Indian Journal of Agricultural Sciences 87 (1): 56–61, January 2017/Article
https://doi.org/10.56093/ijas.v87i1.67020

Response of pomegranate (*Punica granatum*) to drip irrigation system in light textured soils of semi-arid regions

R A MARATHE[1], K DHINESH BABU[2] and D T CHAUDHARI[3]

ICAR - National Research Centre on Pomegranate, Solapur, Maharashtra 413 255

Received: 25 June 2016; Accepted: 31 July 2016

ABSTRACT

The study was designed to evaluate numbers and different arrangements of emitters under surface drip irrigation system in pomegranate (*Punica granatum* L.) cv. Bhagwa orchard grown on light textured soil. A field experiment was conducted at National Research Centre on Pomegranate, Solapur for three consecutive years (2010 to 2013). The treatments consisted of irrigation with 2 online emitters (8 lph) on single lateral (T_1), 3 online emitters (4 lph) on single lateral (T_2), 4 emitters (4 lph), 2 online, 2 through microtube on single lateral placed on four sides of plant (T_3), 6 emitters (2 lph) on double laterals placed 50 cm apart on both side of plants (T_4) and inline lateral having 8 emitters (2 lph) placed in the form of ring encircling the plant (T_5). Experiment was laid out in randomized block design with four replications. Equal quantity of irrigation equivalent to 0.80 E. Pan was applied on every alternate day. The results revealed that irrigation with 6 emitters (2 lph) on double laterals placed 50 cm apart on both sides of plants provide higher and uniform distribution of water in the root zone of the plants, resulted in better nutrient uptake, growth and yield performance of pomegranate plants. Highest leaf content of N (2.36%) and P (0.17%) was observed in this treatment which reflected in highest increase in plant height (20.4%) and plant spread (22.7%) producing highest yield in terms of numbers (36.1) and weight (6.889 kg) of fruits/plant. Plants irrigated with inline lateral having 8 emitters (2 lph) placed in the form of ring encircling the plant recorded highest leaf chlorophyll content (57.2) and maintained cool plant canopy as indicated by lowest leaf temperature during all the fruiting months. Flowering intensity was high in the plants irrigated with 2 dripper (8 lph) on one lateral system but it does not reflected in producing fruit yield due to limited wetting zone inducing moisture stress to the plants as indicated by highest fruit cracking (11.1%) in this system. It can be concluded that irrigation with 6 emitters (2 lph) fixed on two laterals placed on both sides of plants 50 cm away from the trunk along the rows system should be provided to pomegranate grown on light textured soils of semi-arid regions.

Key words: Chlorophyll, Drip irrigation, Fruit yield, Nutrient uptake, Plant growth, Pomegranate, Water distribution pattern

Pomegranate (*Punica granatum* L.) cultivation is successful in arid eco-system as it can withstand the hostile agro-climate and adverse soil conditions prevailing in this ecosystem. In India, during last two decades, pomegranate cultivation has registered a high growth and reached to 1.31 lakh ha with an annual production of 13.45 lakh tonnes. Majority of the pomegranate cultivation is on undulating, shallow and light textured soils where water scarcity is a major constraint (Marathe *et al*. 2006). Hence, it is imperative to adopt holistic strategies to harvest more crop per drop of water by developing irrigation techniques that guarantee maximum efficiency of water. Long back, Badizadegan (1975) reported that pomegranate can tolerate very dry conditions but for optimum plant growth and quality fruit production, irrigation is most essential. In majority of the orchards, irrigation is being provided using drip system of irrigation with two emitters paced on both sides of the plants along the rows. Wetting zone in this system is hardly 30 to 40% of pomegranate tree basin, which required higher soil moisture especially during the period of fruit maturity. In drip irrigation system, arrangement or placement of emitters plays important role to ensure maximum wetting zone and uniform moisture distribution within the tree's root zone (Shirgure and Srivastava 2015). Any method of surface drip irrigation, capable of replenishing the evapo-transpiration demand of the plant, and simultaneously keeping the soil moisture within the desired limit, would ensure a production sustainability of the orchards besides enhancing the orchard's productive life (Capra and Nicosia 1987).

