Prunus mume Clones as Rootstocks for ‘Aurora-1’ Peach in São Paulo State, Brazil and Planting Density

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Abstract
Dwarf rootstocks allow high density in peach (Prunus persica) orchards and increase productivity. Since 1998, a research project has been carried out at the Faculdade de Ciências Agrárias e Veterinárias (FCAV/UNESP), Jaboticabal Campus, Brazil, involving clones of Prunus mume as rootstocks for peach. In this research, two genotypes (‘Clone 15’ and ‘Rigitano’), propagated by herbaceous cuttings, were tested as rootstocks for ‘Aurora-1’ peach in three in-row spacings: 6 m x 2 m, 6 m x 3 m and 6 m x 4 m. The experiment was carried out under field conditions in Vista Alegre do Alto (21°10'14"S, 48°37'45"W, 700 m of altitude), São Paulo State, Brazil. The region has an average accumulation of temperatures \( \leq 7.0^\circ\text{C} \) of 17.9 h per year. Evaluations were taken in 2005 and 2006 (2nd and 3rd year after planting, respectively). There were no differences between the two rootstocks on fruit quality, yield and productivity, and no incompatibility symptoms were found on both scion/rootstock combinations. ‘Rigitano’ and ‘Clone 15’ are recommended as rootstocks for ‘Aurora-1’ peach, and the 6 m x 2 m spacing produced the highest fruit diameter and productivity per ha for ‘Aurora-1’.

INTRODUCTION
In Brazil, there are 20,194 ha of peaches and nectarines, and the production was 220,739 t in 2010. With this production, Brazil ranks 14th in the world. However, the Brazilian average is only 10.93 t/ha, which is below the world average of 13.34 t/ha (FAO, 2012).

In spite of significant results achieved with Brazilian breeding programs for stone fruit cultivars (Barbosa et al., 1997; Raseira and Nakasu, 1998, 2002), peach culture in Brazil also needs both a rootstock genetic improvement program and new technologies to increase productivity. Thus, dwarfing rootstocks with desirable horticultural characteristics and development of new technologies for high density orchards can significantly increase productivity like what has happened with the apple industry in Brazil.

Prunus mume (Sieb. et Zucc.) is reported to be highly resistant to crown gall caused by Pseudomonas tumefaciens (Smith, 1925) (=Agrobacterium tumefaciens) and can be used as a rootstock for stone fruits (Campo Dall’Orto et al., 1992). In 1998 a research project at the Faculdade de Ciências Agrárias e Veterinárias (FCAV/UNESP),
Jaboticabal Campus, São Paulo State, Brazil, was initiated to use *Prunus mume* clones as rootstocks for peach. The research began with vegetative propagation by herbaceous cuttings of selected clone numbers 02, 05, 10 and 15 (Nachtigal et al., 1999). These genotypes had the best propagation success (Nachtigal et al., 1999; Mayer et al., 2001; Mayer and Pereira, 2004). Clones 05, 10 and 15 are resistant to *Meloidogyne javanica* (Mayer et al., 2003) and *M. incognita* (Mayer et al., 2005a). However, they are susceptible to ring nematode *Mesocriconema xenoplax* (Mayer et al., 2005b).

‘Aurora-1’ peach budded onto ‘Clone 05’, ‘Clone 10’ and ‘Clone 15’ rootstocks were grafted compatible (Mayer et al., 2005c; Pereira and Mayer, 2005; Mayer et al., 2006) and had shown some advantages compared to ‘Okinawa’ rootstock [*Prunus persica* (L.) Batsch], which is traditionally used in southeastern Brazil. According to Mathias et al. (2008), fruit on trees of ‘Aurora-1’/‘Clone 10’ or ‘Aurora-1’/‘Clone 15’ had the largest soluble solids content, transversal and longitudinal fruit diameter, and increased fruit fresh weight, comparative to ‘Aurora-1’ budded onto ‘Okinawa’ propagated by seeds or herbaceous cuttings.

