The Effects of Calcium and Naphthalene Acetic Acid Sprays on Cracking Index and Natural Rain Cracking in Sweet Cherry Fruits

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Summary

The effects of spraying sweet cherry trees with calcium nitrate and naphthalene acetic acid (NAA) and their combination during the rainy season were investigated.

1. Spraying with 0.5% calcium nitrate solution significantly reduced the cracking index of 'Napoleon' sweet cherries and the percentage of cracked fruits under rain without any visible residue and damage from the chemicals.

2. Application of NAA at 0.5, 1 and 2 ppm on 'Satohnishiki' reduced the cracking index and the percentages of cracked fruits to 15 to 30% and 13 to 40% of the control, respectively. In 'Napoleon' sprayed with $\text{Ca}(\text{NO}_3)_2$ and NAA, the cracking index and % cracked fruit decreased to 20 to 38% and 26 to 66%, respectively.

3. Spraying with the combination of the 2 reagents more effectively reduced the cracking of 'Napoleon' than did either reagents as a single spray; and the minimum value of the index and the % cracked fruits was about one eighth of the control.

Introduction

Fruit cracking is a serious problem in the production of sweet cherries when rain occurs near harvest time. Selection of cultivars resistant to cracking, use of rain shelters, and spray treatments of several chemicals were thought to be main approaches to reduce the cracking (Yamamoto, 1991).

Spray treatments have been reported to reduce the cracking, e.g., calcium solutions (Ackley and Krueger, 1980; Bangerth, 1973; Bullock, 1952; Foster, 1937; Ono et al., 1951), ethyl oleate as a promoter of transpiration (Harrington et al., 1978), and antitranspirant films as inhibitors of water absorption through fruit surface (Davenport et al., 1972; Tomari and Ishizuka, 1966). However, unfavorable side effects such as spray residue or damage from the chemicals, reduce the practical applications of these methods.

There are only a few reports on spray treatments with plant growth regulators. Results of gibberellic acid spraying (Proebsting et al., 1973) differed too much as to give any reliable indication of their practical value. Naphthalene acetic acid

(NAA) applications showed marked reduction of cracking index of several cultivars of sweet cherries (Bullock, 1952; Tabuenca, 1985). However, only 2 experiments were reported concerning NAA but they omitted the field tests, further experiments should be carried out.

In this trial, we obtained better results in preventing cracking of sweet cherries by spraying with Ca, NAA, and their combination than did the previous researchers. No detrimental side effects were observed, so that the method developed may have practical usage.

Materials and Methods

Three each of 8-year-old 'Satohnishiki' and 'Napoleon' trees, highly crack-susceptible cultivars of sweet cherry, were selected for study. These trees were grown on a sandy loam soil in containers (50 cm diameter and height) and irrigated with about 20 litres of water per pot on alternate days from the middle of May to the middle of July weather permitting.

Lateral branches were sprayed with 0.2, 1 or 2 ppm NAA in 70% ethanol solution containing 0.1% of wetting agent (Atlox B1). Control limbs were sprayed with deionized water containing the same wetting agent. Calcium nitrate solution with

high concentration was thought to be injurious to plant tissue. Therefore, after preliminary tests with 0.3 to 4% $\text{Ca}(\text{NO}_3)_2$ on 'Napoleon' trees to assess possible damage, 0.5% was selected as a safe concentration. Sprays of calcium nitrate were done alone or in combination with NAA (Table 3). In both cultivars, the solutions of NAA were sprayed 24 days before harvest and those of calcium nitrate 7 days before harvest. There were 3 replicates in each treatment.

Fruits with visible cracks were counted among all fruits in each treatment to calculate the percentage of cracked fruits caused by rains. Fifty fruits without cracks per treatment were immersed in deionized water of 20°C for 10 hr. Fruits with visible cracks were counted per treatment and removed from the immersion container at alternate hours to calculate the cracking index following the previous reports (Christensen, 1972; Verner and Blodgett, 1931). The other 10 fruits per treatment were used to measure the mean fruit weight and the mean Brix⁰.

Results and Discussion

1. Damage from calcium solution

In preliminary tests conducted 10 days before

Table 1. The degree of damage from the calcium nitrate solution in relation to the concentration in 'Napoleon'.

Concn. (%)	Fruit apex	Fruit side	Pedicel	Leaf
4	+++ ^z	++	++	+++
2	+++	+	+	++
1	++	—	+	+
0.5	+	—	—	—
0.3	—	—	—	—

^z +++ severe, ++ intermediate, + slight, — none.

harvest, both leaves and fruits of 'Napoleon' were seriously damaged by 2 to 4% calcium nitrate solutions (Table 1). At 1%, apexes of the fruit received moderate damage (Table 1). At 0.5%, slight necrosis occurred occasionally at the fruit apex, probably because of a higher concentration of the chemical by evaporation of water from the persistent droplet. However, the discoloration associated with the slight necrosis often disappeared blending with the natural coloring. Presumably, the necrosis is thought to be derived from the toxicity of nitrate ions at higher concentration and their high rate of absorption or the high osmotic concentration. Unlike the necrosis, a white spray residue of Ca chemicals is evident in spray treatments of other Ca chemicals, namely $\text{Ca}(\text{OH})_2$ (Bangerth, 1973; Bullock, 1952; Verner, 1938), CaCO_3 , or Bordeaux mixture (Foster, 1937; Verner, 1938). These residues are derived from the low solubility and the low rate of absorption of these Ca chemicals through the fruit surface. In the present study, no such residues were observed after spraying with calcium nitrate solutions.

