

## Flowering and Fruit Set of 'Fortune' Hybrid Mandarin. Effect of Girdling and Growth Regulators

A.M.M. Duarte

UCTA-Univ. do Algarve, 8000 Faro, Portugal

J.L. Guardiola

Dep. Biología Vegetal, Univ. Politécnica de Valencia, 46071 Valencia, Spain

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**Abstract.** Young orchards of 'Fortune' mandarin usually have low productivity due to insufficient fruit set. The trees flower profusely, and most of the flowers are borne on leafless inflorescences. Leafy inflorescences are formed in a very low proportion and vegetative sprouts are nearly absent. This sprouting pattern results in a very low leaf/flower ratio. The carbohydrate reserves of the trees are lower than reported for other citrus cultivars, and are depleted shortly after anthesis. Therefore, the growth of the developing fruitlets depends mostly on current photosynthate formation. Most of the ovaries abscise shortly after flowering, having made very little growth. There is a main peak of abscission from early May until the end of June. Late fruitlet abscission lasts until late July. A GA<sub>3</sub> spray at flowering retarded the abscission of reproductive organs, but failed to increase the final fruit set. On the other hand girdling did not affect the main wave of fruit drop, but reduced late abscission, which resulted in an increase in set and final yield. Girdling did not increase the level of carbohydrates in the leaves, which indicates that carbohydrate use is determined by availability and fruit set may be limited by photosynthate supply.

The production of 'Fortune' mandarin is rapidly expanding in Spain and Portugal. The reason for this is the late ripening and high fruit quality. Consequently, high prices are being paid for the fruit.

A negative aspect of this cultivar is the low productivity of young orchards due to insufficient fruit set. The application of gibberellic acid (GA<sub>3</sub>) as a foliar spray at the blossom period has resulted in a significant promotion of set and yield on mandarins and tangelos (Krezdorn and Cohen, 1962; Rivero *et al.*, 1969; Fornes *et al.*, 1992) and this treatment is extensively used. Girdling may also increase fruit set (Monselise *et al.*, 1972; Guardiola, 1988; Goren *et al.*, 1992). In other cultivars failure in fruit set is often associated with high flowering levels and a high competition for metabolites among developing fruitlets (Guardiola *et al.*, 1984).

We have studied the characteristics of sprouting, flowering and flower/fruitlet abscission in this cultivar. This work also evaluates the effect of growth regulators and girdling on fruit set and yield in 'Fortune' mandarin.

### Materials and Methods

*Plant material and orchard management.* The experiments and observations were carried out in a commercial orchard of 'Fortune' mandarin (*Citrus clementina* Hort. ex Tan. x *C. tangerina* Hort. ex Tan) located at

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Castellón (Spain). The trees were grafted onto Troyer citrange and interplanted with trees on sour orange (*C. aurantium* L.) rootstock. All plants (7 years old at the beginning of the experiment) were virus free.

*Sprouting and flowering determinations.* These observations were carried out in the same orchard in two consecutive years (1991 and 1992). Sprouting and flowering were determined in spring on twigs formed during the two previous flushes of growth (summer and autumn flushes from the previous year). The number of shoots per node and the number of flowers and/or leaves per shoot were counted. Data from 1991 were obtained from about 1700 nodes on 12 trees. In 1992 flowering was measured on about 2500 nodes from 18 trees. Shoots were classified according to Guardiola *et al.*, (1977) and the terminology proposed by Guardiola (1981) and Davenport (1990) was used. Five shoot types were considered:

Vegetative (V): Any shoot which bears only leaves;

Single flowered generative (SFG): Any shoot which bears one flower and no leaves;

Multiple flowered generative (MFG): Any shoot which bears two or more flowers and no leaves;

Single flowered mixed (SFM): Any shoot which bears one flower and one or more leaves;

Multiple flowered mixed (MFM): Any shoot which bears two or more flowers and one or more leaves.

Generative shoots are commonly named leafless inflorescences and mixed shoots can be named leafy inflorescences.

