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Original article

The effect of four under tree micro-jet irrigation (180-300^0) systems on fruit yield and quality of Nagpur mandarin in Central India

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A B S T R A C T

A field experiment was conducted for evaluation of the different degree under tree automatic micro-jet irrigation systems on yield, quality and productivity of Nagpur mandarin on 12-15 years old bearing Nagpur mandarin (on Rough lemon) at National Research Centre for Citrus, Nagpur during 2008-2011. Four treatments viz. Irrigation with 180^0 Fan type micro-jet (2/plant), (M_1); Irrigation with 180^0 Ray type micro-jet (2/plant) (M_2); Irrigation with 270^0 Ray type micro-jet (2/plant) (M_3) and Irrigation with 300^0 Ray type micro-jet (2/plant) (M_4) were evaluated with six replications in Randomized Block Design. The quantity of water applied using automatic controller in micro-jet irrigation systems varied from 70.5 to 142.1 litres/day/plant and 82.3 to 134.4 litres/day/plant during 2009-10 and 2010-11 respectively. The soil moisture distribution was observed higher and uniform under irrigation with 180^0 Fan type micro-jet (2/plant) followed by irrigation with 180^0 Ray type micro-jet (2/plant). The highest average increase in canopy volume was recorded in micro-jet 180^0 Fanjet (93.68 m^3) and micro-jet 180^0 Rayjet (90.65 m^3). The highest fruit yield i.e. 29.4 tonnes/ha was recorded with 180^0 Fan type micro-jet (2/plant) followed by irrigation with 300^0 micro-jet (2/plant)(26.2 tonnes/ha), where as the lowest yield was observed in irrigation with 180^0 Rayjet type micro-jet (2/plant) irrigation system (21.9 tonnes/ha). The fruit quality analysis revealed that total soluble solids was highest (9.47 ^{o}Brix) with 300^0 Ray type micro-jet followed by irrigation with 180^0 Fan type micro-jet treatment (9.0 ^{o}Brix). The highest juice content (39.4 %) was found with 180^0 Ray type micro-jet irrigation as compared to irrigation with 180^0 Fan type micro-jet. The TSS to acidity ratio was highest with 300^0 Rayjet type micro-jet irrigation system.

1. Introduction

Citrus is third largest group of fruits grown in India. Nagpur mandarin (*Citrus reticulata* Blanco) is one of the most important mandarin cultivar of the citrus commercially grown in central India. Although the area grown in 0.148 Mha area (bearing area is 0.0862 Mha) the production is 0.875 Mha only. The average productivity is low (10–11 tonnes per ha) due to soil and water resources constraints. Of these, irrigation water scarcity plus the conventional basin method of irrigation as well as drip irrigation with emitters (4 drippers/plant irrigation system) widely practised, do not meet the requirements of soil water regime in the Nagpur mandarin orchards. Nagpur mandarin plants require higher soil moisture constantly throughout its period of plant growth and fruit development. Gravity method (Basin irrigation) is commonly used in Nagpur mandarin orchards, but this has several drawbacks including the irrigation losses (conveyance, percolation, evaporation, and distribution losses) and in addition, the growth, yield, and fruit quality are adversely affected (Shirgure *et al.,* 2001a; 2001b). Due to the scarcity of irrigation water, micro-irrigation is becoming increasingly popular with mandarin growers. However, many growers are still unsure about the efficacy of drip irrigation, especially where soil moisture deficit stress is adopted for regulating stress, vis-a-vis, flowering and lack of uniformity in moisture distribution within the tree's root zone as another possible drawback. Any method of irrigation capable of replenishing the evapo-transpiration demand of the plant, and simultaneously keeping the soil moisture within the desired limit during the different fruit developmental stages, would ensure a production sustainability of Nagpur mandarin orchards besides prolonging the orchard's productive life (Pyle, 1985; Capra and Nicosia, 1987).

