Original Research

Journal Home page : www.jeb.co.in ★ E-mail : editor@jeb.co.in

Journal of Environmental Biology

JEB™ p-ISSN: 0254-8704
e-ISSN: 2394-0379
CODEN: JEBIDP

DOI : http://doi.org/10.22438/jeb/40/5/MRN-982

Evaluation of micro-irrigation methods in pomegranate under semi-arid tropical climate of India

Paper received: 07.08.2018 *Revised received*: 11.01.2019 *Re-revised received*: 05.03.2019 *Accepted*: 30.04.2019

Authors Info

R.A. Marathe*, Jyotsana Sharma and D.T. Chaudhari

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

***Corresponding Author Email :**
ramarathe28@gmail.com

Edited by

Dr. Subhas Babu

Reviewed by

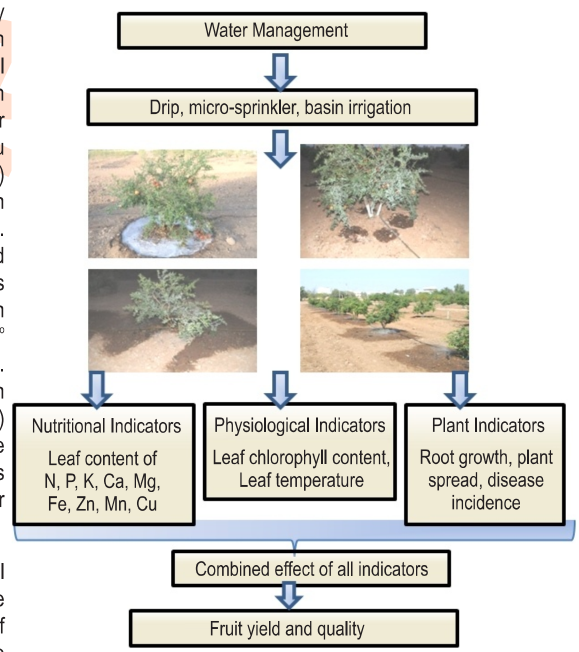
Dr. Anup Das
Dr. M.Thoithoi Devi

Abstract

Aim : To evaluate different micro-irrigation systems against basin irrigation in terms of growth, yield, fruit quality, disease infestation and water use of pomegranate under semi-arid tropical climate of Central India.

Methodology : A field experiment was conducted in newly planted pomegranate cv. Bhagwa orchard with four irrigation treatments, *viz.,* drip (4 lph, 4 $plant^{-1}$), microjet 180° (2 $plant^{-1}$), microjet 360° (2 $plant^{-1}$) and basin (double ring) irrigation replicated five times in a randomised block design (RBD) in heavy textured soil.

Results : Basin irrigation is widely practiced method of irrigation which presently facilitate better soil moisture distribution, resulted in better root proliferation and higher leaf nutrient status (K 0.98%, Cu 105.4 ppm and Zn 35.9 ppm) followed by drip (N 2.12% and Mn 40.4 ppm) system of irrigation. Maximum fruit yield was obtained under basin and drip which was 376.7% and 242.8% higher than that obtained under microjet 180° irrigation system, respectively. Water use efficiency was highest in drip (0.526) than basin (0.499) system of irrigation. Disease incidence in the plants was less under drip while it was high under microjet system of irrigation.



Interpretation : Experimental findings clearly indicate that the areas which had ample amount of irrigation, basin irrigation was the most efficient system in harnessing maximum yields, while drip irrigation resulted in higher water use efficiency under arid to semiarid tropical climate, micro-sprinkler irrigation system is not beneficial for pomegranate orchards.

Key words: Basin irrigation, Chlorophyll content, Micro-sprinklers, Nutrient uptake, *Punica granatum*

How to cite : Marathe, R.A., Jyotsana Sharma and D.T. Chaudhari: Evaluation of micro-irrigation methods in pomegranate under semi-arid tropical climate of India *J. Environ. Biol.*, **40**, 1029-1035 (2019). **DOI :** http://doi.org/10.22438/jeb/40/5/MRN-1982

Introduction

Pomegranate (*Punica granatum* L.) is one of the oldest known edible fruits. In India, pomegranate cultivation has registered a high pace, especially in arid and semi-arid regions of Maharashtra, Karnataka and Andhra Pradesh due to its export potential and hardy nature (Jolikop and Kumar, 2000). Although, its cultivation has reached to 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 water use efficiency and productivity potential. Lack of assured irrigation is the biggest bottleneck in bringing additional land under cultivation. Pomegranate is a hardy crop but it requires constant soil moisture throughout its period of fruit development, especially during Ambia bahar (February flowering) for quality production. Conventional basin irrigation is preferred by the pomegranate growers, but this has several drawbacks including conveyance, percolation, evaporation and distribution losses (Shirgure *et al.,* 2000). Due to scarcity of irrigation water in arid to semi-arid ecosystems, micro-irrigation is becoming increasingly popular with pomegranate growers.