These promising results led to the release of the ‘Rigitano’ rootstock (Pereira et al., 2007), initially labeled as ‘Clone 10’, for its lower vigor among the FCAV/UNESP *P. mume* clones studied (Mayer and Pereira, 2006). ‘Rigitano’ is the first clonal rootstock for peach released in Brazil. Low tree vigor due to dwarfing rootstocks have been reported to improve fruit quality, such as red blush, increased size and sweetness (Beckman and Lang, 2003).

However, there is little information about clonal rootstocks for peaches in combination with reduced in-row spacings in Brazil. The objective of this trial was to study ‘Rigidano’ and ‘Clone 15’ as rootstocks for ‘Aurora-1’ peach in three, in-row spacing treatments.

**MATERIALS AND METHODS**

‘Rigitano’ and ‘Clone 15’ rootstocks (*Prunus mume* Sieb. et Zucc.) were propagated by herbaceous cuttings in an intermittent mist system with a 5 sec dip of 2,000 mg/L of indolebutyric acid (IBA) (Mayer et al., 2001). Later, the rooted cuttings were placed in plastic bags (28 cm x 18 cm) with commercial soilless media and budded with ‘Aurora-1’ peach by chip budding.

The experiment was established in the field at the Santa Alzira Farm, Vista Alegre do Alto (21°10’14”S, 48°37’45”W, 700 m of altitude), São Paulo State, Brazil. The climate is subtropical humid with a dry winter season, according Köppen’s classification. This region has an average accumulation of temperatures \( \leq 7.0^\circ C \) of 17.9 hours per year (Yamanaka, 1992). The soil is a Hapludalfs with sandy medium texture (Oliveira et al., 1999) and was prepared according to pre-plant recommendations (Raij et al., 1996; Pereira et al., 2002).

Holes (50 cm x 50 cm x 50 cm) were pre-dug at 6 m x 2 m, 6 m x 3 m and 6 m x 4 m spacing and fertilized (Pereira et al., 2002). After 30 days, the nursery plants were planted (August, 2003) and were pruned back at 50 cm to stimulate lateral bud break.

Recommended cultural practices for peach culture in a subtropical climate were applied, including micro-sprinkler irrigation, hydrogen cyanamide sprays and two prunings per year (dormant and summer pruning at post harvest) (Pereira et al., 2002). Winter pruning was done in July each year (2005 and 2006) followed by a hydrogen cyanamide application at 0.29% of active ingredient (Nienow, 1997; Pereira et al., 2002).

Evaluations were done in the 2nd and 3rd years (2005 and 2006) after planting for the following variables: 1) number of 1-year-old shoots/tree after winter pruning, evaluated in one tree per plot; 2) fruit number/shoot before thinning; 3) fruit number/shoot after thinning; 4) number of new shoots/1-year-old shoot, evaluated in 20 shoots/plot at 40 days after bloom; 5) fruit number/tree, evaluated at the beginning of harvest period; 6) transversal fruit diameter (mm) at the equatorial suture line and longitudinal fruit diameter (mm) measured with a digital caliper; 7) fruit fresh weight (g) evaluated from 20 ripe fruits randomly harvested; 8) yield/tree (kg/tree), estimated by
fruit number/tree and fruit fresh weight; and 9) productivity/ha (t/ha), estimated by yield/tree and tree number/ha for each in-row spacing (833, 555 or 416 trees/ha, for 6 m x 2 m, 6 m x 3 m or 6 m x 4 m, respectively).

The experimental design was a randomized block, 2 x 3 factorial, with the rootstock factor at two levels (‘Rigatino’ and ‘Clone 15’) and the in-row spacing factor at three levels (6 m x 2 m, 6 m x 3 m and 6 m x 4 m) with four replications. Each plot constituted 12 linear meters, with either 6, 4 or 3 trees for each particular in-row spacing. Data were analyzed by the F-Test, and means compared by Tukey’s Test at 5%.

RESULTS AND DISCUSSION

There was no rootstock influence on fruit number/shoot before and after thinning, number of new shoots/1-year-old-shoot and fruit number/tree (Table 1) in 2005 and 2006. The high production of 1-year-old-shoots (more than 200 per plant) in both rootstocks in the 2nd and 3rd year after planting, confirmed early and high yields. Low chill rootstocks are recommended for low chill peach cultivars cultivated under marginal low chill conditions, especially to enhance leaf bud break and produce sufficient leaf area (Maneethon et al., 2007).