Micro-irrigation systems are commonly used in citrus orchards throughout the world. There is now a gradual shift in method of irrigation from furrow irrigation–overhead sprinkler irrigation systems to under-tree sprinkling systems like micro-jets (Simpson, 1978; Dasberg, 1995; Shirgure *et al.,*2004a). Micro-irrigation systems, viz., drip irrigation, under-tree sprinklers, micro-sprinklers, and micro-jets have been reported to be highly effective in commercial citrus cultivars like Valencia orange (Azzena *et al.*, 1988), Navel orange (Fouche and Bester, 1986), Hamlin orange (Marler and Davis, 1990), Satsuma mandarin (Peng Young Hong and Rabe, 1999), Clementine (Castel, 1994), and lemon (Cevik *et al.,* 1987). Earlier studies in India comparing drip with flood irrigation in Nagpur mandarin (Shirgure *et al.,* 2003a; Shirgure *et al.,* 2003), sweet orange (Kumar and Bhojappa, 1994), and acid lime (Shirgure *et al.,* 2001c; 2001d and 2003a) showed better performance using drip irrigation. The main objective of this investigation is to evaluate the different under tree micro-jet irrigation systems with help of automatic drip irrigation scheduling using controller and to study the effect micro-jet irrigation systems on plant growth, yield, nutritional status, optimum water use, uniform soil moisture distribution and availability and higher production as well as productivity and superiority in qualities of fruits in bearing Nagpur mandarin (*C. reticulata* Blanco) grown under the sub humid tropical climate of India.

2. Materials and methods

To study the different degree under tree micro-jets irrigation systems and the effect on growth and productivity of 12-14 years old Nagpur mandarin (*C. reticulata* Blanco) budded on rough lemon rootstock (*C. jambhiri* Lush) a field experiment was conducted in the block of 50 x 50 m with 6 x 6 m spacing at experimental farm of NRCC during the year 2008-2011. The treatments consisted of irrigation with 180^0 micro-jet (2/plant) Fanjet (M_1), irrigation with 180^0 micro-jet (2/plant) Rayjet (M_2), irrigation with 270^0 micro-jet (2/plant) Rayjet (M_3) and irrigation with 300^0 micro-jet (2/plant) Rayjet (M_4) with six replications in Randomized Block Design (Fig.1). The soil had pH 7.5, $CaCO_3$ 2.6%, sand 31.5%, silt 23.7%, and clay 45.2% in the 0–15 cm depth. Taxonomically, the soil type was classified as fine, alkaline, hyperthermic, calcareous family of *Vertic Ustochrept*. The climate was characterized to be sub-humid tropical with 850 mm of rainfall and temperature difference between mean summer and mean winter months of >5^{0}C. Volumetric soil moisture content at field capacity (FC) and the permanent wilting point (PWP) soil moisture content was determined using pressure plate method. The FC and PWP of the field under study is 29.86% and 20.38% respectively. The available water content of the soil is 9.48%. The bulk density of the soil in field was determined using core sampler having 100 cm^3 volume and oven drying. The bulk density of the field is 1.34 g/cc. The water holding capacity of the soil is 12.7 cm/m depth of soil. The micro-jet irrigation systems were installed in January 2008 and irrigation treatments were imposed in April, 2009. The flow of water to the irrigation treatment was maintained by control solenoid valves and recorded with water meters.

The average daily pan evaporation varied from 3.12 mm in November to as high as 11.64 mm in May. The average discharge from micro-jet 180^0 Fanjet, micro-jet 180^0 Rayet, micro-jet 270^0 Rayet and micro-jet 300^0 Rayet was observed to be 22, 18, 32 and 24 litres per hour per tree respectively, irrigation was accordingly regulated daily by adjusting the operating hours. The Hybrid station controller and solenoid valves were installed in the field for use. The Hybrid Station Controller (E-6, Rain Bird, USA) and Solenoid valve (Hunter, USA) are installed in field. The easy Extra Simple Programmable (ESP) hybrid station controller (4 stations) automatically operated the electronic solenoid valve for the specified programmed duration. It has 3 independent programs having 6 start times and 4 control stations. Each station runs for 4 hours at the most. It has a feature of frequency of irrigation setting also. The water budgeting is also possible fro 10 to 200 % of the time set. Alluminum access tubes (50-mm diameter) were laid into the soil to a depth of 0.70 m within the tree basin and 0.90 m from the trunk considering the zone of maximum feeder root distribution. Soil moisture status in the tree basin was monitored regularly using a Neutron moisture probe at 15-cm, 30-cm, 45-cm, and 60-cm depth of soil using the access tubes. The total month wise quantity of irrigation water automated under various treatments was recorded. The plant growth parameters were recorded during October month of 2008. Increase biometric growth parameters, i. e plant height, and girth and canopy volume, were recorded in October 2009 and 2010. The stock girth was taken 25 cm above the soil surface. The vegetative growth parameters (plant height and tree spread) were recorded and expressed as canopy volume using the formula: canopy volume = 0.54 *HD*2 where *H* and *D* indicate height and diameter, respectively. The leaf canopy temperature of the Nagpur mandarin plants was measured using Infrared thermometer (*AG4-Telatemp*, USA). The canopy temperature was recorded at the interval of 15 days between 13.00 to 14.00 hrs. The infrared thermometer was held 5^0 inclined on the south facing of the tree and 2 m away from the plant. The emissivity of the thermometer was fixed at 0.97.

