Short communication

Manipulation of fruit set and stylar-end fruit split in ‘Nova’ mandarin hybrid

G.H. Barry *, J.P. Bower

Outspan Citrus Centre, Outspan International, P.O. Box 28, Nelspruit, 1200, South Africa

Accepted 12 March 1997

Abstract

‘Nova’ mandarin hybrid is prone to stylar-end fruit splitting when produced in solid, isolated blocks. In addition, self-incompatibility and weak parthenocarpy result in poor fruit set. Calcium nitrate application during flowering reduced fruit split, while girdling using a Spanish girdling tool increased fruit set dramatically. A strategy to increase export packout is presented. © 1997 Elsevier Science B.V.

Keywords: ‘Nova’ mandarin; Fruit set; Stylar-end fruit split

1. Introduction

‘Nova’ mandarin ([Citrus paradisi Macf. X C. reticulata L.] X C. reticulata L.), a ‘Fina’ Clementine (C. reticulata L.) and ‘Orlando’ tangelo (C. paradisi Macf. X C. reticulata L.) hybrid, is one of several citrus cultivars prone to stylar-end fruit splitting (Garcia-Luis et al., 1994; Almela et al., 1994). This phenomenon in ‘Nova’ has been reported in Spain by Garcia-Luis et al., 1994 and Almela et al., 1994, as well as Bono et al. (1988); and in Israel by Monselise et al. (1986) and Goren et al. (1992). Saunt (1990) reported on small cracks appearing at the stylar-end of ‘Nova’ fruit, but did not mention splitting per se.

Stylar-end fruit splitting has also been observed in South Africa when ‘Nova’ is planted in solid, isolated blocks (Burdette, 1989; Barry et al., 1992). The lack of seeds, which is essential for the production of auxins for peel growth and cell flexibility (Garcia-Luis et al., 1994), may be implicated in fruit split, since this phenomenon hardly

* Corresponding author.
occurs in seedy fruit (pers. obs.). However, Gustafson (1939) reported that higher auxin levels were found in parthenocarpic citrus fruit compared with seeded fruit. Under local conditions, up to 30% fruit split is common, occasionally reaching 45% (Barry et al., 1992; Barry and Veldman, 1993). A weak stylar-scar and the presence of a secondary fruitlet (Garcia-Luis et al., 1994) and resultant flavedo cell inflexibility (Kaufman, 1970) manifest as a stylar-end fruit split during the 8–10-week period before fruit maturity (Barry and Veldman, 1993). In South Africa, splitting at the fruit equator has not been observed, while creasing (flavedo breakdown) is not viewed by the authors as the primary cause of ‘Nova’ fruit splitting.

In addition to the problems of fruit split, ‘Nova’ is self-incompatible and weakly parthenocarpic (Bono et al., 1988), resulting in cross-pollination, which is being practised in Florida (Futch and Jackson, 1993) as required to ensure regular cropping. Unfortunately, this also results in excessive numbers of seed that the European fresh fruit market (Saunt, 1990) do not prefer. When planted in solid blocks seedless fruit are produced and fruit set is generally poor, especially in the initial years of flowering (pers. obs.).

Hand-in-hand with poor fruit set is large fruit size, where most of the fruit have unacceptably coarse rind textures, and are inclined to granulate and display slower rind colour development, often with internal fruit maturity preceding rind colour (Bono et al., 1988; Saunt, 1990). Since poor fruit set may be a general characteristic of ‘Nova’ (Goren et al., 1992), it is necessary to force young ‘Nova’ trees into production, producing smaller, high-quality fruit.

In South Africa, the research on ‘Nova’ has been focused on increasing export packout per hectare. Gibberellic acid (GA), which is commonly used on mandarins to increase fruit set, and girdling were tested to set a larger crop. Thereafter, potassium and calcium nitrates and auxins were tested in an attempt to reduce stylar-end fruit split to commercially acceptable levels. This paper reports on the results of this research and provides practical hints, ultimately to achieve higher overall export packouts.