*Effect of GA<sub>3</sub> and girdling on abscission and final fruit set.* The influence of GA<sub>3</sub> applications and girdling on the time course of abscission was determined in four single tree replicates. Gibberellic acid (10 mg l<sup>-1</sup>) was applied on May

13, at full bloom, along with a non-ionic wetting agent (alkylpolyglycol ether, 100 mg l<sup>-1</sup>), with a hand-gun sprayer until run-off. Two litres of solution per tree were used. Girdling was performed in June 17 on the main branches of the tree. A deep cut was made with a sharp knife all around the branches without reaching the wood. No ring of bark was removed.

A net was spread under the trees above ground level in order to retain the abscised organs, which were collected at weekly intervals, classified according to their stage of development and counted.

*Effect of growth regulators and girdling on fruit set and yield.* The following treatments were tested: no treatment (control); gibberellic acid (GA<sub>3</sub>) at 10 mg l<sup>-1</sup>; benzylaminopurine (BA) at 20 mg l<sup>-1</sup>; naphthaleneacetic acid (NAA) at 250 mg l<sup>-1</sup> and girdling. GA<sub>3</sub> and BA were applied on May 13 at full bloom. NAA (ethanol amine salt) was applied on June 17, at the end of June drop. The treatment details were as described above. Girdling was performed as in the previous experiment. A randomised block design with four replications of five trees each was followed. In each treatment half of the trees were grafted on Troyer citrange, and the other half on sour orange. The analysis of the data showed that rootstock did not affect tree performance.

The fruit of the replicates was harvested separately, weighed to the nearest 0.1 kg and the mean fruit weight determined from a random sample of 400 fruits. The number of harvested fruits was calculated.

## Results

'Fortune' mandarin showed an high percentage of sprouted nodes. In 1991, 61% of the nodes sprouted. For 1992 year this figure was 68%. The number of shoots formed per 100 nodes in 1991 and 1992 was, respectively, 80 and 99. The higher number of shoots formed as compared to the sprouted buds resulted from the formation of more than one shoot per node.

In both years the multiple flowered generative shoots were prevalent (Fig. 1). Also, multiple flowered mixed-type inflorescences and single flowered leafless inflorescences were abundant. In contrast, the number of single flowered mixed shoots was very low. The high proportion of multiple flowered shoots lead to a high number of flowers per 100 nodes (326 and 347 flowers per 100 nodes in 1991 and 1992, respectively) and a low leaf/flower ratio (8,5 and 13,5, respectively). Vegetative shoots were nearly absent.

From flowering, in mid May, until mid July, there was a continuous abscission of generative organs. The main peak of flower and fruitlet drop in control trees occurred from late May to mid of June (Fig. 2). From mid June to mid July, abscission of generative organs (mostly small fruitlets) continued at a lower rate. The GA<sub>3</sub> spray reduced abscission during late May and early June but this effect was transient and an increase in fruitlet abscission above the controls occurred at the end of June. In the conditions of our experiments, girdling reduced the rate of abscission during late June and early July.

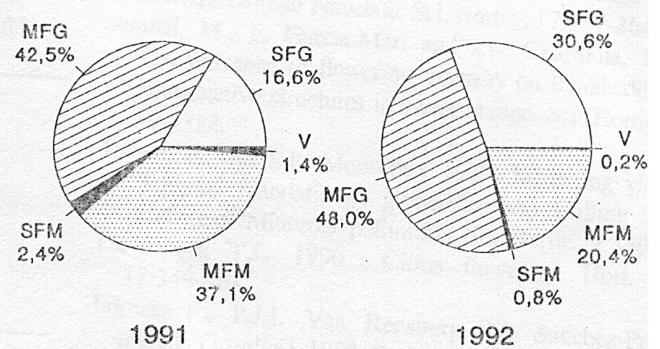


Figure 1. Percentage distribution of shoot types. V - Vegetative; SFG - Single flowered generative; MFG - Multiple flowered generative; SFM - Single flowered mixed; MFM - Multiple flowered mixed