The total fruits harvested from each tree were weighed for computing the yield. A total of 50 fruits per treatment were randomly taken for quality analysis. The total soluble solids were determined using hand refractometer (0-32 ^{o} Brix). Titratable acidity was determined by titrating the juice against 0.1N NaOH. Percent juice content was determined by extracting the fresh juice and weighing. Five- to seven-month-old leaf samples from non-fruiting terminals at 1.5–1.8 m from the ground covering a minimum of 2% trees in an orchard were collected (Srivastava *et al*., 1999). Leaf samples were later thoroughly washed, ground using a Willey grinding machine to obtain homogenous samples, and subsequently digested in tri-acid mixture of 2 parts $HClO_4$ + 5 parts HNO_3 + 1 part H_2SO_4 (Chapman and Pratt, 1961). Analyses made in acid extracts of leaves consisted of N by auto-nitrogen analyser (Model Perkin Elmer-2410), P using *vanadomolybdophosphoric a*cid method, and K by flame photometry. Total numbers of fruits harvested from each tree were weighed to express the yield by weight. Various fruit quality parameters, viz., total soluble solids (TSS) using hand refractometer, acidity, titrimetrically was determined as per procedures outlined by Ranganna (1986). Data generated for all the parameters were statistically subjected to analysis by Least Significant Difference (LSD) according to the method described by Raghava Rao (1983).

3. Results and discussion

3.1. Micro-jet irrigation scheduling, water use and soil moisture distribution pattern

The automatic controlled micro-jet irrigations are given based on open pan evaporation method and by setting the time for each treatment based on the water need of the plant in every month. The daily maximum open pan evaporation ranged from minimum 3.4 mm per day in December to maximum 12.7 mm per day in May.

The daily weather data recorded from NRCC observatory was used for irrigation scheduling based on evaporation. The water budget fixed from 80-120 % of the total during the different months of the year. Water quantity of the plant on daily basis during March 2009 to February 2011 was measured by water meters, which are installed in the experimental plots. The minimum quantity of water given to the mandarin plants was 70.5 to 97.6 litres per day per plant during November – December, 2009 and it was maximum i.e.124.8 to 151.1 litres per day per plant during May 2009. The quantity of water scheduled using automatic micro-jet irrigation and on daily basis to the Nagpur mandarin plants was minimum (83.2 to 93.2 litres per day per plant) during October month and maximum (151.1 to 178.3 litres/day/plant) during May, 2010 (Table 1). The total quantity of irrigation water scheduled on daily basis is nearly same within 10-15 % variation and according to the treatments and program given in controller. There was no much variation on monthly quantity of water applied to the mandarin plants. The *in situ* soil moisture was monitored using moisture probe during the summer months from March to June. The observations were taken from 1^{st} March, 2009 to 22^{nd} June during both the year 2009 and 2010. The volumetric soil moisture at 15, 30, 45 and 60 cm depth was measured at the interval of 4-5 days. The soil moisture was monitored at higher level (above 25 % wet basis) in the automatic micro-irrigation systems studied. The soil moisture status and its distribution at 0-30 cm depth and 1.2 m spread during the different months in which the automatic micro-jet irrigation systems is presented in Fig. 2. The soil moisture above 30% (w/w) was higher in the micro-jet 180^0 Fanjet followed by other jet systems. Such observations were also seen in Nagpur mandarin (Shirgure *et al.,* 2001d) and acid lime (Shirgure *et al.,* 2000a; 2004a) fruit crops.