Wide-scale use of modern irrigation technologies can optimize water supply management and can bring more area under cultivation. Any method of irrigation capable of replenishing the evapotranspiration demand of the plant, and simultaneously keeping the soil moisture continuum within the desired limit during the entire growing period, would ensure a production sustainability of the orchard besides prolonging the orchard's productive life. Sponsorship and adoption of schemes initiated by National Mission on Micro-Irrigation (NMMI) supports arid and semi-arid regions for adopting micro (drip and sprinkler) irrigation systems in India (Naveen kumar and Satyapriya, 2018), also supports the views of Vyas *et al.* (2015) with regard to irrigation for sustainable successful agriculture, preserving life, averts famine and advances the material prosperity of the country.

Micro-irrigation systems are most ideal for undulating and desert tracts of the country. Pomegranate growing areas are characterized by shallow gravel soils formed on undulated topography with meagre water resources and hence, micro-irrigation is becoming increasingly popular (Marathe *et al.,* 2016a). Micro-irrigation systems viz., drip, under-tree sprinklers, micro-sprinklers and microjets have been reported to be highly effective in commercial fruit crops in sub-humid regions (Azzena *et al.,* 1988; Shirgure *et al.,* 2003). There are few literatures available on irrigation aspects in pomegranate (Haneef *et al.,* 2014; Marathe *et al.,* 2018). However, little information is available on efficacy of micro-irrigation, especially micro-jets in pomegranate. Hence, the present study was undertaken to evaluate different micro-irrigation systems against basin irrigation with emphasis on moisture distribution, nutrient uptake and water use efficiency, root growth, plant growth and fruit yield of pomegranate grown under semi-arid tropical climate of India.

Materials and Methods

Experimental site : 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 the months of July-September. The 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 soil had pH 7.8; EC 0.18 dS m^{-1}; organic carbon 0.66 %; calcium carbonate 6.31 %; coarse fragments (> 2.0 mm) 8.4 %; sand 26.6%; silt 20.8%; clay 52.6% with 60 cm depth. The available N, P and K content of surface soil was 337.3, 18.5 and 354.2 kg ha^{-1} while the field capacity and permanent wilting point of soil were 31.8% and 16.8 %, respectively (Chapman and Pratt, 1961).

Experimental design : The experiment was laid out in a randomized block design consisting of 4 treatments and 5 replications with 2 plants per unit. Various 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 microjet 180° placed symmetrically at 0.20 m from the trunk along the row (T_2), 2 Micro-sprinklers as microjet 360° were placed symmetrically at 0.60 m from the trunk along the row (T_3), 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 ETtc was applied every alternate day. The irrigation in microjet and basin method was standardized and maintained at 50% field capacity. The total quantity of irrigation water given under 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 by spraying bleaching powder ($CaOCl_2$) 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.

Estimation of root, leaf nutrient content and physiological parameters : 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 and expressed in terms of root mass density (RMD) and root length density (RLD). Simultaneously, representative leaf samples of 50 fully matured and expanded recent season leaves located at 8^{th} to 10^{th} position from apex were collected during study period. (Marathe and Dhinesh Babu, 2015) and analysed for different macro (N, P, K, Ca, Mg) and micro (Cu, Zn, Fe, Mn) nutrient contents. Chlorophyll content in the leaf as indicated by SPAD values was measured using chlorophyll meter while a handheld infrared thermometer was used to measure leaf temperature between 13:00 and 15:00 hr on sunny days.

Growth, yield and disease infestation : Vegetative growth in terms of plant height and plant spread was recorded 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. The fruit yield data were recorded both in terms of number (count) and weight basis during the year 2013. Cracked fruits were harvested separately and counted in terms of numbers. Incidence of bacterial blight disease (BBD) on leaves, stem and on lemon size fruits of the plants were recorded during 2012 and expressed in terms of BBD index.

