop. The recommended dose of fertilizer (RDF) for garlic was given @100:50:50:50 kg/ha of N:P:K:S respectively. The half dose of N, P, K and S was applied as basal dose and remaining half dose was applied through fertigation in fifteen split at six days interval after planting of cloves and continued up to 90 days after planting as per different treatments. A basal dose of well decomposed farmyard manure @ 20 t ha^{-1} was incorporated in the soil before one month of sowing. The control plot was irrigated in border strip by flood method and fertilizers were applied manually at 100% as recommended doses. The observation on plant height, polar and equatorial diameter, marketable bulb yield and gross bulb yield of garlic were recorded using standard procedures. The total irrigation water and fertilizer applied were recorded and thereafter, water use efficiency, fertilizer use efficiency and water productivity were calculated to quantify crop evapotranspiration requirement. The experiment was carried out in factorial randomized block design (FRBD) with three replications as suggested by Gomez and Gomez [7].

Results and Discussion

Crop growth attributes

The results revealed that all crop growth parameters of garlic were significantly influenced by different irrigation and fertigation treatments (Table 1). The plant height was measured in centimetres from ground level to the tip of the longest leaf with the help of metre scale and an average value was worked out for each treatment. The maximum plant height was obtained in treatment I3F3 (74.19cm) and minimum in treatment I1F1 (61.19cm) which was followed by control (70.50cm) at 120 DAS. The individual and interaction effect of irrigation and fertigation levels on plant height of garlic was found significant. The increased plant height in drip fertigated treatments might be due to better availability of moisture and nutrients during entire crop growth period which favoured the growth attributes. The maximum number of leaves per plant was recorded in treatment I3F3 (10.23) and minimum in treatment I1F1 (8.47) which was closely followed by control (8.70) at 120 DAS. The Higher and better growth noticed may be attributed to drip irrigation treatment created better micro-climate as compared to flood irrigation because of prolonged duration of watering. The maximum polar diameter of bulb was obtained in treatment I3F3 (5.41 cm) and minimum in treatment I1F1 (3.96 cm) which was closely followed by control (4.08 cm). The equatorial diameter of bulb was recorded maximum in treatment I3F3 (5.08 cm) and minimum in treatment I1F1 (4.28 cm) which was closely followed by control (4.35 cm). Further results revealed that with increasing irrigation and fertilizer level the polar and equatorial diameter of bulb increased considerably. In drip fertigation the more nutrient availability especially near the root zone might have increased the translocation of photosynthates to storage organ of bulb resulting in an increased diameter. Similar results were obtained by Sankar *et al.* [8] and Mahadeen [9] in garlic whereas Tripathi *et al.* [10] and Sankar *et al.* [11] in onion.

Table 1: Crop growth attributes of garlic as influenced by different irrigation and fertigation levels

Treatment	Pooled (Year 2014-15 and 2015-16)			
	Plant height (cm)	**Polar diameter (cm)**	**Equatorial diameter (cm)**	**Number of leaves per plant**
I1F1	61.19	3.96	4.28	8.47
I1F2	72.38	4.35	4.52	9.10
I1F3	73.29	4.89	4.79	9.70
I2F1	70.86	4.24	4.44	8.83
I2F2	72.18	4.46	4.63	9.40
I2F3	72.96	5.07	4.92	9.87
I3F1	71.57	4.31	4.55	9.20
I3F2	72.69	4.66	4.69	9.60
I3F3	74.19	5.41	5.08	10.23
Control	70.50	4.08	4.35	8.70
I X F	S	S	S	NS
SEm±	1.90	0.05	0.02	0.04
CD (5%)	4.66	0.12	0.05	0.11

S – Significant, NS – Non-significant

Crop yield attributes

The garlic bulbs were graded in different categories according to their bulb size *viz*., A-Grade (>25 mm), B-Grade (15-25 mm), C-Grade (10-15 mm), D-Grade (<10 mm). The A, B and C grade bulbs were considered under marketable yield and D grade bulbs considered under unmarketable category as presented in Table 2. The result indicated that the different grade bulbs were significantly affected by different irrigation and fertigation treatments. The A-Grade bulbs yield varied from 17.76 to 39.73 q/ha, B-Grade bulbs yield varied from 25.99 to 54.76 q/ha, C-Grade bulbs yield varied from 25.54 to 52.83 q/ha and D-Grade i.e., unmarketable bulbs yield varied from 7.87 to 14.68 q/ha under different treatments. The pooled data clearly indicated that the treatment gave the lowest percentage (8.54%) whereas control treatment gave the highest percentage (12.62%) of unmarketable bulb yield. This might be due to the fulfilment of crop nutrient and water requirement at various growth stages under different fertigation treatments. It is evident fact that drip irrigation ensures better aeration and moisture in the root zone [12]. These results are in accordance with Sankar *et al.* [8] in garlic and Enchalew *et al.* [13] in onion.