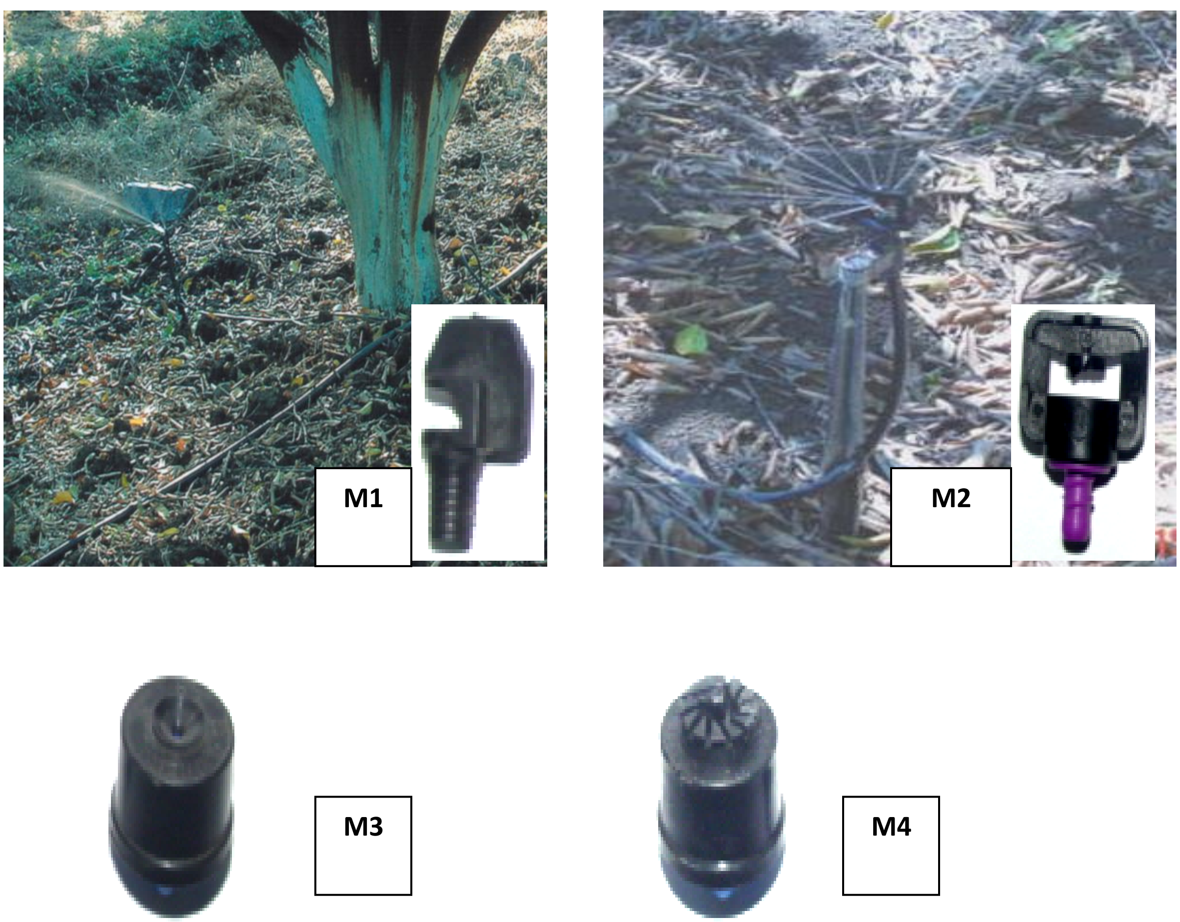

Fig. 1. Micro-jet 180^0 (Fanjet), Micro-jet 180^0 (Rayjet), Micro-jet 270^0 (Rayjet) and Micro-jet 300^0 (Rayjet) used for automatic irrigation in mandarin.