2. Materials and method

2.1. Sites

The study was carried out over two seasons at two sites each season, with the same experimental design and treatments at each site. During the 1992/1993 season, the sites were: Zebediela Estates, Zebediela, C. Transvaal (24°20’S, 29°15’E; 1150 m.a.s.l.; cool, inland citrus production area) and La Rochelle Estates, Malelane, E. Transvaal (25°30’S, 31°30’E; 380 m.a.s.l.; hot, humid citrus production area). During the 1993/1994 season, the former site was not used due to extreme drought conditions prevailing in that area. Therefore, another site at Ryton Estates, Elands Valley, E. Transvaal (25°36’S, 30°35’E; 880 m.a.s.l.; cool, inland citrus production area) was used in conjunction with the La Rochelle site. The trees at Zebediela were planted in 1985 on rough lemon rootstock, in 1990 at La Rochelle on ‘Troyer’ citrange rootstock and 1991 at Ryton on ‘Troyer’ citrange rootstock.
2.2. Treatments

2.2.1. 1992/1993 season

The fruit setting treatments included 10 mg l⁻¹ GA₃ applied at 100% petal drop (PD), 80% fruitlet drop (FD) in mid-January, and girdling at 100% PD by making a single cut through the bark and cambium using a Spanish girdling tool. This was done above the budunion and below the scaffold branches on recently irrigated trees. The fruit split reduction treatments included 2% Ca(NO₃)₂ and 4% KNO₃ applied as separate treatments at 60% full bloom (FB), 100% PD and 80% FD. There was also an untreated control.

2.2.2. 1993/1994 season

A total of 15 mg l⁻¹ GA₃ and girdling were applied as separate treatments, each at 100% PD as fruit set treatments. The fruit split reduction treatments included 2% Ca(NO₃)₂ and 4% KNO₃ as separate treatments at 70% FB. In addition, Folicur, a fungicide that is active against Alternaria brown spot, was applied as a double spray at 160 mg l⁻¹ at 50 and 100% PD in an attempt to minimise fruit split or drop. Other treatments were girdling and fruit split reduction treatments [KNO₃, Ca(NO₃)₂ and Folicur] applied in combination. An auxin, 2,4-dichlorophenoxyacetic acid (2,4-D) was applied at 100 mg l⁻¹ ad interim, as separate treatments at 100% PD and 75% FD, in an attempt to thin fruit that were likely to split (see Table 1).

2.3. Experimental design and analysis

A complete randomized block design was used, with five replications of four-tree plots. Analysis of variance was conducted using the Number Cruncher Statistical System and the means were compared with Fisher's LSD.

Table 1
The effect of various treatments on fruit set and stylar-end fruit split of ‘Nova’ mandarin hybrid at La Rochelle Estates, Malelane during the 1993/1994 season