Table 2: Grade wise bulb yield of garlic as influenced by different irrigation and fertigation treatments

Treatment	Pooled (Year 2014-15 and 2015-16)						
	Grade wise bulb yield (q/ha)				Market-able bulb yield (q/ha)	Gross bulb yield (q/ha)	Unmar-ketable Yield (%)
	Grade A	Grade B	Grade C	Grade D			
I1F1	18.11	25.99	25.54	7.87	69.64	77.51	10.16
I1F2	26.69	38.16	38.32	10.81	103.17	113.98	9.48
I1F3	35.16	49.33	48.09	14.68	132.57	147.25	9.97
I2F1	20.39	28.85	28.03	7.88	77.28	85.16	9.25
I2F2	28.73	40.71	40.86	11.18	110.30	121.47	9.20
I2F3	36.59	50.25	49.99	14.58	136.83	151.42	9.63
I3F1	21.88	30.64	29.95	8.81	82.47	91.28	9.65
I3F2	30.35	42.73	41.66	11.63	114.74	126.37	9.20
I3F3	39.73	54.76	52.83	13.75	147.33	161.07	8.54
Control	17.76	26.11	26.80	10.20	70.67	80.87	12.62

The marketable bulb yield, gross bulb yield, water use efficiency (WUE), fertilizer use efficiency (FUE) and B:C ratio for garlic cultivation were greatly affected by different treatments (Table 3). The marketable bulb yield of garlic was obtained maximum in treatment I3F3 (147.33 q/ha) and minimum in treatment I1F1 (69.64 q/ha) which was closely followed by control (70.67 q/ha). Similarly, the maximum gross bulb yield was recorded in treatment I3F3 (161.07 q/ha) and minimum in treatment I1F1 (77.51 q/ha) which was closely followed by control (80.87 q/ha). The maximum bulb yield was recorded in treatment I3F3 may be due to optimum availability of NPK and S fertilizers which increases the rate of metabolism and synthesized more carbohydrate thus increases bulb yield. These results are in accordance with Ayars [14] and Sankar *et al.* [8] in garlic and Enchalew *et al.* [13] in onion.

The WUE was recorded in treatment combination I1F3 (7.09 q/ha-cm) whereas the lowest in control treatment (1.40 q/ha-cm). The increased water use efficiency in drip irrigated treatments might be due to decreased losses of water by evaporation and leaching as observed with traditional flood irrigation system. The results are in line with that of Mohammad and Zuraiqi [15] and, Chala and Quraishi [16]. The FUE was obtained maximum in treatment I3F3 (64.43 kg/kg) whereas minimum in treatment I1F1 (51.67 kg/kg) which was relatively higher than in control treatment (32.35 kg/kg). The improved fertilizer use efficiency in drip fertigation was as a result of small and controlled amount of fertilizers applied as per the crop requirement in contrast to large amount of fertilizer placed on the bed at the beginning of the season. The present findings are supported by Singh (2015). The B:C ratio was found maximum in treatment I3F3 (5.60) followed by I2F3 (5.23) and least in control (2.79). These results are resemblance with the past findings by Singh [17] in garlic and Tripathi *et al.* [10] in onion.

Table 3: Crop yield attributes, WUE, FUE and B:C ratio for garlic cultivation as influenced by different irrigation and fertigation levels

Treatment	Pooled (Year 2014-15 and 2015-16)				
	Marketable bulb yield (q/ha)	Gross bulb yield (q/ha)	WUE (q/ha-cm)	FUE (Kg/Kg)	B:C ratio
I1F1	69.64	77.51	3.73	51.67	2.81
I1F2	103.17	113.98	5.49	56.99	4.06
I1F3	132.57	147.25	7.09	58.90	5.10
I2F1	77.28	85.16	3.08	56.77	3.10
I2F2	110.30	121.47	4.39	60.74	4.32
I2F3	136.83	151.42	5.47	60.57	5.32
I3F1	82.47	91.28	2.64	60.85	3.28
I3F2	114.74	126.37	3.65	63.19	4.46
I3F3	147.33	161.07	4.65	64.43	5.60
Control	70.67	80.87	1.40	32.35	2.79
I X F	S	S	S	S	-
SEm±	0.77	0.96	0.09	0.65	-
CD (5%)	1.88	2.36	0.22	1.59	-

Conclusion

The drip fertigation resulted in increased water use efficiency and fertilizer use efficiency with additional water saving for garlic cultivation. Based on the two years rabi season experiments, it can be concluded that 100:50:50:50 Kg/ha application of N:P:K:S is the best drip fertigation dose in order to get higher marketable and gross bulb yield for commercial scale garlic cultivation in agro-climatic conditions of Malwa plateau of Madhya Pradesh.

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