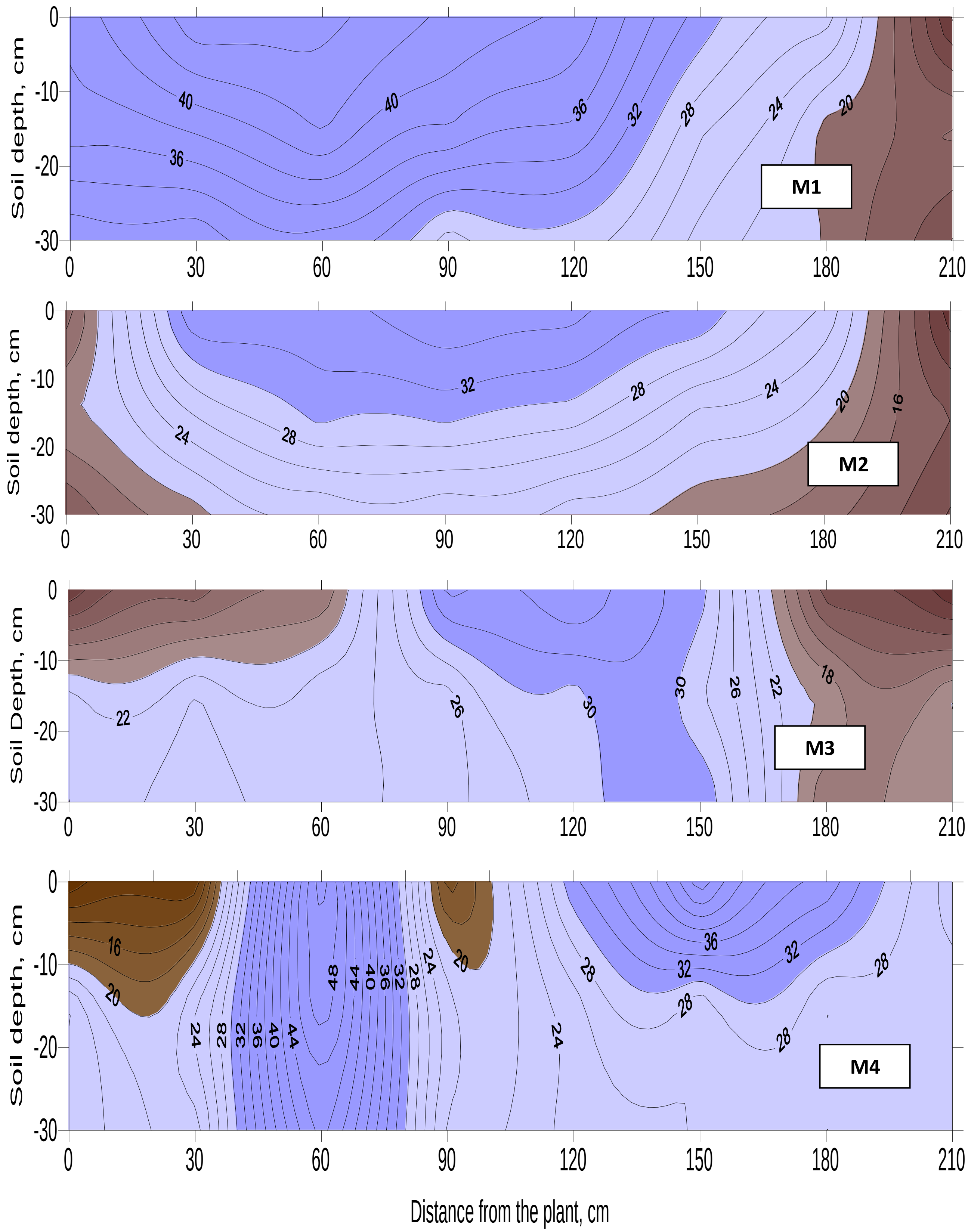

Fig. 2. Soil moisture distribution pattern in tree root zone with micro-jet systems.

3.2. Growth and Canopy volume of Nagpur mandarin plants

The efficacy of an micro-irrigation system is adjudged by the extent to which evapo-transpiration demand of the plant is met at critical growth stages to maintain a constant sap flow, a pre-requisite to dry matter accumulation and its partitioning within the mandarin plant. The canopy volume of plants was significantly affected by the various micro-irrigation systems during the year 2008-2011 (Table 2). However, no response on plant height and stock girth was observed. Maximum cumulative increase in plant canopy volume of 93.68 m^3 was observed with micro-jet 180° Fanjet type (2 $plant^{-1}$) irrigation system followed by micro-jet 180° Rayjet type (2 $plant^{-1}$) irrigation system (90.65 m^3). The micro-jet 300° Rayjet type (2 $plant^{-1}$) irrigation system recorded the lowest increase in canopy volume (71.48 m^3) due to large variation in soil moisture availability from field capacity to as much as 50-70 % of AWC, thereby providing a non-uniform environment for growth. Similar observations were earlier reported with Hamlin orange (Marker and Davies, 1990) and acid lime (Shirgure *et al.,* 2001c; 2003b).

