Vol. 47, No. 2, pp 180-185, 2019
Indian Journal of Soil Conservation
Online URL : http://indianjournals.com/ijor.aspx?target=ijor:ijsc&type=home

Feasibility of micro-sprinklers in pomegranate (*Punica granatum* L.) orchards grown on light textured soils of central India

R.A. Marathe[1,*], D.T. Chaudhari[2] and S. Murali[2]

[1]*ICAR-National Research Centre on Pomegranate, Solapur - 413255, Maharashtra;* [2]*CSIR-Advanced Materials and Processes Research Institute, Bhopal - 462 026, Madhya Pradesh.*

**Corresponding author:*
E-mail: ramarathe28@gmail.com (R.A. Marathe)

ARTICLE INFO

Article history:
Received : March, 2019
Revised : August, 2019
Accepted : August, 2019

Key words:
Micro-sprinklers
Drip
Basin irrigation
Pomegranate
Moisture distribution
Nutrient uptake
Root growth
Flowering
Fruit yield

ABSTRACT

An experiment conducted in newly planted pomegranate (*Punica granatum* L.) to evaluate feasibility of micro-sprinklers against drip and improved basin irrigation in light textured soils revealed that cumulative irrigation and surface wetting zone was maximum under micro-sprinklers, while under basin and drip systems, soil moisture distribution was better in horizontal and vertical directions. Root growth parameters (RMD and RLD values) were higher in drip followed by basin system of irrigation. This facilitated maximum uptake of leaf P (0.155 %) and K (0.78 %) in basin, whereas, maximum leaf content of Ca (2.00%), Cu (97.5 ppm) and Mn (79.8 ppm) was recorded under drip system of irrigation. This was reflected in vigorous growth of pomegranate plants in basin system of irrigation. Maximum fruit yield was produced in basin (8.747 kg plant^{-1}) followed by drip (7.248 kg plant^{-1}), which was 413.6% and 325.6% higher than that obtained under micro-jet 180^{o} irrigation systems, respectively. Fruit yield based water use efficiency (WUE) was higher in drip (0.442) than basin (0.420) system of irrigation. Results indicated that micro-sprinkler irrigation system is not beneficial in arid to semi-arid tropical climate, and drip system results in highest WUE. Improved double ring basin proved to be the most efficient in areas having enough water availability.

1. INTRODUCTION

Pomegranate (*Punica granatum* L.) is one of the oldest known edible fruits. Although native to hot dry regions of Iran, pomegranate has been widely cultivated in Mediterranean regions of Asia, Africa and Europe. In India, pomegranate cultivation has registered a high pace, especially in arid and semi-arid regions of Maharashtra, Karnataka and Andhra Pradesh states due to its export potential and hardy nature (Jolikop and Kumar, 2000). Although, its cultivation reached 216 thousand ha with an annual production of 2613 thousand MT (NHB, 2017), it has low average productivity due to many constraints. Of these, water scarcity and conventional basin irrigation do not achieve the required WUE and productivity potential. Lack of assured irrigation is the biggest bottleneck in bringing additional land under cultivation. Earlier, pomegranate growers preferred conventional basin method of irrigation, which has several drawbacks, including percolation, evaporation and distribution losses. Any method of irrigation capable of replenishing the evapotranspiration demand of the plant, and simultaneously keeping soil moisture within the desired limit during different growing stages, would ensure a production sustainability of orchards besides prolonging orchards' productive life. Pomegranate growing areas are characterized by shallow gravelly soils formed on undulating topography with meagre water resources, and hence, micro-irrigation is becoming increasingly popular (Marathe *et al*., 2016[a]). There have been few studies on surface, drip irrigation and irrigation scheduling in pomegranate (Lawande and Patil, 1994; Haneef *et al*., 2014; Marathe *et al*., 2016a) whereas micro-sprinklers have been reported to be effective in commercial citrus cultivars in sub-humid regions (Azzena *et al*., 1988; Shirgure *et al*., 2003). However, very few information on feasibility of micro-sprinklers in pomegranate orchards is available in literature. Hence, the present study was undertaken to evaluate micro-sprinkler in the form of micro-jets in comparison with drip and improved basin method of irrigation with emphasis on moisture distribution, nutrient uptake and WUE, root growth, plant growth, fruit yield, and quality of pomegranate grown under semi-arid tropical climate of India.