Statistical analysis : To detect significant difference among different treatments, statistical analysis for shortest significant range tests was performed using Tukey's HSD test by using SAS (2011) software.

Results and Discussion

All irrigation treatments influences the volume of water applied to varying proportions. The cumulative irrigation water applied during three seasons was lowest under drip (3485 l) followed by basin (4837 l) while it was maximum under microjet 180° (8219 l) and microjet 360° (7532 l) irrigation methods. During fruiting year, the amount of irrigation under micro-jet 180°, micro-jet 360° and basin irrigation was 86.2%, 74.3% and 23.9% more, respectively, as compared to drip irrigation system. This increase in the amount of irrigation through microjets were ascribed mainly to variation in intrinsic moisture distribution mostly on soil surface, wind-blown evaporation losses while in basin system it was mainly due to percolation losses. Earlier studies reported low irrigation requirements under micro-sprinklers in comparison to basin irrigation in citrus fruit crops (Shirgure *et al.,* 2000). In this experiment, efforts were made to apply water directly into the basin of the plants through pipes reducing conveyance losses to great extent.

The wetting zone under different irrigation systems has major implications on moisture availability, root distribution and nutrient absorption area.

The visible wetting area on the surface of soil was highest (7.5 m^2) under micro-jet 360° followed by 2 micro-jet 180° (4.62 m^2) irrigation methods. It was substantially low under basin (2.43 m^2) and drip (0.50 m^2) irrigation system (Fig. 1). Soil moisture distribution in horizontal direction revealed that the available water content at a distance of 10 cm (8.2 –13.1%), 20 cm (8.7-11.6%), 30 cm (6.6-8.5%), 40 cm (1.2-8.3%) and 50 cm (0.0–8.6%) from the dripper varied significantly amongst the treatments (Fig 2). In all types of irrigation methods, moisture availability was sufficient up to 30 cm while under microjet it was up to 50 cm. Soil moisture content below the dripper was always higher than field capacity and recorded higher soil moisture content up to 30 cm, beyond which soil moisture content drastically reduced and went below permanent witling point beyond 40 cm in drip and basin systems of irrigation. Varied distribution pattern in soil moisture has also been reported in citrus (Castel, 1994) and blueberry (Bryla *et al.,* 2011) to be influenced by the arrangements of emitters under drip system.

In vertical direction, AWC varied from 7.1-13.6%, 6.0 - 9.6%, 2.1 - 8.2%, 0.0 - 7.9% and 0.0 - 6.1% in 0 - 30, 31 - 45, 46 - 60, 61 - 75 and 76 - 90 cm depth, under respective treatments (Fig. 3). Basin irrigation system recorded higher, up to 90 cm depth while it was up to 60 cm under drip. In these treatments, horizontal wetting zone was less and water tend to move in vertical direction thereby increasing soil moisture content in subsurface layers. In microjet systems, AWC content was sufficiently up to 45 cm depth and decreased drastically with further increase in depth. Azzena *et al.* (1988) also reported that soil moisture in horizon-B was always below the permanent wilting point under microjet system of irrigation in Valencia orange soils. Similarly, under high density or dense canopy cover,

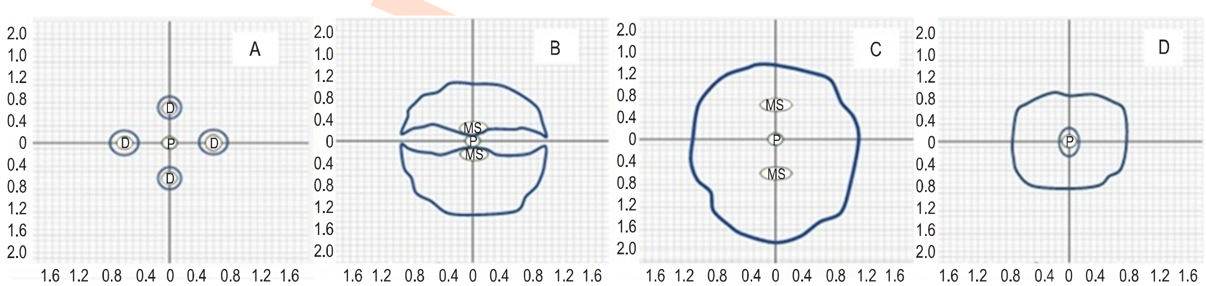


Fig. 1 : Visible surface wetting zones as influenced by drip (A), microjet 180° (B), microjet 360° (C) and basin (D) system of irrigation in pomegranate grown under semiarid tropical climate of India. P: plant, D: dripper, MS: microsprinkler.

