Developing strategies for integrated management of Phytophthora root rot and gummosis in kinnow mandarin (Citrus reticulata)

SHRI KISHAN BAIRWA1*, AKHILESH KUMAR SRIVASTAVA1, PARDEEP KUMAR1, ROOP SINGH MEENA1, CHANDERBHAN2 and RAMSWROOP KOL1

1Agricultural Research Station, S.K. Rajasthan Agricultural University, Sri Ganganagar 335 001, Rajasthan, India
2Krishi Vigyan Kendra, Sri Ganganagar 335 001, Rajasthan, India

ABSTRACT: A field experiment was conducted during 2011-12 to 2013-14 for integrated management of Phytophthora root rot and gummosis on Kinnow mandarin (Citrus reticulata Blanco). Among various treatments tried, bioagents based treatment of stem painting with Bordeaux paste (copper sulphate, lime and water in a 3:3:30 ratio), followed by application of Trichoderma viride ($2 \times 10^7$ cfu/g) at 100g + Pseudomonas fluorescens ($2 \times 10^8$ cfu/gm) at 100g/ tree with carrier material FYM proved most effective which significantly ($P=0.05$) recovered lesion size (22.82%) and reduced feeder root rot index (24.39%). Minimum fruit dropping (20.74%) and maximum fruit yield in terms of number of fruits (1084 fruits/tree) as well as fruit yield (212.84 kg/tree) were also recorded in this treatment and was significantly ($P=0.05$) superior to the control. The treatment module of stem painting with Bordeaux paste followed by application of T. harzianum ($2 \times 10^7$ cfu/g) at 100g/ tree + P. fluorescens ($2 \times 10^8$ cfu/g) at 100g/ tree without carrier material was also found effective and next in order to manage this disease. The reduction in gummosis symptoms were observed mild to moderate in all treatments compared to the control where severe gummosis occurred.

Key words: Bordeaux paste, bioagents, feeder root index, fruit yield and phytophthora root rot

The prevalence of Phytophthora root rot and gummosis in old kinnow mandarin (Citrus reticulata Blanco) orchards is comparatively high in North-Western part of Rajasthan due to high cropping intensity area with heavy soils. Phytophthora spp. are soil-borne pathogens that cause several serious diseases on citrus worldwide. Phytophthora root rot occurs when Phytophthora spp. infect the structural and fibrous roots of rootstock. When pathogen infects above the ground part of the rootstock, the disease is known as Phytophthora foot rot or crown rot. The Phytophthora spp. can also infect the scion, usually starting above the bud union near the ground level. This disease is then known as Phytophthora gummosis, causing necrosis in the inner bark and cambium of the trunk.

Phytophthora root rot, foot rot, and gummosis may cause tree decline and in severe cases even tree are wilted and their death takes place (Graham and Menge, 1999). The general practices to manage this disease are bud union 30-45 cm above the base and soil level at the time of planting, stem painting with Bordeaux paste up to 70 cm and spray with Fosetyl-Al or metalaxyl (Javed et al., 2007). The disease can also be managed by use of resistant rootstocks (Matheron et al., 1998). Several formulations of metalaxyl based fungicides (Ridomil MZ, Matco M-8) are used by citrus growers to control foot rot and gummosis which is a serious disease throughout India (Davis, 1982; Naqvi, 2004). Phytophthora spp. are known to develop resistance to metalaxyl after its repeated use (Gisi et al., 1997; Timmer et al., 1998).

Thind et al. (2009) reported resistance to metalaxyl in P. parasitica isolates collected from Ferozepur district in Punjab where Metalaxyl was being applied for the past over 15 years and was not giving adequate control to foot rot since 4-5 years.