2. MATERIALS AND METHODS

A field experiment was conducted consecutively for four (2010-2013) years at the Research Farm of ICAR-National Research Centre on Pomegranate, Solapur, Maharashtra, India. Climate of the study area is semi-arid, representing hot summer / moderate winter with a mean annual maximum and minimum temperature of 40.4°C and 14.9°C, respectively and average annual rainfall of 694 mm spread over months of July-September. Average monthly maximum and minimum temperature during the experimental period (January to July) varied from 29.9°C to 40.2°C and 15.2°C to 25.1°C, respectively. Daily pan evaporation ranged between 3.7 mm to 19.8 mm. Soil of the experimental field was deep (100 cm), loamy with 15.8% coarse fragments, montmorillonitic mineralogy, with pH 7.66, electrical conductivity 0.18 dS m^{-1}, organic carbon 0.38% and calcium carbonate 6.24%. Available N, P and K_2O content of surface soil was 190.0, 11.5 and 238.4 kg ha^{-1}, respectively. Average monthly maximum and minimum temperature during the experimental period (January to July) varied from 29.9°C to 40.2°C and 15.2°C to 25.1°C, respectively. Daily pan evaporation ranged between 3.7 mm to 19.8 mm. Field capacity (33 kPa) and permanent wilting point (1.5 M Pa) of soil was 24.2% and 13.1%, respectively.

The experiment was laid out in a randomized block design consisting of 4 treatments and 5 replications with 2 plants per unit. The treatments involved application of irrigation water using four drippers (4 l/h, 2 online, 2 on 1 m long micro-tube) placed on four sides of the plant (T_1), 2 micro-sprinklers as micro-jet 180° placed symmetrically at 0.20 m from the trunk along the row (T_2), 2 micro-sprinklers as micro-jet 360° placed symmetrically at 0.60 m from the trunk along the row (T_3), and basin (double ring) method of surface irrigation, water applied directly in basin through irrigation pipe (T_4). In drip system, cumulative irrigation equivalent to 0.80 ETc was applied on every alternate day. The irrigation in micro-jet and basin method was standardized and maintained at 50% field capacity. The available soil moisture content was calculated on the basis of water content at field capacity, permanent wilting point of experimental field soil and periodical gravimetric soil moisture content in the root zone of the plants. The total quantity of irrigation water given under the various treatments was recorded.

Air-layer saplings of pomegranate *cv.* 'Bhagwa' were planted with spacing of 4.5 m apart between rows and 4 m between plants in January 2009 and different treatments were initiated from February to June, 2010. Due to severe infestation of bacterial blight disease, as a management practice, plants were cut to ground level during October 2010 and whole experimental field was disinfected with bleaching powder ($CaOCl_2$) spray on the surface. Plants were allowed to grow and treatments were imposed from December 2011 to June 2012, and again during December 2012 to June 2013. Standard package of practices were followed for bringing up the planted orchard.

After fruit harvest, complete soil (together with roots) was removed from 1/4th portion of 60 cm radius surrounding the plant up to 60 cm depth from each replication. The roots were graded on the basis of root diameter into three categories, *viz*., (i) very fine < 0.5 mm (ii) fine 0.5 ≥ to < 2 mm and (iii) small 2 ≥ to < 5 mm roots (Bohm, 1979) and expressed in terms of root mass density (RMD) (total dry weight of roots / volume of excavated soil) and root length density (RLD) (total length of roots / volume of excavated soil). Simultaneously, representative leaf samples of 50 fully matured and expanded recent season leaves located at 8th to 10th position from apex were collected during every year (Marathe and Dhinesh Babu, 2015) and analysed for different macro-nutrient and micro-nutrient contents. Vegetative growth in terms of plant height and plant spread was recorded in each year and expressed as percent increase over the preceding year. Data on male and hermaphrodite flowers were taken by counting the flowers dropped on the ground and set on plants. Fruit yield data were recorded both in terms of number (count) and weight during the year 2013. Cracked fruits were harvested separately and counted in terms of numbers. To detect significant difference among different treatments, statistical analysis for shortest significant range tests was performed using WASP 2 statistical online software.