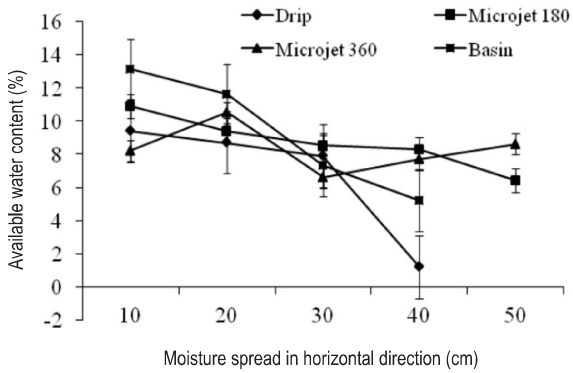


Fig. 2 : Soil moisture distribution in horizontal direction as affected by different irrigation systems in pomegranate orchard grown under semiarid tropical climate of India.

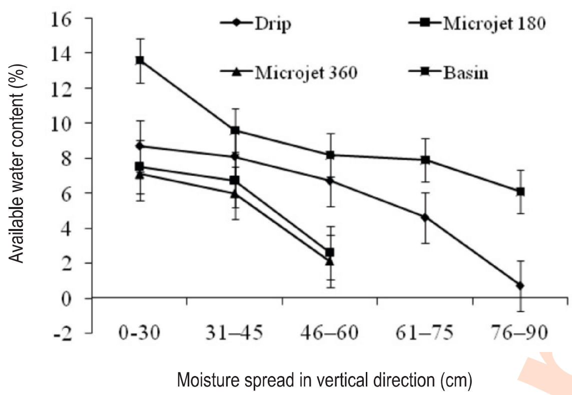


Fig. 3 : Soil moisture distribution in vertical direction as affected by different irrigation systems in pomegranate orchard grown under the semiarid tropical climate of India.

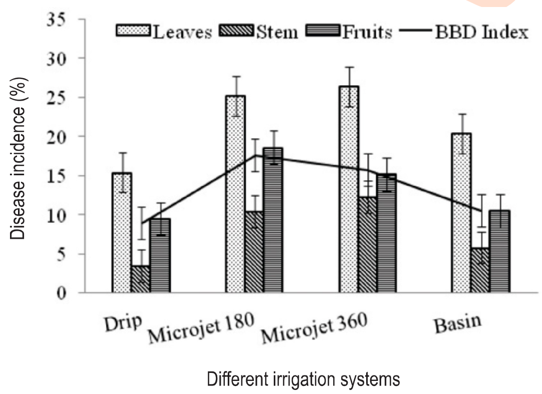


Fig. 4 : Effect of different irrigation systems on the incidence of bacterial blight disease on leaves, stem and fruits of pomegranate grown under semiarid tropical climate of India.

sprinkler system of irrigation does not saturate the roots, hence gets a reduced amount of water, thus, exposing plants to more water stress (Bryla and Strik, 2007). Root growth parameters like RMD and RLD were influenced (Table 1) by soil moisture distribution under all irrigation system and RMD of small roots were more while RLD values were more in fine roots. Drip system recorded maximum RMD values of very fine, fine and total roots and maximum RLD values for very fine and fine roots as compared to basin and micro-jet 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 the soil strength to root penetration and proliferation. Such beneficial effects of irrigation systems on root growth has been reported in strawberry (Sushil Kumar and Dey, 2011). Lowest RMD and RLD values of very fine and fine roots were observed under microjet systems. Moisture stress in subsurface layers substantially restricted root growth in longitudinal directions due to higher wetting radius of these systems (Fig. 3).

Different irrigation systems showed significant response on leaf nutrient content (Table 2). The maximum leaf N (2.12%) and Mn (40.4 ppm) content were found under drip irrigation while leaf K (0.98%), Cu (105.4 ppm) and Zn (35.9 ppm) values were maximum in basin methods of irrigation. The efficient utilization of nutrients under these treatments could be due to enlarged, more fibrous and more active root system as indicated by maximum RLD values. This was also supplemented by relatively better moisture regime which increased the potential for higher nutrient uptake. Poor nutrient uptake under microjet 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.