Recently, several growers in South-western districts of Punjab and Rajasthan have complained of inferior disease control by Metalaxyl-based fungicide formulations after several years of regular applications. The basic principle of integrated disease management is any potential management method may be considered, providing that it is eco-friendly and economically-feasible. The pesticide usage is minimized by combination with other non-chemical methods (Singh et al., 2012). Keeping in view of development of resistance against chemicals, an experiment was conducted to find out an integrated management approach for sustainable management of Phytophthora foot rot and gummosis in kinnow orchards.

MATERIALS AND METHODS

A field trial was laid out in 20 years old kinnow orchard at Agricultural Research Station (S K Rajasthan Agricultural University), Sriganganagar, Rajasthan, during 2011-12 to 2013-14. Five treatment combinations using fungicides and talc-based formulations of local isolates of Trichoderma viride, T. harzianum and Pseudomonas fluorescens were made along with the control. These treatments were: T1, stem painting (up to 90 cm) with Bordeaux paste (copper sulphate, lime and water, 3:3:30); T2, stem painting with Bordeaux paste
followed by application of *T. viride* (2 × 10^7 cfu/g) at 100 g/ plant + *P. fluorescens* (2 × 10^8 cfu/g) at 100 g/ plant with carrier material of FYM (10 kg); T₃, stem painting with Bordeaux paste followed by application of *T. harzianum* (2 × 10^7 cfu/g) at 100 g/ plant; + *P. fluorescens* (2 × 10^8 cfu/g) at 100 g/ plant, T₄, foliar spray of Fosetyl-Al (Aliette 80% WP) at 0.2% and T₅, untreated control.

The experiment was conducted in a randomized block design with four replication, five plants of 20 years old age in each replication following plant-to-plant spacing of 6 m × 6 m. The recommended package of cultural practice with flood irrigation were followed. First application of treatments was given at the onset of monsoon, i.e. second fortnight of June and second application done after one month of first application. Per cent recovery in *Phytophthora* lesion size, gummosis incidence, feeder root rot index, canopy volume, fruit dropping (physiological + pathological) and yield in terms of number of fruits/plant and fruit weight (kg/plant) as well were taken into consideration. Per cent recovery in *Phytophthora* lesion size was calculated as per Gaur et al. (2011), feeder root rot index was calculated by using 0-4 scale, where 0, no visible symptoms of feeder root rotting; 1, traces to 25% feeder roots showing rotting; 2, moderate number of feeder roots (26-50%) showing rotting; 3, majority of feeder roots (51-75%) showing rotting; 4, severe number of feeder roots (>75%) showing rotting, canopy volume was calculated by adopting the formula (Bhatnagar et al., 2007) and per cent fruit dropping was calculated on the basis of total number of fruits-plant counted in July. Data were subjected to analysis of variance and means compared and separated at P=0.05.

RESULTS AND DISCUSSION

Average data of 2011-12 to 2013-14 revealed that bioagent-based treatment of stem painting (up to 90 cm) with Bordeaux paste followed by application of *T. viride* (2 × 10^7 cfu/g) at 100g plus *P. fluorescens* (2 × 10^8 cfu/g) at 100 g/ tree with carrier material of farmyard manure (1 kg) was found most effective to control the disease (Table 4). This treatment significantly recovered *Phytophthora* lesion size (22.82%) and reduced feeder root rot index (24.39%) over the control. Minimum fruit dropping (20.74%) and maximum fruit yield in terms of number of fruits/tree and fruit yield (212.84 kg/tree) were also recorded which was significantly higher than the control trees. The next best treatments was stem painting with Bordeaux paste, followed by application of *T. harzianum* (2 × 10^7 cfu/g) at 100 g/ tree plus *P. fluorescens* (2 × 10^8 cfu/g) at 100 g/ tree without carrier material.