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Fruit set (no. tree⁻¹)</th>
<th>% Split</th>
<th>Yield (kg tree⁻¹)</th>
<th>Fruit mass (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>112ᵇ,c</td>
<td>26.0ᵇ</td>
<td>11.9ᵇ</td>
<td>147.8ᵇ,d,e</td>
</tr>
<tr>
<td>GA₃</td>
<td>174ᵇ,c</td>
<td>44.8ᶜ</td>
<td>11.7ᵇ</td>
<td>132.3ᵃ,b,c,d</td>
</tr>
<tr>
<td>Girdling</td>
<td>220ᵈ,c</td>
<td>42.4ᶜ,d</td>
<td>19.1ᶜ</td>
<td>117.0ᵃ,b</td>
</tr>
<tr>
<td>Ca(NO₃)₂</td>
<td>25ᵃ</td>
<td>15.8ᵃ</td>
<td>3.1ᵃ</td>
<td>152.4ᵈ,e</td>
</tr>
<tr>
<td>KNO₃</td>
<td>98ᵃ,b</td>
<td>20.0ᵃ</td>
<td>10.8ᵇ</td>
<td>146.8ᵇ,d,e</td>
</tr>
<tr>
<td>Folicur</td>
<td>103ᵇ,c</td>
<td>29.2ᵇ,c</td>
<td>11.0ᵇ</td>
<td>149.0ᵇ,d,e</td>
</tr>
<tr>
<td>Girdling + Ca(NO₃)₂</td>
<td>260ᵈ,c</td>
<td>22.4ᵃ</td>
<td>24.6ᶜ</td>
<td>126.4ᵃ,b,c,d</td>
</tr>
<tr>
<td>Girdling + KNO₃</td>
<td>314ᵈ</td>
<td>24.8ᵇ</td>
<td>23.2ᶜ</td>
<td>97.6ᵃ</td>
</tr>
<tr>
<td>Girdling + Folicur</td>
<td>267ᵈ,c</td>
<td>37.6ᶜ,d</td>
<td>20.5ᶜ</td>
<td>120.4ᵃ,b,c</td>
</tr>
<tr>
<td>2,4-D (100% PD)</td>
<td>30ᵃ</td>
<td>22.4ᵃ</td>
<td>6.8ᵃ,b</td>
<td>173.4ᵉ</td>
</tr>
<tr>
<td>2,4-D (75% FD)</td>
<td>68ᵃ</td>
<td>19.2ᵃ</td>
<td>8.2ᵃ,b</td>
<td>144.8ᵇ,c,d,e</td>
</tr>
</tbody>
</table>

Means not followed by the same letter are significantly different at the indicated level of significance (Fisher's LSD).
2.4. Fruit split, fruit set and yield determination

The number of split fruit was recorded weekly from early February through to harvest in late April. At harvest, fruit counts per tree were conducted and the total number of the fruit set at the end of November drop was calculated as the sum of the numbers of fruit split and fruit harvested, hereafter referred to as the total fruit set. From this data, the percentage total fruit split was determined. Yield per tree was determined by weighing actual bags harvested and fruit size distribution by measuring the equatorial diameter of 200 randomly selected fruit per treatment, and fruit mass by dividing harvested yield by number of fruit harvested. The internal fruit quality was analysed using standard fruit testing procedures.

3. Results

3.1. 1992 / 1993 season

3.1.1. La Rochelle

Due to young tree age, fruit set was extremely poor for all treatments except girdling. Girdled trees set a significantly higher number of fruit compared with other treatments, nearly ten times the amount. It appeared to be feasible to force young, nonbearing ‘Nova’ trees into production by girdling during the PD period.

3.1.2. Zebediela

Girdling at 100% PD significantly ($P < 0.01$) increased the yield over all other treatments (121.1 vs 74.4 kg tree$^{-1}$ for girdled and control treatments, respectively). Yields for the other treatments were similar to the control, although GA$_3$ yielded slightly less than the control (50.6 to 63.0 kg tree$^{-1}$ depending on the time of application). The increase in yield was due to a dramatic increase in fruit number as a direct result of girdling ($P < 0.01$), with double the number of fruit being harvested for girdling compared with control treatments (823 vs. 412 fruit tree$^{-1}$, respectively).

All treatments, except girdling, had similar trends in fruit size distribution. The girdled treatment produced significantly less fruit of counts (fruit per 10-kg carton) 48 and 53, and more of counts 60, 69, 75 and 84. This was further demonstrated by fruit mass; girdling decreased fruit mass by 18.3% from 180.6 to 147.1 g fruit$^{-1}$ for control and girdled treatments, respectively. All other treatments had a mean fruit mass of 181.7 ± 10.5 g fruit$^{-1}$. Since the primary objective was to optimise export packout per tree, a smaller and more favourable fruit size are required to help achieve this objective. This may also have positive effects on fruit quality factors. Although the internal quality of the fruit sampled per treatment showed no significant differences for the various criteria measured, there was a tendency to higher acid levels (0.82 vs 0.77%) for fruit from girdled trees implying a lower tendency for granulation.