3. RESULTS AND DISCUSSION

Amount of Applied Irrigation Water

Various irrigation treatments influenced the volume of water applied to varying proportions (Fig. 1). The water applied to the plant was computed to be 438, 1808, 1625 and 725 litres $plant^{-1}$ during the year 2010, which increased to

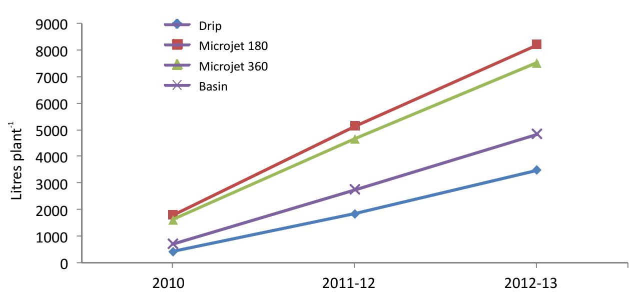

Fig. 1. Amount of irrigation water applied by different irrigation systems

1408, 3357, 3050 and 2031 during 2011-12, and 1640, 3054, 2858 and 2081 litres plant^{-1} during 2012-13, respectively. The amount of applied irrigation water increased with the increasing canopy of the plants, as climatic parameters did not show much variation. The cumulative irrigation water applied during three seasons was lowest under drip (3485 L) followed by basin (4837 L), and very high under micro-jet 180^{o} (8219 L) and micro-jet 360^{o} (7532 L) irrigation systems. Earlier studies reported low irrigation requirements under micro-sprinklers in comparison to basin irrigation in citrus fruit crops (Rodney *et al*., 1977; Shirgure *et al*., 2000). But in this experiment, water was applied directly in the basin of the plants through pipes reducing conveyance losses to great extent. The difference of water use between micro-jet and drip as well as basin irrigation was very high during first year of plant growth. Under drip system, irrigation was applied in rooting zone of the plants whereas large area beyond the plant canopy needs to be wetted under micro-sprinklers irrigation system. During fruiting year (2012-13), the amount of irrigation water used under micro-jet 180^{o}, micro-jet 360^{o} and basin was 86.2%, 74.3% and 23.9% more compared to drip irrigation system. This increase in case of micro-sprinklers systems were ascribed mainly to variation in intrinsic moisture distribution mostly on soil surface, and windblown evaporation losses, while in basin system, it was mainly due to percolation losses.

Surface Wetting Zone and Soil Moisture Distribution

Variation 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 (4.0-8.9%), 20 cm (4.5-7.5%), 30 cm (3.9-8.0%), 40 cm (1.4-6.9%) and 50 cm (0.0-6.9%) from the source varied significantly amongst the treatments (Fig. 2). In all types of irrigation systems, from the source, moisture availability was sufficient up to 30 cm horizontal distance. Micro-jet systems recorded higher moisture content beyond 50 cm. Under drip irrigation, moisture availability was upto 40 cm, while in basin irrigation it reduced drastically at 40 cm horizontal distance.

The available water content below the dripper in vertical direction varied from 4.0-8.2%, 6.0-7.3%, 3.8-7.6%, 0.0-5.4% and 0.0-6.3% in 0-30 cm, 31-45 cm, 46-60 cm, 61-75 cm and 76-90 cm depth, respectively under different treatments (Fig. 3). Basin irrigation system recorded higher available soil moisture content up to 90 cm depth in vertical direction, while under drip it was up to 75 cm and decreased considerably with the further decrease in soil depth. In these treatments, horizontal wetting zone was less and water tends to move in vertical direction, thereby increasing soil moisture content in subsurface layers. In micro-jet systems, available soil moisture content was sufficient only upto 60 cm depth, and in micro-jet 180 it decreased drastically in 61-75 cm soil depth. Azzena *et al*. (1988) also reported that soil

