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Scheduling of drip irrigation and fertigation in *rabi* garlic (*Allium sativum* L.)

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Abstract
An experiment entitled "Scheduling of drip irrigation and fertigation in *rabi* garlic (*Allium sativum* L.)" was conducted on medium black calcareous soil at Farming System Research Centre, Department of Agronomy, College of Agriculture, Junagadh Agricultural University, Junagadh (Gujarat) during *rabi* seasons of 2015-16 and 2016-17. The experiment was laid out in split plot design with four replications. The main plot treatments *viz.*; (i) drip irrigation at 60% PE, (ii) drip irrigation at 80% PE and (iii) drip irrigation at 100% PE, sub plots consist of four fertigation schedules *viz.*; (i) 100% RDF as basal through fertigation, (ii) two equal splits of RDF through fertigation at 30 days interval, (iii) three equal splits of RDF through fertigation at 20 days interval, (iv) four equal splits of RDF through fertigation at 15 days interval. The garlic (cv. Gujarat Garlic-4) was grown with adopting standard package of practices. The results revealed that drip irrigation scheduling at 100% PE with four equal splits of recommended dose of fertilizer through fertigation enhanced growth parameters and yield attributes which ultimately resulted in higher bulb and straw yields of *rabi* garlic.

Keywords: Garlic, drip irrigation, fertigation, scheduling, split

Introduction
Availability of water, an essential requirement for growing the crops is becoming most precious natural resource on this planet as the usable water is under continuous pressure due to burgeoning population, diminishing ground water sources, over exploitation and poor management of the resources. For agriculture sector the availability of water is being challenged due to enhanced water requirements in other sectors of economy. Hence, water management is the need of the hour wherein every drop is to be put to its most efficient use. Irrigation water used for growing the crop needs to be managed on two fronts like firstly, the method of application and secondly being the conservation in field after application. In India, about 82 per cent water is used in agriculture sector which covers around 80 m ha area under irrigation. Currently about 38 per cent of cultivable area is irrigated and more efforts are needed to cover additional area to enhance water productivity. Availability of irrigation water is limited and therefore, it should be utilized most efficiently and judiciously by adopting latest irrigation technologies (Patel *et al.*, 2000) [11].

Drip irrigation is most efficient among all the irrigation methods and reported to help achieve yield gains of up to 100% and water savings of up to 40-80%. It also increased water use efficiency and save associated fertilizer, pesticide, and labours compared to flood irrigation systems. Drip irrigation can be practiced successfully to irrigate wide range of crops especially in vegetables, orchard crops, flowers and plantation crops but on the other hand, limited studies have been conducted under field crops especially narrow spread garlic. The adoption of drip irrigation has significant bearing on the society as a whole and generates various positive and negative externalities. 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 (Chouhan *et al.*, 2015) [6].

Water and fertilizer are the main limiting factors affecting the agricultural production in arid and semi-arid regions. Application of fertilizers with irrigation water has several advantages. By fertigation, the time and rate of fertilizer applied can be regulated precisely. This will also ensure the application of a proper amount of nutrients to the particular growth stage optimizing the nutrient balance in the soil and minimizing the use of soil as storage reservoir for nutrients. Drip fertigation also enables accurate adjustment of water and nutrient supplies to meet the crop requirements.

In addition applying the plant nutrients with the irrigation water is a more convenient and less expensive method. Moreover, most farmers are switching currently from surface to drip irrigation as a mean to increase water use efficiency. With this in mind the traditional management of plant nutrient application must be modified and adjusted to this new trend.