Table 1
Quantity of water (liters / day / plant) with micro-irrigation schedules during March 2009 to February 2010 and March 2010 to February 2011.

Treatments	Year 2009-10							
	March, 09	April, 09	May, 09	June, 09	Oct, 09	Nov-Dec, 09	Jan, 10	Feb, 10
M_1	90.4	142.1	151.1	121.4	98.8	97.6	111.0	99.7
M_2	104.7	116.6	131.2	123.9	91.3	93.9	105.4	92.9
M_3	99.9	139.2	127.7	102.1	82.2	76.9	92.9	79.7
M_4	94.5	116.3	124.8	101.2	79.2	70.5	86.4	76.6
	Year 2010-11							
Treatments	March, 10	April, 10	May, 10	June, 10	Oct, 10	Nov-Dec, 10	Jan, 11	Feb, 11
M_1	110.3	134.4	178.3	160.6	93.2	90.3	98.6	103.4
M_2	103.4	121.7	158.2	139.3	90.7	95.4	94.5	98.8
M_3	95.9	117.7	155.6	162.3	91.2	82.3	97.3	81.3
M_4	93.3	112.1	151.1	149.9	83.6	86.0	93.2	88.7

M_1 - Irrigation with 180^0 Fan type micro-jet (2/plant), M_2 - Irrigation with 180^0 Ray type micro-jet (2/plant).
M_3 - Irrigation with 270^0 Ray type micro-jet (2/plant) and M_4 - Irrigation with 300^0 Ray type micro-jet (2/plant).

Table 2
Growth of Nagpur mandarin with various micro-jet irrigation systems during October 2008-2010.

Treatment	Plant height (m)				Stock girth (cm)				Canopy volume (m^3)			
	2008-09	2009-10	2010-11	Mean	2008-09	2009-10	2010-11	Mean	2008-09	2009-10	2010-11	Mean
M1	5.39	5.82	5.91	5.71	75.42	79.25	81.00	78.56	84.08	97.01	99.96	93.68
M2	5.24	5.63	5.7	5.52	74.08	77.92	81.02	77.67	85.06	92.71	94.17	90.65
M3	5.43	5.74	5.85	5.67	73.75	77.6	79.87	77.07	77.29	90.08	98.04	88.47
M4	5.32	5.53	5.6	5.48	70.00	77.3	79.50	75.60	61.01	74.99	78.44	71.48
LSD *(P = 0.05)*	NS	NS	NS		NS	NS	NS		8.05	10.02	1.08	

M_1 - Irrigation with 180^0 Fan type micro-jet (2/plant), M_2 - Irrigation with 180^0 Ray type micro-jet (2/plant). M_3 - Irrigation with 270^0 Ray type micro-jet (2/plant) and M_4 - Irrigation with 300^0 Ray type micro-jet (2/plant).

3.3. Leaf nutrient status of Nagpur mandarin

The different micro-jet irrigation systems showed a significant response on the leaf nutrient composition of plants (Table 3). Optimum soil moisture distribution during the entire growth period maintained the regulated influx of macro and micro-nutrients within the active rhizosphere zone of plants, and showed that all the Fanjet micro-irrigation system was highly effective over the other three Rayjet micro-irrigation systems. The leaf N, P, and K concentration increased from lower values of 2.03, 0.084, and 1.05 % in micro-jet 300° Rayjet type (2 plant^{-1}) irrigation system to as high as 2.17, 0.084, and 2.38%, respectively, with micro-jet 180^0 Fanjet (2 plant^{-1}). These values were significantly higher than the other micro-jet irrigation systems including micro-jet 180^0 Rayjet (2 plant^{-1}) and micro-jet 270^0 Rayjet (2 plant^{-1}). Similar trends in the uptake of the micro-nutrients (Fe, Mn, Cu and Zn) were observed with various micro-jet systems during 2009-11 (Table 3). Earlier studies on Nagpur mandarin (Shirgure *et al.,* 2001c; Srivastava *et al.,* 2003) and acid lime (Shirgure *et al.,* 2001c; 2004b) as a test crop indicated higher leaf N, P, and K concentration under drip and micro-irrigation systems compared to gravity methods of irrigation.