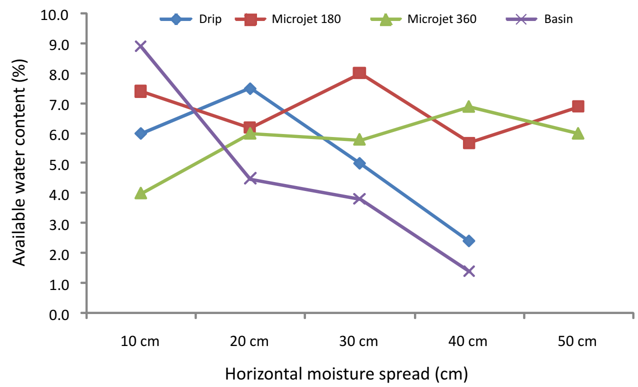

Fig. 2. Moisture spread in horizontal direction as affected by different irrigation systems

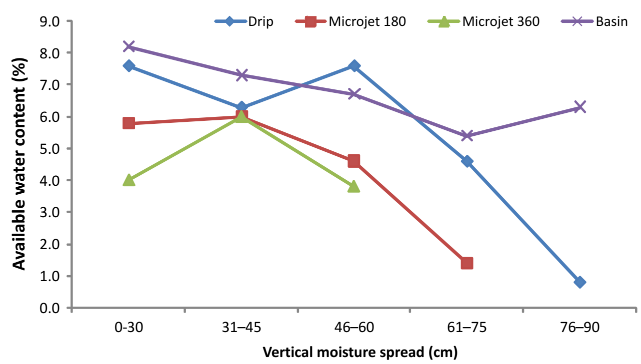

Fig. 3. Moisture spread in vertical direction as affected by different irrigation systems

moisture in horizon-B was always below the permanent wilting point under micro-jet system of irrigation in Valencia orange soils.

Root Growth and Leaf Nutrient Content

Distribution and availability of soil moisture under different irrigation system modified root growth parameters like RMD and RLD (Table 1) of pomegranate. In all the irrigation systems, RMD of small roots were more than fine and very fine roots. On the contrary, RLD values, most important parameter for water and nutrient absorption by the plants, was higher in very fine roots followed by fine and small roots in decreasing order. Maximum RMD values of very fine (1.128) and fine (0.487) roots were observed under drip, while values of small (0.763) and total (1.411) roots were maximum under basin system of irrigation. RLD values of all types of roots was maximum under basin system of irrigation. Favourable soil moisture regime under drip provided better environment for root growth. In addition, the wetter soil under drip and basin methods further helped in reducing soil strength for better root penetration and proliferation. Such beneficial effects of irrigation systems on root growth have also been reported by Kumar and Dey (2011) in strawberry. Lowest RMD and RLD values under micro-jet systems might be due to moisture stress, especially in subsurface layers, and deficiency of P and Ca nutrients in the plants, which induced substantial decrease in plant and root biomass, respectively. Earlier study results revealed that phosphorous deficiency adversely affected the uptake of many nutrients *viz.,* N, K, Ca, Mg and Mn (Marathe *et al*., 2016[b]) thereby decreasing root growth.

Different irrigation systems showed significant response on leaf content of major (P, K, Ca and Mg) and micro (Cu and Mn) nutrients (Table 2). Maximum values of leaf P (0.155%) and K (0.78%) were found under basin irrigation treatment. Basin system moistened maximum area in the root zone, especially in vertical direction, enabling nutrient availability in larger area, which might have resulted in higher nutrient uptake by the plants. This is also supplemented by enlarged, more fibrous and more active root system as indicated by maximum RLD values of all types of roots under this system. Whereas, maximum leaf content of Ca (2.00%), Cu (97.5 ppm) and Mn (79.8 ppm) under basin system of irrigation might be ascribed to relatively higher moisture regime, which increased the potential for higher nutrient uptake. Poor nutrient uptake under micro-jet treatments may be due to less moisture content in subsurface, restricting root growth and nutrient uptake in limited area. This finding was in close conformity with that of Sharma *et al.* (2015) and Marathe *et al.* (2011) who reported decreased uptake of N, P and K with lower moisture levels and thereby microbial population.

