AUTOMATION OF MICRO-JET IRRIGATION SYSTEMS AND PRODUCTION OF NAGPUR MANDARIN (Citrus Reticulata Blanco)

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ABSTRACT

The investigation was done to evaluate the potential of different degree under tree automatic micro-jet irrigation for improving yield and quality of Nagpur mandarin. This study was done on 12–15 years old bearing Nagpur mandarin (on Rough lemon) at National Research Centre for Citrus, Nagpur during 2008–2011. For this four treatments were compared; M1: Irrigation with 180° Fan type micro-jet (2/plant), M2: Irrigation with 180° Ray type micro-jet (2/plant), M3: Irrigation with 270° Ray type micro-jet (2/plant) and M4: Irrigation with 300° Ray type micro-jet (2/plant) with six replications in Randomized Block Design. The hybrid station controller (E-6) and solenoid valves were used for automation of micro-jet irrigation system. The water budget was monitored from 80–120% during October to June months. The quantity of water applied using in micro-jet irrigation systems varied from 97.6 to 151.1 litres/day/plant and 95.4 to 158.2 litres/day/plant during 2009–10 and 2010–11. The moisture distribution pattern, fruit growth rate and leaf nutrient status was also observed under different degree micro-jet treatments. The moisture distribution was observed higher under Irrigation with 180° Fan type micro-jet (2/plant) followed by Irrigation with 180° Ray type micro-jet (2/plant). The highest average increase in canopy volume was recorded in micro-jet 180° (Fanjet) (93.68 m³) and micro-jet (Rayjet) 180° (90.65 m³). Similarly increase in stock girth was more in micro-jet (Fanjet) 180° irrigation system followed micro-jet (Rayjet) 180° irrigation in Nagpur mandarin. There was a significant treatment effect on yield of Nagpur mandarin. The highest yield was recorded with treatment M1 (40.33 t/ha) followed by treatment M3 (39.89 t/ha), whereas the lowest yield was observed in treatment M4 (35.10 t/ha). The fruit quality analysis revealed that TSS was highest (10.12° Brix) with treatment M1 followed by treatment M4 (9.95° Brix). The highest juice content (43.05%) was found with treatment M4 that followed by treatment M1. Fruit acidity was by the different treatments.

Keywords: Automatic Micro-Jet Irrigation Scheduling, Citrus, Micro-Jets, Nagpur Mandarin, Hybrid Station Controller, Fruit Yield and Quality.

1. INTRODUCTION

Citrus is third largest group of fruits grown in India. Nagpur mandarin (Citrus reticulata Blanco) is one of the most important mandarin cultivars of the citrus commercially grown in central India. 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 widely practised, do not meet the requirements of soil water regime in the Nagpur mandarin orchards (Shirgure et al., 2001a). 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 losses and in addition, the growth, yield, and fruit quality are adversely affected (Shirgure et al., 2001b). Due to the scarcity of irrigation, 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-à-vis, flowering and lack of uniformity in moisture distribution within the tree’s root zone as another possible drawback. 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 (Dasberg, 1995; Shirgure et al., 2003). 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 (Murler and Davis, 1990), Satsuma mandarin (Peng Young Hong and Rabe, 1999), and lemon (Cevik et al., 1987). Earlier studies in India comparing drip with flood irrigation in Nagpur mandarin (Shirgure et al., 2001d), sweet orange (Kumar and Bhojappa, 1994), and acid lime (Shirgure et al., 2001c; Shirgure et al., 2004) showed better performance using drip irrigation. The main objective of this investigation is to evaluate the different underwear 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 budded on rough lemon rootstock in a field an experiment was conducted in the block of 0.25 ha with 6 m spacing at farm of NRCC during the year 2008–2011. The treatments consisted of irrigation with 180° micro-jet (2/plant) Fanjet (M1), irrigation with 180° micro-jet (2/plant) Rayjet (M2), irrigation with 270° micro-jet (2/plant) Rayjet (M3) and irrigation with 300° micro-jet (2/plant) Rayjet (M4) with six replications in Randomized Block Design (Figure 1). 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°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 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° Fanjet, micro-jet 180° Rayjet, micro-jet 270° Rayjet and micro-jet 300° Rayjet was observed to be 22, 18, 32 and 24 liters per hour per tree respectively, and 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) were 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. 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 monthwise quantity of irrigation water automated under various treatments was recorded. The plant growth parameters were recorded during month of October 2008. Increase in biometric growth parameters was recorded in October 2009–10. The total fruits harvested from each tree were weighed for computing the yield. The total soluble solids (TSS) using hand refractometer, acidity, titrimetrically were determined as per the procedures. Data generated for all the parameters were statistically subjected to analysis by Least Significant Difference (LSD).

3. RESULTS AND DISCUSSION
The micro-jet systems were operated using automatic controller and irrigations are scheduled based on open pan evaporation 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 (December) to maximum 12.7 mm per day (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 98.8 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 drip irrigation and various duration daily and alternate day basis to the Nagpur mandarin plants was minimum (82.3 to 95.4 litres per day per plant) during October month and maximum (151.1 to 178.3 litres/day/plant) during May, 2010. The total quantity of irrigation water scheduled on daily as well as on alternate day basis was nearly same within 10% 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 1st March, 2009 to 22nd 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 irrigation scheduled.