Materials and method

An investigation on Scheduling of drip irrigation and fertiligation in *rabi* garlic (*Allium sativum* L.) was carried out during *rabi* season of 2015-16 and 2016-17 at Farming System Research Centre, IIFSR, Department of Agronomy, College of Agriculture, Junagadh Agricultural University, Junagadh (Gujarat). The soil of the experimental site was clayey in texture and slightly alkaline in reaction. The soil was medium in available nitrogen, available phosphorus, available potassium and high in available sulphur during 2015-16 and 2016-17. Plant protection measures were taken regularly to control pest and diseases in the experimental field. The experiment was laid out on split plot design with four replications, comprising of three drip irrigation schedules in main plot *viz.*; (i) drip irrigation at 60% PE, (ii) drip irrigation at 80% PE and (iii) drip irrigation at 100% PE, and four fertigation schedules on sub plot *viz.*; (i) 100% RDF as basal through fertigation, (ii) two equal splits of RDF through fertigation at 30 days interval, (iii) three equal splits of RDF through fertigation at 20 days interval, (iv) four equal splits of RDF through fertigation at 15 days interval (RDF: 50:50:50:40 NPKS kg ha^{-1}).

Treatment combinations

Sr. No.	Treatment combinations
1.	I_1F_1 = Drip irrigation at 60% PE + 100% RDF as basal
2.	I_1F_2 = Drip irrigation at 60% PE + 2 equal splits of RDF at 30 days interval
3.	I_1F_3 = Drip irrigation at 60% PE + 3 equal splits of RDF at 20 days interval
4.	I_1F_4 = Drip irrigation at 60% PE + 4 equal splits of RDF at 15 days interval
5.	I_2F_1 = Drip irrigation at 80% PE + 100% RDF as basal
6.	I_2F_2 = Drip irrigation at 80% PE + 2 equal splits of RDF at 30 days interval
7.	I_2F_3 = Drip irrigation at 80% PE + 3 equal splits of RDF at 20 days interval
8.	I_2F_4 = Drip irrigation at 80% PE + 4 equal splits of RDF at 15 days interval
9	I_3F_1 = Drip irrigation at 100% PE + 100% RDF as basal
10.	I_3F_2 = Drip irrigation at 100% PE + 2 equal splits of RDF at 30 days interval
11.	I_3F_3 = Drip irrigation at 100% PE + 3 equal splits of RDF at 20 days interval
12.	I_3F_4 = Drip irrigation at 100% PE + 4 equal splits of RDF at 15 days interval

Drip irrigation system was installed in the experimental field with main and sub main lines of PVC having 110 and 70 mm diameters, respectively. Lateral or distributor lines having 16 mm diameter and dripper having discharge capacity of 4 lit. hr^{-1}. LDPE lateral lines of 16 mm diameter X 2.5 kg cm^{-2} were spaced at 35 cm. Emitters of 4 L h^{-1} discharge were spaced at 45 cm. Lateral cocks of 16 mm at the starting of the lateral lines were installed to control irrigation and fertilizer application as per the treatments. Fertigation was applied through water soluble fertilizers (WSF) like N-P-K as 19-19-19 (Nutrisol) and S as Cosavet as per the treatment. A common irrigation was given just after sowing through flood method to facilitate uniform germination of the crop. The required quantity of water was applied through drip irrigation at alternate days interval on the basis of evaporation. The time of drip system operation and quantity of irrigation water required for varying drip irrigation treatments was calculated as under:

$$T_0 = \frac{\text{PE level} \times \text{CPE} \times \text{dripper spacing (m)} \times 60}{\text{Dripper discharge (lph)}}$$

Where, T_0 = Time of operation (min.)
PE = Fraction of pan evaporation
CPE = Cumulative pan evaporation (mm)
Dripper spacing = 0.45 m
Lateral spacing = 0.35 m
Dripper discharge = 4 lph
Water applied (mm) = PE x CPE
Where, PE = Fraction of pan evaporation
CPE = Cumulative pan evaporation (mm)

Results and discussion

Growth Parameters

The Growth parameters of garlic were influenced by various drip irrigation and fertigation schedules. The results (Table 1) revealed that drip irrigation at 100% PE had favourable effect on growth parameters of garlic. Growth parameter *viz.*, plant height at harvest (39.3 cm) and numbers of leaves per plant at 60 and 90 DAS (5.3 and 6.0, respectively) were found significantly highest under 100% PE of drip irrigation and the lowest value were observed under drip irrigation at 60% PE.