There are few studies on irrigation requirement in pomegranate (Lawande and Patil 1994, Haneef *et al*. 2014). But work related to arrangement of emitters is very meagre.

[1]Principal Scientist (Soil Science) (e mail: ramarathe28@gmail.com). Present address: Central Citrus Research Institute, Nagpur. [2]Principal Scientist (Horticulture) (e mail: ckdhinesh@gmail.com), [3]Senior Technical Assistant (e mail: dinkartc@gmail.com).

In this perspective, the present investigation was undertaken to study the effect of number, capacity and placement of emitters under surface drip irrigation system for pomegranate cv. Bhagwa to ensure maximum water use efficiency and plant productivity under semi-arid regions of India.

MATERIALS AND METHODS

A field experiment was conducted during 2010 to 2013 at the Research Farm of National Research Centre on Pomegranate, Solapur, Maharashtra, India. The site lies at 17°65" N latitude and 75°90" E longitude and 457 m above mean sea level receiving average annual rainfall of 472.8 mm. The soil is sandy loam with 15.8% coarse fragments, montmorillonitic mineralogy, 60 cm deep with pH 7.66, electrical conductivity 0.18 dS/m, organic carbon 0.38% and calcium carbonate 6.24%. The available N, P and K content of surface soil was 190.0, 11.5 and 238.4 kg/ha, respectively. The field capacity (33 kPa) and permanent wilting point (1.5 M Pa) of soil was 24.2 and 13.1%, respectively. Average monthly maximum and minimum temperature during the experimental period (January to July) varied from 29.9 to 40.2° C and 15.2 to 25.1°C, respectively. The daily pan evaporation ranged between 3.7 to 19.8 mm.

The experiment was arranged in randomized block design with 4 replications having 2 plants per unit. There were 5 treatments consisting of application of irrigation with 2 online emitters of 8 lph (litres per hour) capacity, one on each side of the plant fixed on one lateral tied to the trunk (T_1), 3 online emitters of 4 lph capacity, one on each side and one near the plant, fixed on one lateral tied to the trunk (T_2), 4 emitters of 4 lph capacity placed on four sides of the plant, 2 online and 2 through micro-tubes fixed on one lateral (T_3), 6 emitters of 2 lph capacity fixed on two laterals placed on both side of plants 50 cm away from the trunk along the rows (T_4) and lateral having 8 inline emitters of 2 lph capacity placed in the form of ring encircling the plant (T_5). Equal quantity of cumulative irrigation equivalent to 0.80 E-pan was provided on every alternate day through drip system of irrigation. The water requirement of pomegranate crop was computed on daily basis using the following equation (Mane *et al*. 2006).

$$V = E_p \times K_p \times K_c \times S_c \times W_p$$

where, V = volume of water (litres/day/plant), E_p = open pan evaporation (mm/day), K_p = pan coefficient, K_c = crop coefficient, S_c = crop spacing (plant to plant × row to row in meter) and W_p = wetting factor. Irrigation efficiency of drip was considered as 90%. The effective rainfall was calculated by balance sheet method from the actual rainfall received and was used for daily water requirement of crop. Measured quantity of irrigation water was provided to the plants using water meters and separate pipeline for every treatment.

In all the treatments, 150-days-old air-layer saplings of pomegranate cv. Bhagwa were planted during January 2009 and maintained by adopting similar cultivation practices. It was experienced that for pomegranate, supplemental irrigation is required only during summer season of the year. Accordingly, treatments were imposed during December to June months of the years as per the crop requirements. Equal quantity of irrigation water was applied to the plants grown under each treatment. During the years 2010, 2011-12 and 2012-13 total amount of irrigation water per plant was 500.9, 1407.8 and 639.6 litres, respectively.

Leaf samples were collected from individual plant and processed for nutrient analysis. The samples were digested (Chapman and Pratt 1961) in di-acid mixture (H_2SO_4:$HClO_4$ in 1:2.5). Nitrogen was determined by using micro-kjeldhal steam distillation method, phosphorus by Vanadomolybdo phosphoric acid method, potassium by flame photometer and Ca^{2+} + Mg^{2+} by versenate titration method. All micronutrients (Fe, Zn, Mn and Cu) were determined using atomic absorption spectrophotometer.