Table 3
Leaf nutrient status of Napur mandarin under different micro-jet irrigation treatments in 2008-11.

Treatments	Leaf nutrient status						
	Macronutrients (%)			Micronutrients (ppm)			
	N	P	K	Fe	Mn	Cu	Zn
				2009-10			
M_1	2.17	0.084	0.93	81.0	52.4	10.0	17.1
M_2	2.17	0.078	1.04	86.6	48.0	10.4	21.5
M_3	2.11	0.075	0.90	110.0	58.9	9.8	19.5
M_4	2.03	0.084	1.05	140.7	33.0	8.9	14.7
CD(*P*=0.05)	NS	NS	NS	NS	NS	NS	NS
				2010-11			
M_1	2.34	0.12	1.42	85.4	47.6	9.8	24.8
M_2	2.14	0.08	1.13	90.9	56.2	8.8	16.6
M_3	2.12	0.07	0.98	94.5	52.8	9.6	15.8
M_4	2.00	0.09	1.10	91.7	55.1	7.8	19.4
CD(*P*=0.05)	0.18	0.02	0.21	NS	NS	NS	NS

M_1 - Irrigation with 180^0 Fan type micro-jet (2/plant), M_2 - Irrigation with 180^0 Ray type micro-jet (2/plant).
M_3 - Irrigation with 270^0 Ray type micro-jet (2/plant) and M_4 - Irrigation with 300^0 Ray type micro-jet (2/plant).

3.4. Fruit yield and quality of Nagpur mandarin

The fruit yield and quality were highly influenced by the various different degrees under tree micro-jet irrigation systems (Table 4). However, the response of Fanjet micro-jet was more pronounced than the other three micro-jet Ray type irrigation treatments. Higher yield under micro-jet irrigation was attributed to consistently and regulated supply of soil moisture within the plant rhizosphere. The highest mandarin fruit yield was recorded with micro-jet 180^0 Fanjet (2 plant^{-1}) i.e. 29.4 tonnes/ha (Table 5). The moderate yield was observed with micro-jet 300^0 Rayjet (2 plant^{-1}) (26.2 tonnes/ha) followed by micro-jet 270^0 Rayjet (2 plant^{-1}) (23.6 tonnes/ha). The lowest fruit yield(21.9 tonnes/ha) was seen with micro-jet 180^0 Rayjet (2 plant^{-1}) scheduled daily. This clearly indicated that the micro-jet irrigation systems maintained higher as well as continuous soil moisture pattern influenced by the water and nutrient uptake resulting into good quality fruits besides enhancing the yield. The highest average fruit weight (159.8 g.) and lowest acidity (0.77) is observed with micro-jet 180^0 Fanjet (2 plant^{-1}). The TSS (9.47 ^{o}Brix) and juice percent (39.1 %) was more in the with micro-jet 300^0 Rayjet (2 plant^{-1}). The TSS/acidity is indicator of sweetness of the fruit of *Ambia* flush during October-November month. If the TSS to acidity ratio is high means that the fruits have more TSS (total soluble solids) and less acidity. This ratio was analysed for all the treatments (Table 5). The highest TSS/acidity was found with micro-jet 300^0 Rayjet (2 plant^{-1}) (12.3) followed by with micro-jet 270^0 Rayjet (2 plant^{-1}) (10.9). The lowest TSS/acidity (10.8) was observed with micro-jet 180^0 Fanjet (2 plant^{-1}) and with micro-jet 180^0 Rayjet (2 plant^{-1}) micro-jet irrigation systems. An improvement in fruit yield in response to irrigation systems was reported in Navel orange (Fouche and Bester, 1986), sweet orange (Kumar and Bhojappa, 1994), Satsuma mandarin (Peng Young Hong and Rabe, 1999), and Valencia orange (Smajstrala, 1993).