Growth Response

Efficacy of irrigation system is judged by the extent to which the evapotranspiration demand of the plant is met at critical growth stages to maintain constant sap flow, a pre-requisite to dry matter accumulation and it's portioning within the plant. Results of the study indicated that during fourth year, maximum plant height (159.5 cm) and average plant spread (185.0 cm) was recorded in basin method of irrigation, which was significantly higher than rest of the treatments. Optimum irrigation under this system, eliminated water stress to the plants resulting in better nutrient uptake favouring greater vigour of the plants. In pomegranate, plant growth was found to increase with increasing amount of irrigation water. Higher irrigation equivalent 1.0 IW/CPE and 100% pan evaporation for surface and drip systems, respectively was recommended for vigorous growth of pomegranate plants (Lawande and Patil, 1994; Haneef *et al*., 2014).

Flowering, Fruit Yield and Quality

A critical stage in fruit production is the transition to and completion of flowering. Flowering intensity significantly varied from 324.7-403.8 flowers plant^{-1} amongst the treatments and was maximum in micro-jet 360° followed by micro-jet 180° treatment (Table 3). These treatment recorded less moisture content in subsurface layers (Fig. 3). Fruit yield in terms of number and weight were significantly influenced by various irrigation systems (Table 3). However, the response of basin (8.747 kg plant^{-1}) and drip (7.248 kg plant^{-1}) was more pronounced than micro-jet irrigation systems. Yield obtained under basin and drip was 413.6% and 325.6% higher than the yield obtained under micro-jet 180° irrigation system, respectively. The increase in yield could be attributed to consistently regulated supply of soil moisture within the soil rhizosphere, inducing better plant growth, balanced nutrient uptake, bigger fruit size and least fruit cracking under these treatments.

Fruit cracking to the extent of 58.2% and 47.6% was

Table: 1
Root distribution parameters of pomegranate as affected by different irrigation systems

Irrigation systems	Root mass density (kg m^{-3})				Root length density (km m^{-3})			
	Very fine	Fine	Small	Total	Very fine	Fine	Small	Total
Drip	0.128	0.487	0.724	1.339	1.879	0.661	0.194	2.734
Micro-jet 180°	0.108	0.404	0.631	1.144	1.522	0.505	0.129	2.155
Micro-jet 360°	0.103	0.421	0.565	1.089	1.465	0.522	0.131	2.117
Basin	0.143	0.505	0.763	1.411	2.166	0.828	0.202	3.195
CD (p = 0.05)	0.011*	0.026*	0.030*	0.050*	0.151*	0.063*	0.013*	0.169*

**Significant at 1%, Very fine roots (< 0.5 mm), Fine roots (0.5 < to < 2 mm), Small roots (2 < to < 5 mm)*

Table: 2
Leaf nutrient content of pomegranate as affected by different irrigation systems

Irrigation systems	Macro-nutrients (%)					Micro-nutrients (ppm)			
	N	P	K	Ca	Mg	Cu	Zn	Fe	Mn
Drip	2.16	0.138	0.65	2.00	0.44	97.5	26.5	123.8	76.6
Micro-jet 180°	2.06	0.113	0.56	1.55	0.34	110.6	27.0	115.8	79.8
Micro-jet 360°	2.13	0.119	0.70	1.70	0.48	86.2	28.4	114.8	77.9
Basin	2.24	0.155	0.78	1.50	0.42	82.9	26.9	110.0	65.8
CD (p = 0.05)	NS	0.02*	0.07*	0.30	0.42	13.3*	NS	NS	6.5*