Vegetative growth in terms of plant height and plant spread was recorded in meters every year and expressed as percent increase over the last year. Data on male and hermaphrodite flowers were taken by counting the flowers dropped on the ground and set on plants. The fruit yield data was recorded both in terms of number count and fruit weight (kg/plant) during the year 2013. Cracked fruits were harvested separately and counted in terms of numbers. Chlorophyll content in the leaves as indicated by SPAD values was measured during 2012 using chlorophyll meter. Leaf temperature was measured using infrared thermometer.

Soil moisture distribution pattern under different treatments was studied by collecting soil samples on next day of irrigation at a distance of 10, 20, 30, 40 and 50 cm away from the dripper in horizontal direction as well as 0-30, 30-45, 45-60, 60-75 and 75-90 cm below the dripper in vertical direction during May 2012 and soil moisture content was determined gravimetrically (Singh 1989).

The data obtained were subjected to statistical analysis such as analysis of variance (ANOVA) using software package of MS Excel and online software developed by ICAR Research Complex, Goa.

RESULTS AND DISCUSSION

Soil moisture distribution pattern

Variations in soil moisture distribution during fruit development period was monitored and analysed. Soil available water content in horizontal direction at a distance of 10 cm (5.4–6.9%), 20 cm (4.7–6.5%), 30 cm (3.2–5.1%), 40 cm (0.0–3.9%) and 50 cm (0.0–3.1%) away from the dripper varied significantly amongst the treatments (Fig 1). In all types of irrigation systems, moisture availability was sufficient up to 30 cm horizontal distance. Under 3 emitters and 4 emitters (4 lph) irrigation systems, moisture availability was sufficient up to 30 cm which decreased in 40 cm and was very low in 50 cm horizontal distance. While in 2 dripper (8 lph), 6 emitters fixed on two lateral and inline lateral in the form of ring systems, horizontal spread was only up to 40. Field observations revealed that in ring system, complete circular area around the plant have

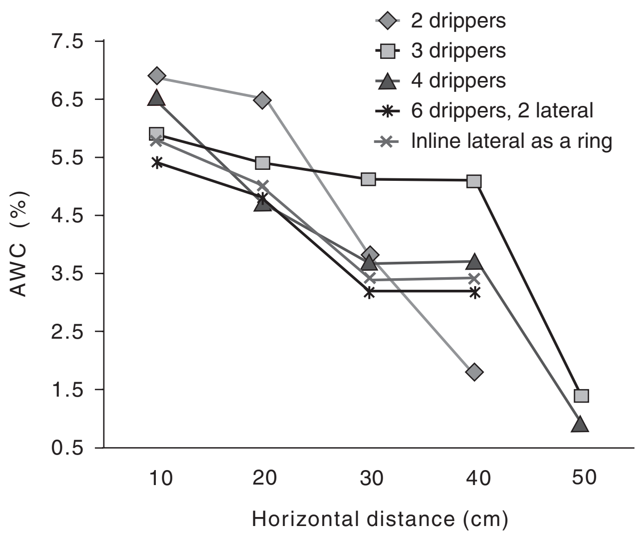

Fig 1 Horizontal moisture spread under different irrigation systems

continuous wet conditions in surface layer. Wetting area found to increase with increasing number of emitters under different systems. Variations in soil moisture distribution pattern as affected by arrangement of the emitters in drip irrigation system was reported by Castel (1994) and Shirgure and Srivastava (2015).

The available water content below the dripper in vertical direction varied from 3.7-5.5%, 3.8-6.7%, 3.0-5.9%, 1.1-5.4% and 0.0-4.4% in 0-30, 30-45, 45-60, 60-75 and 75-90 cm depth, respectively under different treatments (Fig 2). In 2 dripper irrigation system, sufficient moisture availability was up to 90 cm depth. In this treatment wetting zone in horizontal direction was less and water tends to move in vertical direction thereby increasing soil moisture content in subsurface layers. Similarly, in 3 and 4 drippers system sufficient moisture availability was observed up to 75 cm and decreased considerably in 76-90 cm depth.