This treatment showed recovery in lesion size (19.08%), reduction in feeder root index (15.50%), fruit dropping (24.36%) and fruit yield (194.28 kg/tree). The gummosis symptoms were observed mild to moderate in both the treatments. The data showed that initial and final Phytophthora lesion size was non-significant while per cent recovery significantly (P=0.05) superior to the
Table 3. Integrated management of Phytophthora root rot of Kinnow mandarin (2013-14)

<table>
<thead>
<tr>
<th>Phytophthora lesion size (cm)</th>
<th>Gumm-osisa</th>
<th>Feeder root rot index</th>
<th>Canopy Vol (m³)</th>
<th>Fruit dropping (%)</th>
<th>Fruit yield (kg/tree)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial</td>
<td>Final</td>
<td>Recovery (%)</td>
<td>Initial</td>
<td>Final</td>
<td>Reduction (%)</td>
</tr>
<tr>
<td>T₁</td>
<td>109.85</td>
<td>100.38</td>
<td>7.60 (17.13)</td>
<td>++</td>
<td>2.31</td>
</tr>
<tr>
<td>T₂</td>
<td>120.04</td>
<td>94.10</td>
<td>27.30 (31.15)</td>
<td>+ to ++</td>
<td>1.58</td>
</tr>
<tr>
<td>T₃</td>
<td>164.10</td>
<td>129.98</td>
<td>19.89 (26.40)</td>
<td>+ to ++</td>
<td>1.58</td>
</tr>
<tr>
<td>T₄</td>
<td>74.98</td>
<td>61.90</td>
<td>17.62 (24.73)</td>
<td>++</td>
<td>2.28</td>
</tr>
<tr>
<td>Control</td>
<td>96.90</td>
<td>118.73</td>
<td>(-) 23.41 (28.78)</td>
<td>+++</td>
<td>2.20</td>
</tr>
<tr>
<td>CD (P=0.05)</td>
<td>NS</td>
<td>NS</td>
<td>7.28</td>
<td>0.44</td>
<td>0.59</td>
</tr>
</tbody>
</table>

Arc sine transformed values in parentheses; a + = mild; ++ = moderate; +++ = severe

Table 2. Integrated management of Phytophthora root rot of Kinnow mandarin (2012-13)

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<tr>
<th>Phytophthora lesion size (cm)</th>
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<th>Feeder root rot index</th>
<th>Canopy Vol (m³)</th>
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<th>Fruit yield (kg/tree)</th>
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<td>Final</td>
<td>Recovery (%)</td>
<td>Initial</td>
<td>Final</td>
<td>Reduction (%)</td>
</tr>
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<td>80.98</td>
<td>10.49 (18.53)</td>
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<tr>
<td>T₂</td>
<td>121.98</td>
<td>94.10</td>
<td>27.30 (31.15)</td>
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</table>

Arc sine transformed values in parentheses; a + = mild; ++ = moderate; +++ = severe
control. Similarly, initial and final feeder root index, percent reduction in feeder root index and canopy volume were also found non-significant in these treatments (Tables 1, 2 and 3). The present findings are in agreement with Thind and Sharma (1996), Gaur et al. (2004) and Javed et al. (2007), who reported that stem painting with Bordeaux paste and soil application of bio-agents successfully reduced the disease severity in terms of reduction in lesion size, reduction in feeder root index and increase in fruit yield.

Our findings were also in corroboration with those of Gade and Koche (2012), who recorded reduction in population density, decrease in intensity of root rot and gummosis in Nagpur mandarin in their integrated management module, comprising stem painting with Bordeaux paste, application of 50 g P. fluorescens, application of 25 kg FYM and soil application of micronutrients. In vitro efficacy of biocontrol agents T. viride, T. harzianum and P. fluorescens against Phytophthora spp. in sweet orange and mandarin orange has also been reported by Dhavale et al. (2012) and Thosar et al. (2012). According to Gaur et al. (2011) soil application of T. harzianum found effective to manage Phytophthora root rot/gummosis in Kinnow mandarin. Thus, it can be concluded that integration of chemical and biological control under field condition is necessary for successful management of root rot and gummosis in Kinnow mandarin and also provides options for fruit growers to manage resistance problem in Phytophthora spp. against recent fungicides.

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