**Significant at 1%*

observed in micro-jet 180° and micro-jet 360° irrigation system, respectively. Despite higher flowering intensity and fruit setting, drastic reduction in yield was observed in these treatments mainly due to very high fruit cracking. Low soil moisture content, especially in soil subsurface might have created water stress to the plants, especially at the time of fruit maturity, resulting in cracking of the fruits. Higher ambient temperature and dry wind during fruit development period also aggravated fruit cracking. Fruit cracking to the extent of 63% was observed in pomegranate under extremely arid climate of western Rajasthan due to high air temperature (Pant, 1976). In 'Manfalouty' pomegranate, it was considerably reduced (3.7%) with the application of 60% field capacity irrigation or regular irrigation during rainless periods (Abou-Aziz *et al*., 1995; Charan, 1984).

Various fruit quality parameters were significantly influenced by various irrigation treatments (Table 4). Fruits of bigger size as indicated by maximum fruit height (69.7 mm), fruit diameter (73.5 mm) and rind thickness were produced in basin system of irrigation. Better fruit quality in terms of highest juice content (50.0%), lowest juice acidity (0.44%), highest TSS (15.8 °Bricks) and TSS : acidity ratio (36.0) were produced in the plants irrigated with drip system of irrigation. Drastic reduction in fruit quality parameters was observed in both micro-jet 180 ° and micro-jet 360° irrigation treatments. The deterioration of fruit quality was observed mainly during fruit development and maturity period due to lack of moisture resulting in shrinkage and cracking of the fruits.

Water Use Efficiency (WUE)

Higher WUE is a significant factor, particularly in arid and semi arid parts having scarcity of water sources. During fruiting year, total irrigation applied was 1640-3054 L producing yield of 1.703-8.747 kg plant^{-1} under different treatments (Table 3). Though fruit yield was better in basin system, fruit yield based WUE was highest in drip (0.442) than basin (0.420) system of irrigation. The increased WUE under drip may be due to excellent soil-water-air relationship with better aeration in the root zone and efficient utilization of water and nutrients under optimum soil water availability. The corresponding values of WUE for micro-jet 180° and micro-jet 360° treatments were 0.056 and 0.069, respectively. Significantly low WUE under these treatments was mainly due to less yield and higher amount of irrigation water in these treatments.

4. CONCLUSIONS

The irrigation requirement under drip system was substantially low as compared to micro-sprinkler and basin irrigation. Though micro-sprinkler systems recorded success in other fruit crops of sub-humid regions, their utility in pomegranate has severe limitations due to very high evaporation losses, severe fruit cracking, and very low yield and WUE under semi-arid to arid regions. In areas having ample availability of water, farmers can adopt improved double ring basin system of irrigation where water should be applied directly in the basin of the plants through irrigation pipes to reduce conveyance losses. However, in water scarcity areas drip system of irrigation is better option.

REFERENCES

Abou-Aziz, A.B., El-Kassas, S.E., Boutros, B., El-Sese, A.M. and Soliman, S. 1995. Yield and fruit quality of 'Manfalouty' pomegranate trees in response to soil moisture and irrigation regime. *Assuit J. Agric. Sci*. 26: 116-128.

Table: 3
Flowering, yield parameters and water use efficiency of pomegranate as affected different irrigation systems

Irrigation systems	Plant height (cm)	Plant spread (cm)	Total flowers (plant^{-1})	Number of fruits (plant^{-1})	Cracked fruits (%)	Fruit yield (kg plant^{-1})	WUE (t ha^{-1}cm^{-1})
Drip	137.1	164.3	328.4	31.9	0.0	7.248	0.442
Micro-jet 180°	139.9	142.9	388.7	10.1	58.2	1.703	0.056
Micro-jet 360°	139.9	165.6	403.8	13.0	47.6	1.966	0.069
Basin	159.5	185.0	324.7	40.0	0.0	8.747	0.420
CD (p = 0.05)	9.35	11.21	38.1*	3.35*	5.06*	0.516*	0.027*