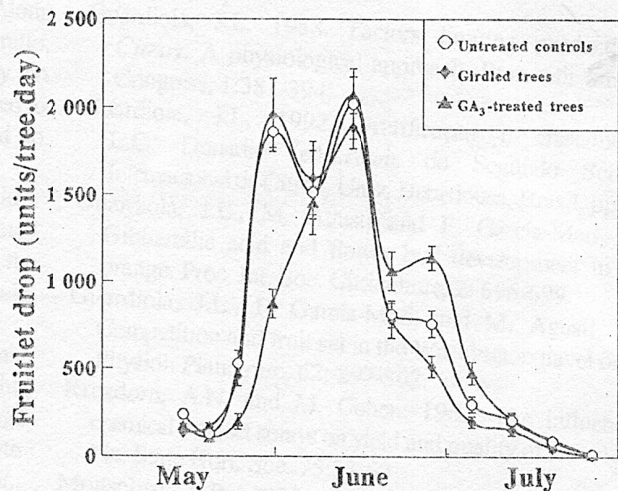


Figure 2. Effect of girdling and GA<sub>3</sub> application on the time course of abscission. Values are means from four trees, all with a similar initial number of flowers. Standard errors shown by vertical bars

From July to harvest, in March the following year, no significant fruit drop occurred. Fruit count at harvest was similar to the number of fruits set at the end of July. As shown in Table 1, the number of fruits finally set was higher in girdled trees than in untreated controls. Girdling was the only treatment which increased yield. Gibberellic acid application slightly increased the number of fruits per tree but did not increase yield. BA and NAA sprays had no significant effect on either set or final yield. Differences in average fruit weight fell within the experimental error.

Table 1. Effect of girdling and growth regulators applications on fruit set and yield

	Fruit set (fruits per tree)	Yield (kg/tree)	Average fruit weight (g)
Untreated controls	163 a	14 a	93
GA <sub>3</sub> - treated trees	200 ab	15 a	85
BA - treated trees	146 a	13 a	94
NAA - treated trees	188 ab	16 a	84
Girdled trees	266 b	23 b	85
SE	27	2	5
Significance <sup>1</sup>	P ≤ 0.07	P ≤ 0.05	N.S.

<sup>1</sup> Determined from a full analysis of variance; N.S. not significant

### Discussion

Spring sprouting of 'Fortune' mandarin varies from year to year but constant trends were found in the two years covered by this study. Flowering levels of this cultivar are comparable to the highest previously described for other cultivars (Agustí *et al.*, 1982b; Guardiola *et al.*, 1984; Monselise, 1985). Along with a high flower number we found a low leaf to flower ratio, a low number of leafy inflorescences and practically no vegetative sprouts. High flowering levels have been related to a low quality of the flowers (Guardiola, 1992) and to unproductivity (Guardiola *et al.*, 1984).

The abscission of reproductive organs reached a peak between the middle of May and the end of June. After a small increase in size after flowering (ovary stage) most of the reproductive organs (83% of the total) abscised post-anthesis, without making much growth.

Gibberellic acid applications resulted in a marginal increase in fruit set ( $P \leq 0.07$ ; Table 1) but failed to increase yield. This effect on set is similar to that found in 'Navelate' sweet orange (Agustí *et al.*, 1982a). The GA<sub>3</sub> spray stimulated the growth rate of the ovaries and retarded their shedding (Zucconi *et al.*, 1978) but final fruit set was not increased probably due to the strong competition which is established among the developing fruitlets and with other developing organs.

We found that girdling increased fruit set and final yield (Brosh and Monselise, 1977), but this did not result in the trees bearing satisfactory crops. Both the GA<sub>3</sub> and the girdling effect indicated that failure in fruit set of 'Fortune' mandarin is due to high competition during flowering and fruit set periods. Compared with the figures published for other cultivars, the carbohydrate content found in leaves in 'Fortune' mandarin during the fruit set period was lower and declined faster after anthesis (data not shown).

Competition can be reduced by NAA application due to its thinning effect and an increase in yield or fruit size can potentially be obtained (Ortolá *et al.*, 1991). In our experiments, however, NAA had no effect either on yield or in fruit size.

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