In 2005, 34% of fruits were removed by hand thinning, confirming the high fruit set on 2nd year trees. However, environmental conditions in 2006 were adverse to fruit set, with lower relative humidity from May to September (70.1%, 66.4%, 60.2%, 52.5% and 60.4%, respectively) and longer sunlight days (249.4 h, 267.7 h, 271.4 h, 305.6 h and 229.7 h, respectively) compared to historical averages (73.4%, 70.5%, 64.1%, 58.2% and 61.4% for air relative humidity and 228.1 h, 223.0 h, 248.4 h, 240.3 h and 198.7 h for sunlight from May to September, respectively) (Volpe, 2006a, 2006b). Some days during bloom season, air relative humidity was below 12% and may have had a negative effect on pollen viability. With these adverse climate conditions, fruit thinning was not necessary in 2006 (Table 1). The new shoots/fruit ratio for ‘Aurora-1’ was considered satisfactory in both rootstocks with at least 3.2 new shoots per fruit at thinning time.

For both rootstocks, the high productive capacity of ‘Aurora-1’ peach (more than 265 fruits/tree) in 2005 stands out (Table 1). With the adverse climate conditions, fruit number per tree decreased in 2006, showing a drop of 2.2 times compared to the previous year’s production. High summer and fall air temperatures and low winter chill hours makes peach cultivation a risky activity in tropical and subtropical climates. However, with technologies like micro-sprinkler irrigation, hydrogen cyanamide in “winter”, bi-annual pruning (May-June and Oct-Nov) (Nienow, 1997; Pereira et al., 2002) and adapted genotypes of peach, production (August to October) is possible and profitable for Northwest São Paulo State peach growers (Pereira et al., 2002).

In the second year (2005) after planting, in-row spacing had no influence on shoot number/tree, fruit number/shoot before and after thinning, new shoots/1-year-old-shoot and fruit number/tree (Table 1). However, for the third year (2006) after planting, all these variables were significantly affected by in-row spacing. The values observed in the traditional spacing of 6 m x 4 m recommended for Northwest São Paulo State area (Pereira et al., 2002) had poorer results, such as fewer 1-year-old shoots/tree, less fruit number/shoot before and after thinning, fewer new shoots/1-year-old shoot and lower fruit number/tree, compared to the 6 m x 2 m in-row spacing. The 6 m x 2 m had 2.7 times the fruit number/tree. According to Barbosa et al. (1999), ‘Aurora-1’ was the best cultivar in orchards with 4 m x 1.5 m spacing that received biennial drastic pruning after harvest among 13 peach and nectarines genotypes in a low chill region (average accumulation of temperatures ≤ 7.0°C of 40 hours per year, 22°41’S, 46°43’W).

Likely, the shadow of each tree decreased the negative effect of excessive sunlight (i.e., heat) and low air relative humidity on buds and fruits, thus improving fruit and tree development. Besides these effects, the smaller in-row spacing (6 m x 2 m) doubled tree number/ha (416 to 833 trees/ha) in relation to the traditional spacing of 6 m x 4 m recommended for Northwest São Paulo State (Pereira et al., 2002), and subsequently increased productivity significantly (Table 2). Thereby, reducing in-row spacing to 6 m x
2 m is a new technology that can be adopted in low chill areas in Brazil with the goal of improved fruit quality and productivity.

There were no differences between both studied rootstocks on the transversal and longitudinal fruit diameter, yield/tree and productivity/ha (Table 2). A significant difference was detected in 2005 for fruit fresh weight, when ‘Aurora-1’ peaches were largest on ‘Clone 15’. However, in 2006 this difference was not significant.

The high yield/tree (> 23 kg/tree) in both rootstocks stands out for the second year (2005) after planting. This result in productivity is more than 14.5 t/ha. However, the adverse climate conditions decreased yield/tree and productivity/ha in 2006 (Table 2). For ‘Aurora-1’/‘Okinawa’ at the same soil and climate conditions, the yield/tree in 2005 was 19.23 and 22.27 kg/tree and the productivity was 11.61 and 13.53 t/ha, with the rootstock propagated by seeds or herbaceous cuttings, respectively (Mayer and Pereira, 2012). Thus, P. mume ‘Clone 15’ and ‘Rigitano’ can provide advantages compared to the traditional ‘Okinawa’ rootstock.