It is well established fact that where sufficient soil moisture for continued growth is maintained by providing drip irrigation which leads to greater development of green tissue area and results in a higher photosynthetic assimilation. As a result, plant growth improves leading to higher accumulation of the total dry matter. The plants are able to maintain higher water potential with increasing PE ratio under drip irrigation which improves physiological and biochemical activities. These facts clearly suggested the importance of adequate supply of water for the optimum metabolism in the plants for better growth and development. Singh *et al.* (2011) [16] reported increased plant height and number of leaves as the amount of irrigation increased from 25% to 100% of potential evapotranspiraton with drip irrigation. The results are in agreement with that of Sankar *et al.* (2008a) [13] in garlic and Sankar *et al.* (2008b) [14] in onion, who concluded that drip irrigation at 100% PE had improved the plant height and number of leaves of garlic and onion crop as compared to surface irrigation method. Gajbhiye *et al.* (2009) [7] also reported higher growth parameters with drip irrigation in garlic. Similar findings also agreed with Tripathi *et al.* (2010) [17] and Bagali *et al.* (2012) [4] in onion crop.

Table 1: Effect of drip irrigation and fertigation schedules on growth of garlic (pooled)

Treatments	Plant height (cm)	Number of leaves per plant	
		60 Das	90 Das
Drip irrigation (I)			
I_1	30.3	4.0	4.5
I_2	34.3	4.7	5.4
I_3	39.3	5.3	6.0
S.Em. ±	0.8	0.1	0.1
C.D. at 5%	2.5	0.3	0.3
C.V. %	15.3	16.1	12.7
Fertigation schedules (F)			
F_1	31.0	4.3	4.9
F_2	32.9	4.3	5.0
F_3	37.0	5.0	5.5
F_4	37.8	5.1	5.8
S.Em. ±	1.1	0.2	0.1
C.D. at 5%	3.0	0.4	0.4
C.V. %	12.0	11.7	9.0
Interaction I x F			
S.Em. ±	1.8	0.3	0.2
C.D. at 5%	NS	NS	NS

Growth parameters like plant height at harvest and number of leaves per plant at 60 and 90 DAS were noted significantly higher with four equal splits of recommended dose of fertilizer through fertigation, however, it was statistically comparable with three equal splits of recommended dose of fertilizer through fertigation. The improvement in growth parameters with different fertigation schedules might have resulted in better and timely availability of nutrients and their utilization by plant as judged from nutrient content of clove and straw. Adequate quantity of nutrients coupled with adequate moisture might have resulted in higher growth. With the application of readily available form of fertilizer, by reducing the quantity of nutrients at one application, the crops were able to utilize maximum quantity of nutrients, thereby reducing leaching and volatilization loss and increasing the nutrient use efficiency which might have resulted in higher growth. The results are in close proximity with that of Veerana (2000) [18], Savitha *et al.* (2010) [15], Rajaraman and Paramguru (2011) [12], Gupta *et al.* (2015) [8] and Meena *et al*. (2017) [10].

Yield attributes and yield

The results presented in Table 2 showed that increasing the drip irrigation schedules from 60% PE to 100% PE caused significant increase in yield attributing characters *viz.*; Diameter of bulb (3.9 cm), fresh weight of bulb (22.5 g), dry weight of bulb (14.1 g), number of cloves per bulb (20.3), 100 cloves weight (70.6 g), bulb yield (8.18 t ha^{-1}) and straw yield (1.89 t ha^{-1}). However, harvest index not significantly affected by drip irrigation schedules. The vigorous growth in garlic means production of more leaves, which helped in the synthesis of more photosynthates and thus resulting in increased accumulation of carbohydrates and other metabolites, which ultimately determined the size and weight of bulbs. The above findings are in close conformity with the findings of Ahmed *et al.* (2009) [1]. This probably could be attributed to the fact that adequate irrigation may have stimulated growth, development and yield. This result confirmed the findings of Barrios *et al.* (2006) [5], Ayars (2008) [3], Sankar *et al.* (2008a) [13] and Gajbhiye *et al*. (2009) [7] in garlic, Tripathi *et al.* (2010) [17] and Yadav *et al.,* (2010) [19] in onion.