Table 4
Fruit yield and quality of the Nagpur mandarin during 2008-2011.

Treatments	Fruits/plant			Yield (tonnes/ha)			Avg. weight of fruit (g)			TSS (^{0}Brix)			Juice (%)			Acidity(%)		
Year	**2008-2009**	**2009-2010**	**2010-2011**	**2008-2009**	**2009-2010**	**2010-2011**	**2008-2009**	**2009-2010**	**2010-2011**	**2008-2009**	**2009-2010**	**2010-2011**	**2008-2009**	**2009-2010**	**2010-2011**	**2008-2009**	**2009-2010**	**2010-2011**
M_1	500	633	763	18.9	28.7	40.3	136.6	164.4	142.6	8.30	8.57	10.12	33.30	40.42	42.36	0.64	1.12	0.75
M_2	442	278	977	18.8	11.6	35.4	153.9	154.6	149.4	9.00	8.20	9.73	35.40	40.86	41.99	0.70	1.03	0.77
M_3	650	88	963	26.7	4.3	39.9	148.5	171.9	150.8	9.20	7.57	9.63	30.10	38.41	40.60	0.70	1.00	0.72
M_4	821	228	1015	31.5	12.0	35.1	138.7	189.4	151.5	10.10	8.35	9.95	35.90	38.50	43.05	0.64	0.92	0.74
LSD(*P = 0.05*)	NS	140	121	NS	7.6	2.31	NS	23.3	1.24	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 5
Average fruit yield and quality of the Nagpur mandarin during 2008-2011 (pooled data of 3 years).

Treatment	No. of fruits	Yield, t/ha	TSS, ^{0}Brix	Average wt. of fruit, g	Juice, %	Acidity, %	TSS/acid ratio
M_1	632	29.4	9.00	147.9	38.7	0.84	10.8
M_2	566	21.9	8.98	152.6	39.4	0.83	10.8
M_3	567	23.6	8.80	157.1	36.4	0.81	10.9
M_4	688	26.2	9.47	159.81	39.1	0.77	12.3
LSD (P=0.05)	NS	2.17	0.19	4.81	1.21	0.02	NS

M_1 - Irrigation with 180^0 Fan type micro-jet (2/plant), M_2 - Irrigation with 180^0 Ray type micro-jet (2/plant)
M_3 - Irrigation with 270^0 Ray type micro-jet (2/plant) and M_4 - Irrigation with 300^0 Ray type micro-jet (2/plant)

Grieve (1988) reported an increase in fruit yield of Valencia orange by 12% and WUE using micro-irrigation systems by 22% compared with basin method of irrigation. Koo and Smajstrala (1984) observed that fruit quality of Valencia orange was obtained with various trickle irrigation systems. Studies comparing drip systems with flood irrigation also demonstrated comparatively higher fruit weight, rind thickness, and juice content in sweet orange (Kumar and Bhojappa, 1993; Madrid *et al.,* 1989).

4. Conclusion

The sustainable and higher yield and fruit quality of Nagpur mandarin is possible with different degree under tree micro-jet irrigation systems using automatic scheduling daily. The automatic irrigation scheduling using hybrid station controller maintained to the higher water application to the mandarin plants. The Nagpur mandarin yield was highest with micro-jet 180^0 Fanjet (2 $plant^{-1}$) irrigation system. The fruit quality is also affected with automatic micro-jet irrigation systems. Highest fruit weight, TSS, juice percent and TSS/acidity ratio was found with micro-jet 300^0 Rayjet. The automatic micro-jet irrigation could be better substitute for drip irrigation and enhancing the water yield fruit quality, water and fertilizer use efficiency. The irrigation requirement under Ray type micro-jet irrigation systems was substantially optimum compared to Fanjet type micro-jet irrigation system. Depleting water resource in Central India and other citrus growing areas needs more precise management of water in lieu of growing conditions where flowering is regulated by imposing soil-water deficit stress. The micro-jet 180° Fanjet or Rayjet (2 $plant^{-1}$) can be used in commercial production of Nagpur mandarin in Central India. The yield and fruit quality of Nagpur mandarin could be substantially improved by adopting micro-jet irrigation systems and may also be used for better soil moisture pattern which mainly required during fruit development stages.

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