Leaf chlorophyll content was significantly highest in basin (62.5) followed by drip system (61.9), indicating better photosynthetic capacity of the plants (Table 3) which might be due to better nutrient uptake and water availability. Leaf temperature, irrespective of irrigation systems was lower than that of ambient temperature and was found lowest in basin followed by drip system (Table 3). Higher soil moisture content in these treatments provided required soil moisture levels for increased rate of transpiration, minimizing temperature of the leaves. Cool canopy was found to be an important physiological principle for tolerance to high temperature stress (Munjal and Rena, 2003). Higher leaf temperature in micro-jet indicated stress conditions due to limited moisture availability. Under mild water stress conditions, reduction in leaf photosynthetic rate, transpiration rate, soluble protein, chlorophyll and carotenoid contents, stomata opening and water potential has been observed in coffee tree (Liu *et al.,* 2016). Increase in plant height and average plant spread was higher in basin followed by drip system of irrigation (Table 3). Plant growth in basin was significantly superior over other systems of irrigation. Optimum moisture availability under this system resulted in better nutrient uptake and plants vigour. Microjet 360°

Table 1 : Root distribution parameters of pomegranate grown under semiarid tropical climate of India during 2010-2013 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	0.060^{a}	0.358^{a}	0.744^{a}	1.162^{a}	0.775^{a}	0.910^{a}	0.135^{a}	1.821^{a}
Micro-jet 180°	0.046^{bc}	0.331^{ab}	0.710^{a}	1.087^{bc}	0.661^{ab}	0.828^{ab}	0.137	1.627^{bc}
Micro-jet 360°	0.040^{c}	0.315^{b}	0.725^{a}	1.080^{c}	0.594^{b}	0.791^{b}	0.138	1.523^{c}
Basin	0.051^{ab}	0.339^{ab}	0.747^{a}	1.137^{ab}	0.736^{a}	0.897^{a}	0.143	1.776^{ab}
Tukey's HSD at 5%	0.009	0.034	0.038	0.057	0.141	0.099	NS	0.189

Very fine roots (< 0.5 mm), Fine roots (0.5 < to < 2 mm), Small roots (2 < to < 5 mm); Means sharing a common letter within the column are not significant by Tukey's HSD test at P < 0.05; NS non significant

Table 2 : Leaf nutrient content of pomegranate grown under semiarid tropical climate of India during 2010-2013 as affected by irrigation systems

Irrigation systems	Macronutrients (%)					Micronutrients (ppm)			
	N	P	K	Ca	Mg	Cu	Zn	Fe	Mn
Drip	2.11^{a}	0.16	0.91^{ab}	1.52	0.44	93.8^{ab}	33.2^{ab}	136.1	40.4^{a}
Micro-jet 180°	1.96^{ab}	0.15	0.80^{b}	1.57	0.34	80.5b	30.6^{ab}	129.2	36.5^{a}
Micro-jet 360°	1.79^{b}	0.16	0.84^{ab}	1.36	0.48	92.3^{ab}	29.0^{b}	140.3	36.3^{a}
Basin	1.92^{ab}	0.14	0.98^{a}	1.32	0.42	105.4^{a}	35.5^{a}	152.5	30.4^{b}
Tukey's HSD at 5%	0.27	NS	0.18	NS	NS	22.4	5.6	NS	5.1

Means sharing common letter within the column are not significant by Tukey's HSD test at P < 0.05; NS: non significant

Table 3 : Plant vegetative growth of pomegranate grown under semiarid tropical climate of India during 2010-2013 as affected by different irrigation systems

Irrigation systems	Percent increase during 2010		*Percent increase during 2011-12		Percent increase during 2012-13		Leaf chlorophyll content (SPAD)	Leaf temperature (°F)		
	Plant height	Canopy spread	Plant height	Canopy spread	Plant height	Canopy spread		March	April	May
Drip	40.7	45.1^{b}	15.8	15.6	24.1^{b}	31.0^{b}	61.9	95.1	100.2	103
Micro-jet 180°	40.0	41.3^{bc}	16.1	15.0	20.2^{b}	27.4^{b}	59.9	97.6	103.8	106.2
Micro-jet 360°	39.3	40.7^{c}	16.1	15.4	22.2^{b}	28.9^{b}	61.3	98.6	103.6	107
Basin	43.1	49.7^{a}	16.2	17.6	28.3^{a}	35.7^{a}	62.5	93.9	99.4	100
Tukey's HSD at 5%	NS	4.0	NS	NS	4.1	4.2	1.70	1.68*	2.25*	2.35*