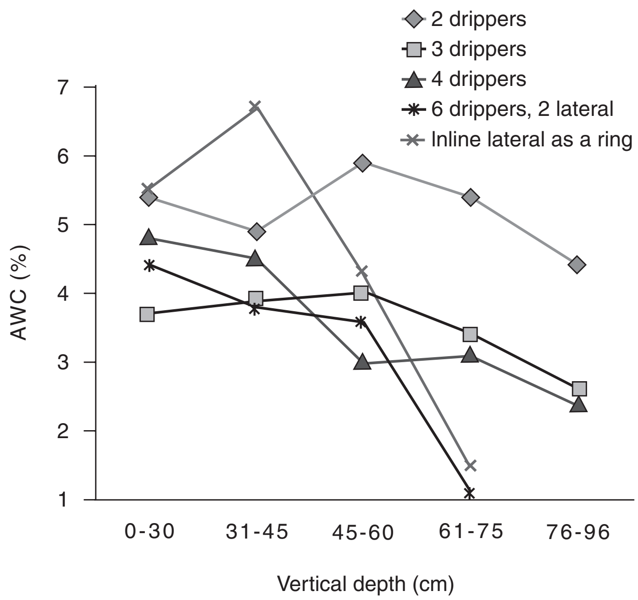

Fig 2 Vertical moisture spread under different irrigation systems

It might be due to higher hydraulic conductivity of light textured soil as reported earlier by Marathe *et al*. (2003). In 6 dripper, 2 laterals and inline lateral as ring systems, moisture availability was sufficient only up to 60 cm depth and reduced considerably in 61-75 cm depth. Though soil moisture content was low in these systems, it has maximum wetting area in the root zone of the plants. Shirgure and Srivastava (2015) reported better soil moisture distribution in 6 emitters on 2 laterals arrangement system in citrus orchards.

Leaf nutrient content

Different arrangement of irrigation emitters had marked effect on major (N, P and K) nutrient content in the leaves (Table 1). The leaf N, P and K content significantly varied from 1.99 - 2.36, 0.14 - 0.17 and 0.49 - 0.62%, respectively amongst the treatments. Highest leaf content of N and P was observed in the plants irrigated with 6 emitters fixed on 2 laterals system. Moderate level of irrigation water maintained good aeration and sufficient moisture content in the soil. This system also moistened maximum area in the root zone, enabling nutrient availability in larger area which might have resulted in higher nutrient uptake by the plants. Highest leaf K content was observed in 4 emitters placed on four sides of the plants and was at par with all other treatments except two dripper system. The higher K uptake under almost all the treatments might be due to its higher availability in soil of central India which are rich in potassium bearing minerals (Patil and Malewar 1997). Significantly lowest content of major nutrients were observed in the plants irrigated with two drippers system. Due to limited horizontal wetting zone under this system, root growth and nutrient uptake remained confined to limited area due to lack of soil moisture. This finding was in close conformity with the findings of Haneef *et al*. (2014) and Sharma *et al.* (2015) who reported decreased uptake of N, P and K with lower moisture levels.

Leaf chlorophyll content and leaf temperature

The leaf chlorophyll content as indicated by SPAD values significantly varied from 53.9 – 57.2 amongst the treatments (Fig 3). It was the highest in the plants irrigated with in line lateral having 8 emitters placed in the form of ring encircling the plant indicating better photosynthetic capacity of the plants. Lowest chlorophyll content was recorded in two dripper system and found to increase with the increasing wetting zone under different treatments. This might be due to better nutrient uptake and ample water availability to the plants. Leaf temperature recorded during different period of fruit development increased with the increase in ambient temperature (Fig 4). It was highest in the month of May followed by April and March. Minimum leaf temperature was recorded in the plants irrigated with inline lateral having 8 emitters placed in the form of ring encircling the plant. Cool canopy was found to be an important physiological parameter for tolerance to high temperature stress (Munjal and Rena 2003). During