Only longitudinal fruit diameter and yield/tree in 2005 and fruit fresh weight in 2006 were not influenced by in-row spacing (Table 2). For the other variables, significant differences were detected and again, the worst results were observed for the traditional in-row spacing (6 m x 4 m) with smaller transversal fruit diameter and productivity in both years. In areas with higher chill accumulation like Georgia, USA, Rieger and Myers (1997) measured yield/tree, yield efficiency and fruit weight of ‘Garnet Beauty’ peach and verified that results were better on 2 m in-row than 1 m.

The most important effect of spacing was on productivity/ha (Table 2). In the 6 m x 2 m, the productivity was 20.46 t/ha (2005) and 18.19 t/ha (2006), both statistically higher than 6 m x 4 m. Even with adverse climatic conditions in 2006 when compared to historical data (e.g., higher temperatures and sunlight), the 6 m x 2 m spacing still had satisfactory productivity (18.19 t/ha).

CONCLUSIONS

There were no differences between the two rootstocks in fruit quality, yield and productivity, and furthermore, no incompatibility symptoms were found between P. mume rootstocks and peach. ‘Rigitano’ and ‘Clone 15’ can be used successfully as rootstocks for ‘Aurora-1’ peach, and the 6 m x 2 m spacing yielded the largest fruit and productivity per ha for the ‘Aurora-1’ peach cultivar.

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Literature Cited


Table 1. Shoot growth effects of *P. mume* clonal rootstocks and in-row spacing in ‘Aurora-1’ peach (2\textsuperscript{nd} and 3\textsuperscript{rd} year in field) at Vista Alegre do Alto, São Paulo State, Brazil.

<table>
<thead>
<tr>
<th>Rootstock</th>
<th>1-year-old shoot number/tree</th>
<th>Fruit number/shoot before thinning</th>
<th>Fruit number/shoot after thinning</th>
<th>New shoots number/1-year-old shoot</th>
<th>Fruit number/tree</th>
</tr>
</thead>
<tbody>
<tr>
<td>‘Rigitano’</td>
<td>208.1 a</td>
<td>246.5 a</td>
<td>2.1 a</td>
<td>0.7 a</td>
<td>1.4 a</td>
</tr>
<tr>
<td>‘Clone 15’</td>
<td>238.7 a</td>
<td>207.1 b</td>
<td>2.1 a</td>
<td>0.7 a</td>
<td>1.4 a</td>
</tr>
<tr>
<td>F rootstock</td>
<td>2.99\textsuperscript{ns}</td>
<td>5.75\textsuperscript{*}</td>
<td>0.01\textsuperscript{ns}</td>
<td>0.002\textsuperscript{ns}</td>
<td>0.02\textsuperscript{ns}</td>
</tr>
<tr>
<td>Spacing</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 x 2 m</td>
<td>222.0 a</td>
<td>276.3 a</td>
<td>2.5 a</td>
<td>1.0 a</td>
<td>1.6 a</td>
</tr>
<tr>
<td>6 x 3 m</td>
<td>244.3 a</td>
<td>243.3 a</td>
<td>2.1 a</td>
<td>0.7 ab</td>
<td>1.4 a</td>
</tr>
<tr>
<td>6 x 4 m</td>
<td>203.9 a</td>
<td>160.9 b</td>
<td>1.8 a</td>
<td>0.3 b</td>
<td>1.2 a</td>
</tr>
<tr>
<td>F spacing</td>
<td>1.74\textsuperscript{ns}</td>
<td>17.44\textsuperscript{**}</td>
<td>1.39\textsuperscript{ns}</td>
<td>5.65\textsuperscript{*}</td>
<td>2.49\textsuperscript{ns}</td>
</tr>
<tr>
<td>F rootst. x spacing</td>
<td>0.24\textsuperscript{ns}</td>
<td>0.63\textsuperscript{ns}</td>
<td>3.55\textsuperscript{ns}</td>
<td>0.07\textsuperscript{ns}</td>
<td>2.36\textsuperscript{ns}</td>
</tr>
<tr>
<td>F blocks</td>
<td>0.82\textsuperscript{ns}</td>
<td>4.13\textsuperscript{*}</td>
<td>1.27\textsuperscript{ns}</td>
<td>0.32\textsuperscript{ns}</td>
<td>1.61\textsuperscript{ns}</td>
</tr>
<tr>
<td>CV (%)</td>
<td>19.4</td>
<td>17.7</td>
<td>36.7</td>
<td>67.4</td>
<td>26.4</td>
</tr>
</tbody>
</table>

