# FACTORS AFFECTING RIND PITTING IN THE MANDARIN HYBRIDS "FORTUNE" AND "NOVA". THE INFLUENCE OF EXOGENOUS GROWTH REGULATORS.

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Abstract

The commercialization of the mandarin hybrids "Fortune" and "Nova" is hindered by the development of cold-induced pitting in the fruit rind which may develop either in the orchard or during storage and transport.

In the late cropping cultivar "Fortune", the pitting develops on tree during the winter months and affects mainly the exposed fruit from the north-west quadrant of the tree. The induction of symptoms under uniform conditions in the cold-room reveals differences in the susceptibility to chilling injury among the fruits and the fruit sides. The green fruit is not susceptible. Susceptibility develops as pigmentation progresses, and it is higher for the exposed than for the non-exposed (covered by the foliage) fruits. The application of $GA_3$ at colour-break delays pigmentation and retards the development of susceptibility. The waxing of the fruit offers some protection to cold in the cold-room. However, the incidence of pitting is not related to the wax content of the fruit rind and the application of a wax coverage on tree had only a marginal protective effect.

No pitting is usually found on tree in the fruit of the early ripening "Nova" cultivar, which is usually harvested before the winter chilling. The pitting develops during cold storage (8-10 °C), and is reduced by $GA_3$ application at colour break, an effect related to the delay in rind pigmentation.

Additional index words: Chilling injury, citrus, gibberellic acid, susceptibility to chilling, wax.

## 1. Introduction

The culture of the mandarin hybrids "Fortune" and "Nova" has gained importance in Spain during the last years. Despite the many favourable traits of these cultivars, their commercialization is hindered by the development of rind blemishes, either in the orchard or during storage and transport.

The fruits of "Fortune" mandarin develop a characteristic pitting on tree during the winter months. This pitting shows as brown or black sunken lesions on localized areas of the fruit surface, which may increase in size and coalesce, forming extensive brown rind stains. Usually the oil glands remain unharmed (Almela *et al*., 1992). The incidence of this alteration is widespread, but its intensity varies markedly with the orchard and the year. It is far more important on the exposed fruit than on the fruit and the fruit side protected by the foliage, which has been related to the direct effect of wind and low temperature on the exposed side of the fruits. This pitting is induced during low temperature storage (Pozzan, 1992). As fruits stored at 4°C develop a more intense pitting than fruits stored at higher temperatures, the causative effect of low temperatures seems clear. In addition, other rind blemishes are also frequent in the fruit of this cultivar.

In the present work we have determined the effect of fruit position in the tree on the incidence of pitting. Through the induction of its development under controlled conditions, we have determined the changes in the susceptibility of the fruits to chilling injury during maturation. This parameter was determined for fruits from different tree quadrants and positions and, for the exposed fruits, for both fruit sides, i.e. the side facing the tree and the outer side.

The effect of several treatments on the presence of rind blemishes was also investigated. As a $GA_3$ application at colour break was reported to delay peel senescence in several mandarins

including "Nova" (Agustí *et al.*, 1988), we tested the effectiveness of this treatment to reduce rind blemishes in "Fortune" and "Nova". As waxing affords some protection towards the development of rind pitting during the cold storage of "Fortune" (Pozzan, 1992), we have tested the effect of a wax spray to reduce rind damages in the field in "Fortune".

## 2.Material and methods

### 2.1.Experiments with "Fortune" mandarin.

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The experiments and observations have been carried out in two orchards of 8-year-old "Fortune" (*C. clementina* Hort. ex Tan. x *C. tangerina* Hort. ex Tan.) trees sited in Almenara and Castellón. In the Almenara orchard the rootstock was sour orange (*Citrus aurantium* L.). The trees were planted 4x3 m apart in rows oriented west to east. In the Castellón orchard the trees were grafted onto Troyer citrange and interplanted with trees on sour orange. Rows were oriented west to east.

Both orchards were watered as needed with a drip irrigation system.

#### 2.1.1.Incidence of pitting in the orchard and fruit susceptibility to cold.

The time course of pitting incidence was determined in the Almenara orchard for non-exposed fruits covered by the foliage (inside fruits) and for exposed fruits from both the south and the north quadrants of the tree. From each fruit type, samples of 300 fruits were taken at random from 30 trees. Until all fruits became orange, samples of green and orange fruits were taken separately. On the outside fruits a mark was made on the exposed side of the fruit (the side facing outwards the tree). The samples were brought to the laboratory and the damages on the rind were assessed.

The non damaged fruits were used for the determination of cold susceptibility. These fruits were stored at 4 °C and rind damages were evaluated periodically.