Although it was expected that fruit split would increase with yield, this did not occur. In fact, there was a concomitant reduction in fruit splitting with an increase in fruit set, where $r^2 = -0.71$ between percentage fruit split and crop load. This was due to the actual numbers of fruit split per tree being similar ($79.3 ± 39.7$ vs $89.1 ± 34.4$) for
girdled and control treatments, respectively. The girdling treatment had significantly lower split percentages (9.5 vs 17.9% for control), while GA$_3$ applied during blossom performed the worst, increasing the split (34.0%). In addition, post-bloom applications of GA$_3$, after final fruit set (mid-January) also delayed rind colour development. At the 10% level of significance, Ca(NO$_3$)$_2$ at 100% PD and KNO$_3$ at 60% FB without girdling gave lower split levels (15.9 and 17.3%, respectively). This implies that, depending on nutrient levels, early applications of KNO$_3$ and Ca(NO$_3$)$_2$ may help to reduce split levels.

### 3.2. 1993 / 1994 season

#### 3.2.1. La Rochelle

The total number of fruit set at the end of November drop was significantly ($P < 0.01$) higher for all the girdled treatments, viz., girdling + 4% KNO$_3$, girdling + Folicur, girdling + Ca(NO$_3$)$_2$ and girdling alone, than the control trees (Table 1, column 2). The trees receiving a GA$_3$ application set slightly, but not significantly, more fruit than the control (174 fruit tree$^{-1}$). The treatments not involving girdling set less fruit than the control.

There appeared to be a good relationship between crop load and fruit split, with the percentage fruit split being higher for treatments with heavy fruit sets, and significantly higher than the control ($P < 0.05$) for the GA$_3$ and girdling treatments (Table 1, column 3). The effect of the fruit split reduction treatments appear to be less marked when the crop load was low, i.e., the nonfruit set treatments, e.g., Ca(NO$_3$)$_2$, 2,4-D (both timings) and KNO$_3$, tended to have less fruit split than the control (NS). Whether the fruit split treatments, Ca(NO$_3$)$_2$ and KNO$_3$, resulted in a lower incidence of fruit split, may be dependent on the lower crop load, resulting in relatively less split occurring. However, when these fruit split treatments were applied in combination with girdling, fruit set was increased and total fruit split was similar to that of the control, but significantly less than girdling alone and GA$_3$ ($P < 0.05$) (Table 1, column 3). Although GA$_3$ only increased fruit set slightly above the control, the incidence of split was the highest, reaching 44.8% of the total fruit set, similar to the results of Garcia-Luis et al. (1994).

The final yield is an interaction of total fruit set, fruit split and fruit mass. Table 1 (column 4) shows that the treatments involving girdling had significantly higher final yield than all other treatments ($P < 0.05$). Although GA$_3$ set more fruit than the control, final yield was similar due to the high incidence of split, thereby nullifying any positive effect of GA$_3$ on fruit set. The lower percentage split of the girdling + Ca(NO$_3$)$_2$ treatment (22.4%) resulted in this treatment having the highest final yield.

Fruit mass from the fruit set treatments was lower than the control, while girdling + KNO$_3$ and girdling alone were significantly lower ($P < 0.01$), but of acceptable size (Table 1, column 5).

The large fruit from the 2,4-D at 100% PD treatment had significantly less juice (56.5%) than the slightly smaller control fruit ($P < 0.05$) (data not shown). However, juice content was high enough to meet export requirements. There were slight differences in TSS level between the fruit of different size. Large fruit had significantly lower TSS (9.9%) compared with smaller fruit (10.3%) ($P < 0.05$). The acid level of larger fruit was slightly, but not significantly, lower (0.63%) than smaller fruit (0.68%).
Table 2
The effect of various treatments on fruit set and stylar-end fruit split of 'Nova' mandarin hybrid at Ryton Estates, Elands Valley during the 1993/1994 season