Table 1 Leaf nutrient content of pomegranate as affected by irrigation systems

Treatment	N	P	K	Ca	Mg	Cu	Zn	Fe	Mn
	(%)					(ppm)			
T1	1.99	0.14	0.49	1.56	0.57	78.1	25.9	118.6	50.9
T2	2.16	0.15	0.62	2.00	0.63	77.3	26.8	125.1	61.8
T3	2.14	0.14	0.62	2.25	0.58	69.7	27.5	122.6	52.2
T4	2.36	0.17	0.56	1.75	0.54	81.5	28.4	140.1	62.7
T5	2.22	0.15	0.58	1.75	0.57	75.0	30.2	132.2	53.5
CD (P=0.05)	0.20	NS	0.062*	NS	NS	NS	NS	NS	NS

Irrigation through T_1 – 2 emitters; T_2 – 3 emitters; T_3 – 4 emitters; T_4 – 6 emitters (2 lph), on 2 laterals; T_5 – inline lateral in the form of ring; NS-Non-significant; *Significant at 1%.

all the months, higher leaf temperature was recorded in 2 dripper irrigation system indicating stress conditions. As soil water becomes limited, transpiration got reduced and leaf temperature increased.

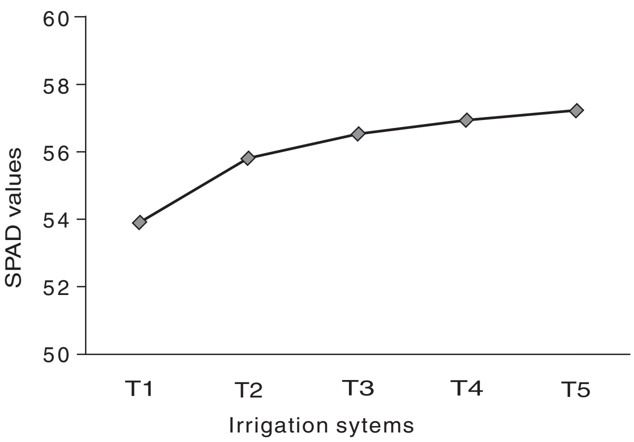

Fig 3 Leaf chlorophyll content (SPAD) as affected by irrigation systems moisture spread under different irrigation systems

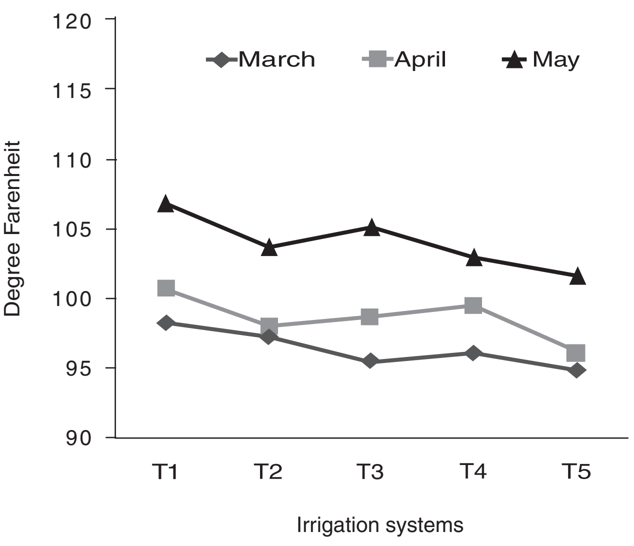

Fig 4 Leaf temperature (°F) in fruiting period as affected by irrigation systems

Vegetative growth

Percent increase in plant height and plant spread was very high during first year of plantation but showed non-significant variation amongst the treatment (Table 2). These findings are in agreement with the results of Chopade and Gorantiwar (1998) who reported that in pomegranate, plant growth did not differ significantly during initial years with the application of irrigation using drip, bubbler and check basin methods. During the year 2011-12, growth in terms of percent increase in average plant spread (15.0 -16.9%) showed significant variation while it was non-significant in case of plant height. During 2012-13 percent increase in plant height and plant spread significantly varied from 13.0 - 20.4% and 16.0 - 22.7%, respectively amongst the treatments. Height and spread was significantly highest in the plants irrigated with 6 emitters fixed on 2 laterals system followed by inline lateral encircling the plant in the form of ring system. Higher moisture content in root zone, good aeration and better nutrient uptake might have resulted in increased growth of the plant. Increase in plant growth was lowest in 2 dripper system followed by 3 dripper irrigation system. In these systems, due to light texture of the soil, most of the irrigation water percolated downwards below the root zone of the plant inducing stress to the plant thereby hampering plant growth.