Within each column, means followed by the same letter are not significantly different by 5% Tukey’s Test. \textsuperscript{ns}, \textsuperscript{*}, \textsuperscript{**} denotes non-significance, significance at *P* < 0.05 and 0.01, respectively.
Table 2. Fruit size and yield of *P. mume* clonal rootstocks and 3 in-row spacings for ‘Aurora-1’ peach (2nd and 3rd year in field) at Vista Alegre do Alto, São Paulo State, Brazil.

<table>
<thead>
<tr>
<th>Rootstock</th>
<th>Transversal fruit diameter (mm)</th>
<th>Longitudinal fruit diameter (mm)</th>
<th>Fruit fresh weight (g)</th>
<th>Yield/tree (kg)</th>
<th>Productivity (t/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>‘Rigitano’</td>
<td>55.3 a 59.9 a</td>
<td>65.9 a 70.7 a</td>
<td>88.4 b 121.2 a</td>
<td>23.7 a 14.5 a</td>
<td>14.5 a 9.9 a</td>
</tr>
<tr>
<td>‘Clone 15’</td>
<td>55.8 a 59.6 a</td>
<td>66.8 a 70.0 a</td>
<td>92.9 a 123.3 a</td>
<td>25.5 a 14.0 a</td>
<td>15.2 a 9.4 a</td>
</tr>
<tr>
<td>F rootstock</td>
<td>1.23 ns 0.11 ns</td>
<td>3.69 ns 0.49 ns</td>
<td>4.52* 0.20 ns</td>
<td>0.35 ns 0.10 ns</td>
<td>0.10 ns 0.18 ns</td>
</tr>
<tr>
<td>Spacing</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 x 2 m</td>
<td>55.8 a 61.4 a</td>
<td>66.8 a 72.2 a</td>
<td>92.9 a 129.0 a</td>
<td>24.6 a 21.8 a</td>
<td>20.5 a 18.2 a</td>
</tr>
<tr>
<td>6 x 3 m</td>
<td>56.3 a 59.4 ab</td>
<td>66.8 a 70.1 ab</td>
<td>93.4 a 120.7 a</td>
<td>26.6 a 13.8 b</td>
<td>14.8 ab 7.7 b</td>
</tr>
<tr>
<td>6 x 4 m</td>
<td>54.6 b 58.4 b</td>
<td>65.4 a 68.7 b</td>
<td>85.8 b 117.0 a</td>
<td>22.6 a 7.2 c</td>
<td>9.4 b 3.0 c</td>
</tr>
<tr>
<td>F spacing</td>
<td>6.68** 4.20* 4.36* 4.37* 5.42* 2.30 ns</td>
<td>0.58 ns 28.26**</td>
<td>8.22** 51.04**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>F rootst. x spacing</td>
<td>1.95 ns 0.77 ns 3.38 ns 0.08 ns 1.69 ns 0.68 ns 1.31 ns 1.94 ns 0.93 ns 1.38 ns</td>
<td>F blocks</td>
<td>2.78 ns 1.33 ns 1.44 ns 1.69 ns 1.12 ns 0.67 ns 0.64 ns 1.90 ns 0.48 ns 1.20 ns</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CV (%)</td>
<td>1.7</td>
<td>3.5</td>
<td>1.7 3.4 5.7 9.4 30.4 27.3 36.8 32.1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Within each column, means followed by the same letter are not significantly different by 5% Tukey’s Test. ns, *, ** denotes non-significance, significance at *P* < 0.05 and 0.01, respectively.