*re-growth of plants after uniform pruning at ground level; Means sharing common letter within the column are not significant by Tukey's HSD test at P < 0.05; NS: non significant

Table 4 : Flowering, yield parameters and water use efficiency of pomegranate grown under semiarid tropical climate of India during 2010-2013 as affected by different irrigation systems

Irrigation systems	Male flowers (plant^{-1})	Hermaphrodite flowers (plant^{-1})	Number of fruits (plant^{-1})	Cracked fruits (%)	Fruit yield (kg plant-1)	Weight of each fruit (g)	WUE (t ha^{-1} cm^{-1})
Drip	205.5^{ab}	132.7^{b}	35.8^{b}	0.0^{b}	8.62^{b}	242.3^{a}	0.526^{a}
Microjet 180°	230.3^{a}	150.7^{ab}	14.0^{c}	46.3^{a}	2.22^{d}	159.0^{b}	0.073^{b}
Microjet 360°	221.0^{ab}	160.9^{a}	17.5^{c}	42.6^{a}	2.87^{c}	165.1^{b}	0.100^{b}
Basin	195.8^{b}	140.8^{ab}	45.0^{a}	0.0^{b}	10.39^{a}	231.3^{a}	0.499^{a}
Tukey's HSD at 5%	29.3	22.3	5.5	7.9	0.64	28.7	0.031

Means sharing common letter within the column are not significant by Tukey's HSD test at P < 0.05; NS: non significant and microjet 180° systems recorded significantly the lowest increase in plant growth. In pomegranate, growth is mostly governed by nutrient availability. Deficiency of P and Ca nutrients induced substantial decrease in plant and root biomass. Phosphorous was the most influential nutrient and its deficiency adversely affected the uptake of many nutrients viz. N, K, Ca, Mg and Mn (Marathe *et al.,* 2016b)

A critical stage in fruit production is the transition to and completion of flowering. Significantly the highest numbers of male and hermaphrodite flowers were produced in micro-jet system (Table 4). These systems have very less moisture content in subsurface layers (Fig. 3). Early and more intense flowering due to soil moisture stress was reported in Nagpur mandarin and pomegranate fruit crops (Marathe *et al.,* 2003, 2016). Fruit yield was significantly more in basin (10.39 kg plant^{-1}) followed by drip (8.62 kg plant^{-1}) system of irrigation. Yield obtained under basin and drip was 376.7 and 242.8% higher as compared to micro-jet 180° irrigation. 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. Despite higher flowering intensity, drastic reduction in fruit yield was recorded in microjet systems, mainly due to high fruit cracking (42.6 and 46.3 %) in these treatments. Low soil moisture content, especially in subsurface coupled with higher leaf temperature might have created water stress to the plants, particularly at the time of fruit maturity, resulting in cracking of fruits.

Higher water use efficiency (WUE) is an important factor particularly in arid and semi arid parts having scarcity of water sources. Though fruit yield was better in basin, WUE was higher in drip (0.526 t ha^{-1} cm^{-1}) than basin (0.499 t ha^{-1} cm^{-1}) method of irrigation (Table 4). 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. Significantly lower WUE in microjet systems (0.073 and 0.100) was mainly due to less yield and higher amount of irrigation water loss to evaporation in these treatments. Significantly higher WUE was observed under drip irrigation system when compared with microsprinklers or microsprays and became progressively less efficient when more irrigation water was added (Bryla *et al.,* 2011).

Prevalence of most serious bacterial blight disease, affecting all plant parts was observed on almost all the plants under experimentation. Disease index calculated on the basis of overall incidence on all plant parts varied from 8.89 % to 17.62 % and was lowest in drip followed by basin system (Fig 4). Significantly higher disease incidence was observed in plants irrigated with micro-jet systems of irrigation. In these systems, water droplets fall on the stem, leaf and even fruits of the plants. The surface wetting zone is very high and soil near the stem remained wet, resulting in increased humidity in micro-climate of the plants which is congenial for increasing incidence and severity of the disease. Significant and positive correlation between relative humidity and bacterial blight disease development was reported in pomegranate (Sharma *et al.,* 2012). Incidence of wilt disease was observed in all treatments but no fixed trend was observed. It is reported that wilt, the widespread and destructive disease of pomegranate has been found in mild to severe form in most of the orchards of all the major pomegranate states of India (Sharma *et al.,* 2010). Thus, from the present study it was concluded that drip system of irrigation recorded highest WUE and should be adopted in severe water scarcity areas. Modified basin system can be adopted in the areas having ample availability of water. Micro-sprinklers (microjets) are not suitable for pomegranate orchards due to very high evaporation loss, increased disease incidence and severe fruit cracking.