Flowering, yield and quality of fruits

Flowering intensity in terms of number of male and hermaphrodite flowers significantly varied from 180.6 - 243.0 and 111.6 -141.6, respectively amongst the treatments (Table 3). It was the highest in the plants irrigated through 2 emitters followed by 3 emitters drip irrigation system. In pomegranate, moisture stress encouraged reproductive phase, i.e. flowering intensity. The results indicated that sufficient moisture may not be available to the plants irrigated with 2 drippers system thereby producing highest number of male and hermaphrodite flowers. Lowest flowering was observed in the plants irrigated with inline lateral having 8 emitters (2 lph) placed in the form of ring encircling the plant system. In general, flowering intensity increased with decreased surface wetting zone under the plant canopy.

Table 2 Vegetative growth of the plants as affected by different irrigation systems

Treatment	Percent increase during February to October 2010		Percent increase during December 2011 to July 2012		Percent increase during December 2012 to July, 2013	
	Plant height	Average plant spread	Plant height	Average plant spread	Plant height	Average plant spread
T1	31.1	46.8	15.0	15.2	13.0	16.0
T2	27.7	46.3	16.0	15.7	15.1	18.2
T3	32.3	48.1	16.9	15.0	16.5	20.1
T4	32.5	46.4	15.7	18.5	20.4	22.7
T5	33.6	49.0	14.9	18.4	18.1	20.3
CD (P=0.05)	NS	NS	NS	2.43	1.88*	2.37*

Irrigation through T_1 – 2 emitters; T_2 – 3 emitters; T_3 – 4 emitters; T_4 – 6 emitters (2 lph), on 2 laterals; T_5 – inline lateral in the form of ring; NS-Non-significant; *Significant at 1%.

Table 3 Flowering and fruit yield (kg/plant) as affected by irrigation systems

Treatment	Male flowers	Hermaphrodite Flowers	Number of fruits / plant	Fruit yield (kg)	Average fruit weight (g)	Cracked fruits (%)
T1	243.0	141.6	22.4	4.434	200.8	11.1
T2	241.5	131.3	25.0	4.596	186.0	5.0
T3	210.1	122.1	28.6	5.397	194.0	1.1
T4	215.4	130.0	36.1	6.889	192.4	0.6
T5	180.6	111.6	32.4	5.698	178.2	2.3
CD (P=0.05)	31.79*	6.61*	4.78*	0.571*	NS	5.6*

Irrigation through T_1 – 2 emitters; T_2 – 3 emitters; T_3 – 4 emitters; T_4 – 6 emitters (2 lph), on 2 laterals; T_5 – inline lateral in the form of ring; NS-Non-significant; *Significant at 1%.

Fruit yield in terms of number and weight of the fruits/ plant significantly varied from 22.4-36.1 and 4.434-6.889 kg, respectively amongst the treatments. Significantly highest fruit yield was observed in the plants irrigated with 6 emitters fixed on 2 laterals followed by inline lateral placed in the form of ring encircling the plant system (Table 3). The increased yield was mainly due to increased number of fruits as indicated by non-significant variation in individual fruit weight. The increase in yield could be attributed to better plant growth, balanced nutrient uptake and least fruit cracking under these treatments. Lowest fruit yield was recorded in the plants irrigated with 2 emitter followed by 3 emitter irrigation systems. Though, flowering intensity was high in these treatments, it does not reflected in terms of fruit yield. It might be due to moisture stress in the plants as indicated by fruit cracking to the extent of 11.1 and 5.0%, respectively, in these treatments. Cracking of pomegranate fruits to the extent of 63.0% was reported under extremely arid climate of western Rajasthan (Pant 1976).