**Significant at 1%*

Table: 4
Quality of pomegranate fruits as affected different irrigation systems

Irrigation systems	Fruit height (mm)	Fruit diameter (mm)	Rind thickness (mm)	Fruit Juice (%)	Juice acidity (%)	TSS (°Bricks)	TSS : acid ratio
Drip	69.7	73.5	3.09	48.1	0.46	15.6	33.9
Micro-jet 180°	59.7	63.4	2.43	43.0	0.54	15.0	28.2
Micro-jet 360°	61.8	65.5	2.59	43.7	0.52	14.9	28.8
Basin	69.0	71.7	2.86	50.0	0.44	15.8	36.0
CD	5.07*	4.94*	0.38*	3.30*	0.033	0.346*	1.90*

**Significant at 1%*

Azzena, M., Deidda, P. and Dettori, S. 1988. Drip and microsprinkler irrigation for young Valencia orange trees. *In: Proc. Sixth International Citrus Congress*, Tel Aviv, Isreal, pp 747-751.

Bohm, W. 1979. *Methods of Studying Root Systems*. New York: Springer-Verlag. pp 188-194.

Charan, R. 1984. *Studies on fruit cracking in pomegranate*. Ph.D. Thesis, University of Jodhpur, India.

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 J. Hort*. 71: 45-48.

Jolikop, S.H. and Kumar, P.S. 2000. New fruit crop varieties for arid regions: Ruby (pomegranate) and Arka Sahan (custard apple). *Indian Hort*. 45: 19-20.

Lawande, B.T. and Patil, V.K. 1994. Effect of different water regimes on growth, flowering and fruiting of pomegranate. *J. Maharashtra Agric. Univ*. 19: 220-223.

Marathe, R.A. and Dhinesh Babu, K. 2015. Determination of sampling period and leaf position for critical nutrient analysis in pomegranate cv. Bhagwa. *Indian J. Hort*. 72: 562-565.

Marathe, R.A., Dhinesh Babu, K. and Sharma, J. 2016a. Identification of suitable soils for cultivation of pomegranate (*Punica granatum*) *cv.* Ganesh. *Indian J. Agri. Sci.,* 86: 227-233.

Marathe, R.A., Mohanty, S. and Singh, S. 2003. Soil characterization in relation to growth and yield of Nagpur mandarin (*Citrus reticulata* Blanco). *J. Indian Soc. Soil Sci*., 51: 70-73.

Marathe, R.A., Murkute, A.A. and Dhinesh Babu, K. 2016[b]. Mineral nutrient deficiencies and nutrient interactions in pomegranate. *Natl. Acad. Sci. Lett*., 39: 407-410.

Marathe, R.A., Ram Chandra, Maity, A., Sharma, J. and Jadhav, V.T. 2011. Effect of different microbial inoculants on soil properties, nutrient acquisition and growth of pomegranate (*Punica granatum* L.). *Indian J. Agric. Sci.,* 81: 622-627.

NHB. 2017. National Horticulture Board, Ministry of Agriculture, Government of India, Gurgaon, Haryana, website www.nhb.gov.in 2015-16.

Pant, T. 1976. Fruit cracking in pomegranate (*Punica granatum* L.) in variety Jodhpuri. *Udyanika*, 2: 29-35.

Rodney, D.R., Roth, R.L. and Gardner, B.R. 1977. Citrus response to irrigation methods. *Proc. Int. Soc. Citriculture*, 1: 106-110.

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 J. Hort.,* 72: 133-138.

Shirgure, P.S., Lallan Ram, Singh, S., Marathe, R.A. and Yadav, R.P. 2000. Water-use and growth of acid lime (*Citrus aurantifolia*) under different irrigation systems. *Indian J. Agril. Sci*., 70: 125-127.

Shirgure, P.S., Srivastava, A.K. and Singh, S. 2003. Evaluating micro-irrigation systems in Nagpur mandarin (*Citrus reticulata* Blanco*)* under the sub-humid tropical climate of Central India. *Trop. Agric*. (Trinidad), 80: 91-96.

Kumar, S. and Dey, P. 2011. Effect of different mulches and irrigation methods on root growth, nutrient uptake, water use efficiency and yield of strawberry. *Sci. Hortic*., 127: 318-324.