Acknowledgments

The author is grateful to the then Director Late Dr. V.T. Jadhav for his consistent guidance and encouragement in designing the experimentation and Dr. K. Dhinesh Babu, Principal Scientist (Horticulture) for his assistance extended towards data collection on horticultural parameters and their compilation.

References

Azzena, M., P. Deidda and S. Dettori: Drip and microsprinkler irrigation for young Valencia orange trees. In: Proc. 6th Inter. Citrus Congress, Tel Aviv, Isreal, pp. 747-751 (1988).

Bryla, D.R. and B.C. Strik: Effects of cultivar and plant spacing on the seasonal water requirements of highbush blueberry. *J. Amer. Soc. Hort. Sci.,* **132**, 270-277 (2007).

Bryla, D.R., J.L. Garatung and B.C. Strik: Evaluation of irrigation methods for highbush blueberry–I. Growth and water requirements of young plants. *Hort Sci.,* **46**, 95-101 (2011).

Castel, J.R.: Response of young *Clementine citrus* trees to drip irrigation. I. Irrigation amount and number of drippers. *J. Hort. Sci.,* **69**, 481-489 (1994).

Chapman, H.D. and P.F. Pratt: Methods of Analysis for Soil, Plants and Water. Division of Agricultural Sciences, University of California, USA, pp.182-186 (1961).

Haneef, M., R.A. Kaushik, D.K. Sarolia, A. Mordia and M. Dhakar: Irrigation scheduling and fertigation in pomegranate cv. Bhagawa under high density planting system. *Indian J. Hort.,* **71**, 45-48 (2014).

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

Liu, X., F. Li, Q. Yang and X. Wang: Effect of alternate drip irrigation and superabsorbent polymers on growth and water use of young coffee tree. *J. Environ. Biol.,* **37**, 485-491 (2016).

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

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

Marathe, R.A., K. Dhinesh Babu and D.T. Chaudhari: Effect of irrigation frequencies on nutrient uptake, growth and yield of pomegranate grown on heavy textured soils of semi-arid region. *Indian J. Agric. Sci.,* **86**, 1559-1565 (2016).

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

Marathe, R.A., K.D. Babu and D.T. Chaudhari: Nutrient uptake, growth and yield of pomegranate as influenced by irrigation frequencies under light textured soils. *J. Environ. Biol.,* **39**, 143-148 (2018).

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

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

Munjal, R. and R.K. Rana: Evaluation of physiological traits in wheat (*Triticum aestivum* L.) for terminal high temperature tolerance. In: *Proc. Tenth Inter. Wheat Genetics Symp.,* Poestum, Italy, pp. 804-805 (2003).

Naveen kumar, M.R. and E. Sathyapriya: Microirrigation systems in agricultural context- An overview. In: *National Conference on Microirrigation,* Water Technology Centre, TNAU, Coimbatore, pp. 26-28 (2018).

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

SAS: SAS Institute Inc. ver. 9.3., 2011 Guide Cary, NC, USA, ISBN 978-1 – 60764 – 895 – 6 (2011).

Sharma, Jyotsana, K.K. Sharma and V.T. Jadhav: Diseases of pomegranate. current status of economically important diseases of crops in India. Indian Phytopathol. Soci., New Delhi (2012).

Sharma, K.K., Jyotsana Sharma and V.T. Jadhav: Etiology of pomegranate wilt and its management. *Fruits, Vegetables, Cereal Sci. Biotechnol.,* **4**, 96-104 (2010).

Sharma, R., S.K. Pandey and T.A. Sharma: Influence of soil moisture on growth and nutrient content in healthy and malformed panicles of mango varieties. *Indian J. Hort.,* **72**, 133-138 (2015).

Shirgure, P.S., A.K. Srivastava and S. Singh: 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 (2003).

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

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

Vyas, R.K., S. Roy and K. Kumar: Management of micro irrigation system in arid areas of India: A conceptual framework. *Int. J. Appl. Eng. Res.,* **10**, 3689-3693 (2015).