Efficacy of an irrigation system is judged by the extent to which evapo-transpiration demand of the plant is met at critical growth stages to maintain a constant sap flow, a prerequisite to dry matter accumulation and its partitioning within the plant. The canopy volume of plants was significantly affected by the various micro-irrigation systems during the year.
2008–2011 (Table 1). However, no response on plant height and girth was observed. Maximum cumulative increase in plant canopy volume of 93.68 m³ 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 m³). The micro-jet 300° Rayjet type (2 plant−1) irrigation system recorded the lowest increase in canopy volume (71.48 m³) 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., 2003).

Table 1: Growth of Nagpur Mandarin with Various Micro-Jet Systems during October 2008–2010

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Plant Height (m)</th>
<th>Stock Girth (cm)</th>
<th>Canopy Volume (m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>M1</td>
<td>5.39</td>
<td>5.82</td>
<td>5.91</td>
</tr>
<tr>
<td>M2</td>
<td>5.24</td>
<td>5.63</td>
<td>5.7</td>
</tr>
<tr>
<td>M3</td>
<td>5.43</td>
<td>5.74</td>
<td>5.85</td>
</tr>
<tr>
<td>M4</td>
<td>5.32</td>
<td>5.53</td>
<td>5.6</td>
</tr>
<tr>
<td>LSD (P = 0.05)</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
</tbody>
</table>

Fruit yield and WUE were influenced by the various micro-irrigation systems. However, the response of micro-jet 180° (Fan type and Rayjet type) micro-jets was more pronounced than micro-jet 270° and 300° (2 plant−1) irrigation treatment. Higher yield under micro-jets irrigation method of irrigation was attributed to consistently regulated supply of soil moisture within the plant rhizosphere. Micro-jet 180° (2 plant−1) Fanjet irrigation system recorded higher fruit yield (29.4 tonnes/ha) which was significantly better than microjet 300° (26.2 tonnes/ha) Rayjet, microjet 270° (23.6 tonnes/ha) Rayjet, and Micro-jet 180° Rayjet irrigation system (21.9 tonnes/ha). 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). 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. Various fruit quality parameters, viz., TSS, juice content, and acidity were influenced by various treatments (Table 2).

Table 2: Average Fruit Yield and Quality of the Nagpur Mandarin during 2008–2011 (pooled data)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>No. of Fruits</th>
<th>Yield, t/ha</th>
<th>TSS, °Brix</th>
<th>Average wt. of Fruit, g</th>
<th>Juice,%</th>
<th>Acidity,%</th>
<th>TSS/Acid Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>M1</td>
<td>632</td>
<td>29.4</td>
<td>9.00</td>
<td>147.9</td>
<td>38.7</td>
<td>0.84</td>
<td>10.8</td>
</tr>
<tr>
<td>M2</td>
<td>566</td>
<td>21.9</td>
<td>8.98</td>
<td>152.6</td>
<td>39.4</td>
<td>0.83</td>
<td>10.8</td>
</tr>
<tr>
<td>M3</td>
<td>567</td>
<td>23.6</td>
<td>8.80</td>
<td>157.1</td>
<td>36.4</td>
<td>0.81</td>
<td>10.9</td>
</tr>
<tr>
<td>M4</td>
<td>688</td>
<td>26.2</td>
<td>9.47</td>
<td>159.81</td>
<td>39.1</td>
<td>0.77</td>
<td>12.3</td>
</tr>
<tr>
<td>LSD (P=0.05)</td>
<td>NS</td>
<td>2.17</td>
<td>0.19</td>
<td>4.81</td>
<td>1.21</td>
<td>0.02</td>
<td>NS</td>
</tr>
</tbody>
</table>

Although TSS and juice content from the first to the third year of experimentation did not vary, Microjet 270° irrigation systems resulted in significantly lower TSS (8.8° Brix) compared to180° Fanjet micro-irrigation systems (9.0° Brix) and with microjet 300° Rayjet being the most effective (9.47° Brix). Juice content also showed a similar response and microjet 300° and 180° Rayjet were superior over either Microjet 180° Fanjet Microjet 270° Rayjet irrigation. Microjet 300° registered the lowest acidity (077%) while Microjet 180° Fanjet irrigation resulted in the highest acidity (0.84%) considering all the observations. 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 irrigation requirement under micro-irrigation systems was substantially lower compared to basin irrigation. Depleting water resource availability in Central India and other citrus growing areas of the world, warrants more
investigations in lieu of growing conditions where flowering is regulated by withholding irrigation, *i.e.*, through soil-water deficit stress. The micro-jet 180° or 300° (2 plant−1) can be used in commercial orchards of Nagpur mandarin in Central India. The quantity of water saved by adopting micro-irrigation systems may be used for further expansion of irrigated area under citrus to meet the growing fruit demand.

REFERENCES