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Fruit set (no. tree−1)</th>
<th>% split</th>
<th>Yield (kg tree−1)</th>
<th>Fruit mass (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>69ab</td>
<td>0.10abc</td>
<td>6.8ab</td>
<td>103.0cd</td>
</tr>
<tr>
<td>GA 3</td>
<td>249abcdef</td>
<td>0.50abcd</td>
<td>21.0abcdef</td>
<td>86.4ab</td>
</tr>
<tr>
<td>Girdling</td>
<td>372abcdef</td>
<td>0.26abc</td>
<td>29.8ab</td>
<td>80.6ab</td>
</tr>
<tr>
<td>Ca(NO3)2</td>
<td>185bcdef</td>
<td>0.58c</td>
<td>18.3bcdef</td>
<td>103.0cd</td>
</tr>
<tr>
<td>KNO3</td>
<td>130abc</td>
<td>0.18b</td>
<td>13.5abc</td>
<td>107.0cd</td>
</tr>
<tr>
<td>Folicur</td>
<td>233abcdef</td>
<td>0.52bc</td>
<td>20.9cde</td>
<td>93.8bc</td>
</tr>
<tr>
<td>Girdling + Ca(NO3)2</td>
<td>403f</td>
<td>0.30abc</td>
<td>29.1ef</td>
<td>78.2a</td>
</tr>
<tr>
<td>Girdling + KNO3</td>
<td>291cdef</td>
<td>0.40abc</td>
<td>21.0cdef</td>
<td>78.2a</td>
</tr>
<tr>
<td>Girdling + Folicur</td>
<td>341cdef</td>
<td>0.52bc</td>
<td>24.4cde</td>
<td>72.4b</td>
</tr>
<tr>
<td>2,4-D (100% PD)</td>
<td>97ab</td>
<td>0.06a</td>
<td>10.5ab</td>
<td>114.0d</td>
</tr>
<tr>
<td>2,4-D (75% FD)</td>
<td>137abc</td>
<td>0.24abc</td>
<td>13.7ab</td>
<td>102.6cd</td>
</tr>
<tr>
<td>Level of significance</td>
<td>P &lt; 0.01</td>
<td></td>
<td>P &lt; 0.05</td>
<td>P &lt; 0.05</td>
</tr>
</tbody>
</table>

Means not followed by the same letter are significantly different at the indicated level of significance (Fisher's LSD).

3.2.2. Ryton

All the fruit set treatments set significantly more fruit than the control (P < 0.01) (Table 2, column 2). Fruit set at Ryton was higher than at La Rochelle, although the trees were smaller and one year younger. This can be attributed to the cooler climate experienced at Ryton than that at La Rochelle. There was very little split in the cooler Ryton climate and was considered commercially insignificant (Table 2).

Yield was significantly increased by girdling alone, girdling + Ca(NO3)2, girdling + Folicur, girdling + KNO3, GA 3 and Folicur treatments as compared with the untreated control (P < 0.01).

The heavier crop load and cooler growing conditions at Ryton (lower heat units resulting in this being a relatively smaller fruit size area than La Rochelle), resulted in considerably smaller fruit size at Ryton than La Rochelle (Table 2, column 5). Fruit size was significantly smaller for the girdled trees than the control, and of marginal but acceptable fruit size.

The larger fruit generally had a lower, but still acceptable, juice content (NS) than the smaller fruit. There were slight differences in TSS and acid contents, but no trends with fruit size or treatment were apparent, with TSS content ranging from 12.3 to 13.9% and acid levels from 0.94 to 1.05%.

4. Discussion

A total of 15 mg l−1 GA 3 sprayed at 100% PD was less effective than girdling for increasing fruit set. This poor fruit setting performance of GA 3 on ‘Nova’ mandarin has previously been shown by Garcia-Luis et al. (1994), and has only been shown to be effective on ‘Nova’ at high dosages of 50 mg l−1 (Goren et al., 1992).

Girdling at 100% PD by making a single cut through the bark and cambium using a Spanish girdling tool proved to be an effective means of increasing fruit set in ‘Nova’ mandarin. This has previously been shown with other citrus cultivars (Krezdorn, 1960;
Monselise and Goldschmidt, 1982; Cohen, 1984), sometimes with variable results. However, there was an adverse effect on vegetative growth and tree size. Smaller tree size, per se, is beneficial to closer spaced orchards and the high-density concept, but long-term effects on cumulative production and tree or limb longevity are unknown.