The surface wax content of the rind was determined on three separate samples of exposed and non-exposed fruits. The wax was extracted immersing the fruits three times during 1 min in dichloromethane at 35 °C. The combined dichloromethane extract solutions were taken to dryness, and the amount of wax was determined by weight (Sala *et al.*, 1992). Wax content is expressed per unit of fruit surface area. Fruit area was calculated from its linear dimensions (diameter and height) according to Turrell (1946) assuming its shape as oblate-spheroid.

#### 2.1.2.Effect of $GA_3$ and Ca treatments on pitting.

The following treatments were tested: $GA_3$ (20 mg $l^{-1}$); $GA_3$ (20 mg $l^{-1}$) +$Ca(NO_3)_2$ (2%); $GA_3$ (20 mg $l^{-1}$)+$Ca(NO_3)_2$ (2%)+2,4-D (16 mg $l^{-1}$). Untreated trees served as controls. All solutions were applied with a hand-gun sprayer at colour-break (25 November) along with a non-ionic wetting agent (alkylpolyglicol ether, 100 mg $l^{-1}$). Each treatment had 8 replicates of 8 trees each.

Periodically the incidence of pitting and fruit susceptibility to chilling was determined on exposed fruits from the south quadrant of the tree as described above.

At maturity the replicates were harvested separately. The percentage of damaged fruits was determined by random samples of 400 fruits.

#### 2.1.3.Effect of a wax spray on pitting.

The experiment was carried out during 1992/93 in the Castellón orchard. We tested 3 commercial wax formulations: a non ionic wax (a 23% solution of oxidized polyethylene), and two anionic waxes named in the text as anionic waxes A and B. Anionic wax A was a 10% solution of oxidized polyethylene, shellac and wood resin. Anionic wax B was a 16 % solution of $K^+$ and $NH_4^+$ salts of oleic acid-based vegetal oils. The spray solutions were prepared from the commercial

formulations using a concentration of 2.5 % and adding a sequestering agent (Ethylene diamine tetracetic acid; EDTA) at 0.75 %. Each solution was applied at 2 volumes: low volume (l.v.: 3 litres per tree) and high volume (h.v.: 6 litres per tree). The applications were performed on the 2nd January. The experiment followed a random block design with 5 replicates of 5 trees each. Data were obtained as described for the previous experiment.

2.2.Effect of a $GA_3$ and calcium application on rind characteristics and pitting in "Nova" mandarin.

The experiment was carried out in an eight-year-old orchard of the "Nova" mandarin hybrid (*C. clementina* Hort. ex Tan. x (*C. paradisi* Macfadyen x C. tangerina Hort. ex Tan.)) located at Castellón.The trees were grafted onto Troyer citrange and interplanted with trees on sour orange (Citrus aurantium L.) rootstock.

The orchard was watered as needed by using a drip irrigation system.

A factorial design with two $GA_3$ levels (0 and 20 mg $l^{-1}$ $GA_3$) and two calcium levels (0 and 2% $Ca(NO_3)_2$) was followed. Each treatment was replicated 12 times using 3-tree plots. The chemicals were sprayed at colour-break (5 November) adding a wetting agent as described for the "Fortune" experiment. The fruit was harvested at commercial maturity (14 January) and separate samples were used to monitor rind blemishes and determine fruit characteristics. A sample of fruits was stored for 16 days at 8-10 °C to determine fruit susceptibility. As the calcium applications had no influence on any of the parameters determined, the means of the +Ca and -Ca treatments are presented.

## 3. Results

### 3.1.The time-course of on tree pitting development in "Fortune" mandarin.

No pitting was present in the fruits before January. Pitting developed during February and March mainly on the exposed fruits (Figure 1). Non-exposed fruits showed almost no pitting.

The green (non-pigmented) fruits showed no pitting.

### 3.2.The susceptibility of the fruit to chilling injury.

When pigmented fruits were stored at 4°C they developed a pitting similar in appearance to that found on tree. A significant proportion of fruits were pitted after 2 weeks storage. Both the size of the pitted areas and the number of pitted fruits increased with time for up to 4 weeks. At this time, up to 90 % of the cold-stored fruits were pitted in some experiments. As control fruits stored at room temperature (higher than 10°C) under otherwise identical conditions developed almost no pitting (less than 3 % of the fruits), the influence of low temperature on the incidence of pitting is evident.

Differences were noticed among fruit samples in the rate of pitting development and the size of the affected areas, and both parameters could be used to assess the susceptibility of the fruit to chilling injury. For practical reasons we used as an index the percentage of pitted fruit after 4 weeks' storage.