The yield attributes *viz.*; Diameter of bulb (3.7 cm), fresh weight of bulb (22.1 g), dry weight of bulb (13.3 g), number of cloves per bulb (20.2), 100 cloves weight (71.5 g), bulb yield (7.77 t ha^{-1}) and straw yield (1.85 t ha^{-1}) were recorded significantly higher under application of four equal splits of RDF through fertigation while remained at par with three equal splits of recommended dose of fertilizer through fertigation except number of cloves per bulb and 100 cloves weight. However, harvest index was not significantly affected by fertigation schedules. The increase in yield under fertigation schedules might be due to the fact that fertigation with more readily available form obviously resulted in higher availability of all the major nutrients in the soil solution which led to higher uptake and better translocation of assimilates from source to sink thus in turn increased the yield, Anitta and Muthukrishnan (2013) [2]. The present findings are within the close vicinity of those reported by Rajaraman and Paramguru (2011) [12], Khan *et al*. (2016) [9] and Meena *et al*. (2017) [10].

Table 2: Effect of drip irrigation and fertigation schedules on yield attributes and yield of garlic (pooled)

Treatments	Diameter of bulb (cm)	Fresh weight of bulb (g)	Dry weight of bulb (g)	Number of cloves per bulb	100 cloves weight (g)	Bulb yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest index
Drip irrigation (I)								
I_1	3.0	17.1	10.7	17.1	61.9	6.17	1.49	80.4
I_2	3.4	20.5	11.9	17.8	65.4	7.24	1.72	80.8
I_3	3.9	22.5	14.1	20.3	70.6	8.18	1.89	81.1
S.Em. ±	0.1	0.4	0.3	0.4	1.3	0.17	0.04	0.3
C.D. at 5%	0.2	1.2	0.9	1.3	3.9	0.53	0.12	NS
C.V. %	13.5	11.3	14.1	12.5	12.1	13.80	12.71	2.2
Fertigation schedules (F)								
F_1	3.1	17.8	11.2	16.8	61.6	6.53	1.55	80.6

F_2	3.2	19.1	11.8	17.6	64.1	6.92	1.64	80.8
F_3	3.5	21.2	12.6	18.9	66.7	7.55	1.76	81.1
F_4	3.7	22.1	13.3	20.3	71.5	7.77	1.85	80.6
S.Em. ±	0.1	0.4	0.4	0.4	1.5	0.20	0.04	0.4
C.D. at 5%	0.3	1.2	1.0	1.2	4.4	0.57	0.11	NS
C.V. %	11.8	10.6	13.9	11.4	10.3	13.59	10.95	2.2
Interaction I x F								
S.Em. ±	0.2	0.7	0.6	0.7	2.7	0.35	0.07	0.6
C.D. at 5%	NS	2.1	1.7	2.1	NS	1.00	0.19	NS

Conclusion

Based on the results of the experiment conducted during two consecutive seasons, it can be concluded that potential production from *rabi* garlic (GG-4) can be secured by applying one common surface irrigation and adopting the drip irrigation schedule at 100% PE (lateral spacing 35 cm, drippers spacing 45 cm and dripper discharge 4.0 lph) at an interval of alternate day of irrigation and apply RDF (50:50:50:40 kg N:P:K:S ha^{-1}) in the form of NPK as Nutrisol (19:19:19%) and S as Cosavet through fertigation in four equal splits at 15 days interval starting from 7 days after sowing of the crop under medium black calcareous soil of South Saurashtra conditions

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