The study clearly indicated that the different number and arrangement of emitters in drip irrigation system had marked effect on moisture distribution pattern in the rootzone of the plants. This pattern influences nutrient uptake, chlorophyll content, leaf temperature and growth of the plants transforming in the fruit production. Water scarcity and depleting water resources in pomegranate growing areas where flowering is regulated by soil-water deficit stress, needs more precise irrigation techniques in the form of arrangement and management of emitters. Providing irrigation to pomegranate plants using 6 emitters (2 lph) fixed on 2 laterals, placed on both sides of the plants along the row system provided proper water distribution in the active root zone of the plants and increased plant performance substantially. Irrigation with inline lateral in the form of ring and 4 emitters using micro-tubes systems also performed better but were very tedious and difficult to manage over a period of time.

REFERENCES

Badizadegan M. 1975. Growth of pomegranate (*Punica granatum* L.) as affected by soil moisture tension. *Journal of Horticultural Sciences* **50**: 227–32.

Capra A and Nicosia O U D. 1987. Irrigation management in citrus orchards. *Irrigazine* **34**: 3–15.

Castel J R. 1994. Response of young Clementine citrus trees to drip irrigation. I. Irrigation amount and number of drippers. *Journal of Horticultural Science* **69**: 481–9.

Chapman H D and Pratt P F. 1961. *Methods of Analysis for Soil, Plants and Water*, pp 182–6. Division of Agricultural Sciences, University of California, USA.

Chopade S O and Gorantiwar S D. 1998. Effect of various methods of irrigation on growth and yield of pomegranate. *Annals of Plant Physiology* **12**: 98–102.

Haneef M, Kaushik R A, Sarolia D K, Mordia A and Dhakar M. 2014. Irrigation scheduling and fertigation in pomegranate cv. Bhagawa under high density planting system. *Indian Journal*

of Horticulture **71**: 45–8.
Lawande B T and Patil V K. 1994. Effect of different water regimes on growth, flowering and fruiting of pomegranate. *Journal of Maharashtra Agricultural Universities* **19**: 220–3.
Mane M S, Ayare B L and Magar S S. 2006. *Principles of Drip Irrigation System*, pp 24–87. Jain Brothers, New Delhi.
Marathe R A, Chandra R and Kumar P. 2006. Soil types and micronutrient status of pomegranate (*Punica granatum* L.) orchards of Nasik regions of Maharashtra. *Proceedings of National Symposium on Improving Input Use Efficiency in Horticulture*, IIHR, Bangalore, India, p 174.
Marathe R A, Mohanty S and Singh S. 2003. Soil characterization in relation to growth and yield of Nagpur mandarin (*Citrus reticulata* Blanco). *Journal of the Indian Society of Soil Science* **51**: 70–3.
Munjal R and Rana R K. 2003. Evaluation of physiological traits in wheat (*Triticum aestivum* L.) for terminal high temperature tolerance. *Proceedings of Tenth International Wheat Genetics Symposium*, Vol. 2, Classical and Molecular Breeding, Poestum, Italy, pp 804–5.
Pant T. 1976. Fruit cracking in pomegranate (*Punica granatum* L.) in variety Jodhpuri. *Udyanika* **2**: 29–35.
Patil V K and Malewar G U. 1997. Assessment of micronutrient status of sweet orange orchards by soil analysis. *Proceedings of National Symposium on Citriculture*, Nagpur, Maharashtra, India, pp 205–8.
Sharma R, Pandey S K and Sharma T A. 2015. Influence of soil moisture on growth and nutrient content in healthy and malformed panicles of mango varieties. *Indian Journal of Horticulture* **72**: 133–8.
Shirgure P S and Srivastava A K. 2015. Evaluation of drip irrigation emitters and its effect on soil moisture, leaf nutrients, yield and quality of Nagpur mandarin (*Citrus reticulata*). *Indian Journal of Agricultural Sciences* **85**(12): 1586–91.
Singh R A. 1989. *Soil Physical Analysis*, pp 22–8. Kalyani Publishers, New Delhi.