The seasonal changes in fruit susceptibility are shown in figure 2. The susceptibility increased markedly after January up to fruit maturation, and was markedly higher for the exposed fruit than for fruit protected by the foliage (non-exposed fruit). In the evaluation carried out on 20th January, the exposed fruit from the south quadrant of the tree was less susceptible (32 % pitted fruits after

4 weeks storage) than fruit from the south side (54 %). In later determinations, no significant differences among tree quadrants were found.

The influence of exposure on susceptibility was evident when the position of the pitted areas in the fruit was considered. Only 20 % of the exposed fruits which developed pitting during cold storage had pitted areas in the side which was originally facing the tree. The remaining 80 % of these fruits had the pitted areas limited to the exposed side of the fruit.

Green (non-pigmented) fruit was not susceptible. After 4 weeks storage only 3% of them developed pitted areas.

### 3.3.Effect of $GA_3$, 2,4-D and Ca treatments on pitting.

The application of $GA_3$+Ca retarded slightly the increase in fruit susceptibility to pitting as determined by the cold-storage test. This effect was transient, and after late February the susceptibility was identical for treated and untreated fruits (Table 1).

At harvest there were no significant differences in pitting between treated and control trees. Some reduction in other rind blemishes was found in $GA_3$+Ca-treated trees. 2,4-D did not influence the $GA_3$+Ca effects (Table 2).

### 3.4.Effect of a wax spray on pitting of "Fortune" mandarin.

The on-tree application of an anionic wax reduced the incidence of pitting but accelerated the development of other rind blemishes. On 31$^{st}$ March, close to harvest time, the percentage of damaged fruits was lower in treated trees than in controls (Table 3). At this date, the chilling susceptibility was lower for the wax treated (69% of fruits pitted) than for the untreated fruits (98%).

The evaluation of pitting on the whole crop at harvest showed a trend towards a lower value for the trees which received the high volume of the anionic wax sprays (Table 4). Differences to the control were, however, non-significant. Fruits from wax-treated trees showed a higher incidence of other rind blemishes than fruits from the control trees (P=0.90).

In view of the protective effect of some of the wax sprays on pitting, we compared the natural wax content of fruits differing in susceptibility. The amount of wax per unit surface area was higher for exposed (67 ± 4 µg/cm$^2$) than for non exposed fruits (57 ± 1 µg/cm$^2$).

### 3.5.Effect of a $GA_3$ spray on peel senescence and susceptibility to chilling injury of "Nova" mandarin.

An application of $GA_3$ at colour break delayed peel pigmentation and senescence. The treated fruits were more resistant to penetration by puncturing (5 mm probe) and to deformation under pressure (1 Kg) than untreated ones (Table 5). The treated fruits showed less pitting after 2 weeks' storage at 8-10 °C.

## 4. Discussion

The pitting of the peel is a physiological disorder associated with chilling injury, which develops either on tree ("Fortune") or during cold storage ("Fortune" and "Nova"). The time-course of on-tree pitting development in Fortune (Figure 1) reflects undoubtedly the interaction between the ambient temperature and fruit susceptibility, most of the damages occurring during late February and March, when the susceptibility of the fruit increases markedly (Figure 2). In agreement with Saucedo (1989) and Martinez-Tellez (1993), we found a low chilling susceptibility of the fruit at

colour break, and the transient reduction in susceptibility caused by the $GA_3$ application (Table 1) may be related to the effect on pigmentation (Table 5). The differences in pigmentation may contribute to the differences in susceptibility between exposed and non-exposed fruits, and the higher susceptibility of the north-quadrant fruit during the early samplings. Whichever the ultimate cause of these differences, the pattern of pitting incidence in the different positions of the tree follows closely the susceptibility of the fruits.

Although conflicting results have been reported about the effect of waxing on chilling injury (Grierson, 1986), this practice mitigated it on cold-stored "Fortune" mandarin (Saucedo, 1989; Martínez-Jávega *et al.*, 1992) as it did in our experiments when applied on-tree (Table 3). The response varied markedly with the nature of the wax (Table 4). Further, this application resulted in an increase in other rind blemishes (Table 4), which are reduced by treatments that decrease the natural wax content of the fruit (El-Otmani and Coggins, 1985). The attempts to correlate the chilling susceptibility of the fruit with the natural wax content gave results opposite to the expectations, as the fact that the wax content was higher in the chilling-susceptible exposed fruits. However the physicochemical and structural characteristics of the wax may be more important than total wax content (Albrigo, 1973; El-Otmani and Coggins, 1985), and they may be altered by a non-enzymatic photo-oxidation (Albrigo, 1973). In this way, the higher susceptibility of the exposed fruit side may become established.

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