Increasing fruit set of difficult-to-set, weakly parthenocarpic cultivars, such as ‘Nova’, is especially important in the early years of production, as seen at Ryton where the control trees set poorly due to young tree age. In their second season of blossoming, girdling forced the trees into production.

Fruit split was dependent on climatic area and crop load. Citrus rind is generally thicker in cooler areas, and such areas are less split prone (van Rensburg, pers. comm. 1). The conditions required for fruit split may have been less prevalent at Ryton. However, one can expect an increase in percentage fruit split with increasing crop load. Ca(NO₃)₂ and KNO₃ reduced the incidence of split in the cooler area, although their physiological effects are undetermined. According to Garcia-Luis et al. (1994), the presence of the stylar-end aperture results in increased fruit split. Further research needs to be conducted to confirm whether fruit are split-prone due to the stylar-end aperture, and whether Ca(NO₃)₂ or KNO₃ are able to reduce the incidence of this aperture.

When ‘Nova’ are produced in solid blocks, fruit split can be expected due to the absence of seeds. Planting ‘Nova’ in relatively cool climatic areas will result in less fruit split than warmer areas, and 2% Ca(NO₃)₂ at 70% full bloom plus girdling at 100% PD, and 4% KNO₃ plus girdling at the same timings were the most promising treatments in terms of final yield, particularly in hot areas.

Since the overall objective of this research was to optimize export packout per hectare, fruit size and internal fruit quality also need to be considered. The effect of setting a heavier crop, by girdling, also resulted in fruit of smaller size and higher internal quality (higher juice, TSS and acid levels). Furthermore, granulation can be coupled to large fruit size and low acid content; therefore, the influence of a larger crop of smaller fruit of slightly higher acid content will be manifested in a lower incidence of granulation and higher export packout. The negative effect was a greater percentage of unacceptably small fruit size. Therefore, it would be necessary to thin the excessive fruit numbers from trees which have set excessively. Selective hand thinning of fruit with a visible stylar-end aperture should be evaluated in an attempt to increase fruit size, where required, reduce fruit split and improve export packout. A demonstration trial at Ryton on border trees in this trial showed a shift by one count when hand-thinned. Optimal timing and severity of hand thinning also need to be ascertained so that a fruit thinning model can be integrated with the fruit set and split strategy.

5. Conclusions

Under experimental conditions, girdling provided a more feasible method than GA₃ to increase fruit set in ‘Nova’, and fruit split in hot areas may be reduced by the addition of Ca(NO₃)₂, thereby enhancing export packout per hectare.

1 P.J.J. van Rensburg, Outspan International, Stellenbosch, South Africa.
The objective to increase export packout per hectare of ‘Nova’ mandarin can be achieved by applying the strategy: (i) 2% Ca(NO₃)₂ at 70% full bloom plus girdling at 100% PD; and (ii) hand-thinning fruit with a stylar-end aperture and external blemishes from mid-December to mid-January by removing 20 to 30% of the total crop, where necessary, to reduce the number of unacceptably small fruit. The latter is especially important in cool areas where fruit size may be a problem.

Although the economics of hand thinning was not shown in this experiment, where labour is relatively inexpensive and available, and due to the small size of ‘Nova’ trees and the necessity to ‘harvest’ the fruit at some stage in any case, thinning is a necessary technique to be used in conjunction with girdling. The latter increases fruit set, sometimes to the extent of producing unmarketably small fruit, and thinning is a mechanism to overcome this adverse effect.

The long-term effects of girdling on tree longevity are still unknown, and whether only one or two seasons of girdling are required to force young ‘Nova’ trees into production and then allowing them to set without girdling still needs to be ascertained.

References


Monselise, S.P., Costa, J., Galili, D., 1986. Additional experiments to reduce the incidence of citrus fruit splitting by 2,4-D and calcium. Alon Hanotea, 40, 1237–1238 (cited by Garcia-Luis et al., 1994).