2. The effects on the cracking index and the percentage of cracked fruits under natural rains

Total precipitations during 2 weeks before harvest, a period including the fruit growing stage sensitive to cracking, were 67 mm for 'Satohnishiki' and 111 mm for 'Napoleon'.

Spray treatments with NAA led to a large reduction in the cracking of 'Satohnishiki' (Table 2); at 0.5, 1 or 2 ppm NAA, the cracking index was reduced to 15 to 30% of the control, while the percentage of cracked fruits under rains decreased by 13 to 40%.

Likewise in 'Napoleon', NAA, Ca and the combined treatments led to a significant reduction in both the cracking index and the percentage of

Table 2. The effect of NAA spraying treatments on the cracking index and the percentage of cracked fruits under rains of potted 'Satohnishiki' trees.

Treatment	Cracking index	% of cracked fruits	No. of fruit tested	Mean fruit wt(g)	Mean Brix ⁰
Control	27.55	15.46	207	4.85 ^y	12.29 ^x
0.5 ppm NAA	8.44	2.01 ^{**z}	149	4.75	11.39
1 ppm NAA	10.67	4.89 ^{**}	245	5.33	11.97
2 ppm NAA	4.88	6.04 ^{**}	298	5.11	11.27

^z Significantly different from control at 1% level by a normal distribution test.

^y LSD (5% level)=0.74.

^x LSD (5% level)=1.88.

cracked fruits (Table 3). A single spray of NAA at 3 concentrations reduced cracking index to 20 to 38% of the control, while the percentage of cracked fruits was reduced to 26 to 66% of the water treatment. The maximum reduction in the combined treatment of 1 ppm NAA and 0.5% calcium nitrate amounted one eighth of the control for both the cracking index and percentage of cracked fruits (Table 3). The mean Brix⁰ of the treated fruits as well as that of the fruits treated with 2% NAA was significantly lower than that of control fruits (Table 3). Table 3 shows that more useful results could be obtained with the combined spray treatments than with the single ones at all concentrations of NAA.

3. Cumulative percentages of cracked fruits in the immersion treatment

Cumulative percentages of cracked fruits and the cracking index were calculated (Figs. 1 and 2). These curves show the inhibition of cracking by application of these chemicals. However, the mechanism of the inhibition is not fully explained in previous reports. Several ions, especially calcium ions, which have a strong effect in preventing fruit cracking, are thought to have a strong precipitation or cross-linking effect on pectin (Bangerth, 1973). This suggests that the calcium in the cell wall, especially that in the middle lamella, plays an important role in the fruit cracking process. On the other hand, Glenn and Poovaiah (1989) confirmed that Ca has no effect on the rate of water absorption by cherry fruits.

Bullock (1952) demonstrated in a laboratory test

that with 'Bing' fruits sprayed early in the season with NAA, the percentage of ripe fruits which cracked in the immersion solution was about one third of the control. This effect of NAA was reexamined by Tabuenca (1985) who found that the cracking index was reduced to about one half of the control by prespraying 'Bing', 'Napoleon', 'Marmotte' and 'Daiber' with 1 ppm NAA, whereas in our present study, we found the cracking index in the control to be 42.22 (Table 3). Glenn and Poovaiah (1989) reported that water absorption increased markedly through cuticular frac-

Fig. 1. The cumulative percentages of cracked fruits in immersion treatments as affected by NAA spray treatments in 'Satohnishiki'.

Table 3. The effect of NAA, Ca and combined spraying treatments on the cracking index and the percentage of cracked fruits under rains of potted 'Napoleon' trees.

Treatment	Cracking index	% of cracked fruits	No. of fruit observed	Mean fruit wt(g)	Mean Brix ⁰
Control	42.22	14.59	377	6.22 ^w	12.64
0.5%Ca ^z	15.56	8.29 ^{*y}	205	6.15	12.78
0.5 ppm NAA	16.00	9.54	220	5.63	12.20
0.5 ppm NAA + 0.5%Ca	11.11	4.10 ^{**x}	169	6.58	12.18
1 ppm NAA	13.78	6.73 ^{**}	208	5.94	12.70
1 ppm NAA + 0.5%Ca	5.33	1.70 ^{**}	176	5.22	11.08 ^{*v}
2 ppm NAA	8.44	3.74 ^{**}	188	5.55	11.37 [*]
2 ppm NAA + 0.5%Ca	8.00	2.00 ^{**}	200	6.04	12.46

^z Concentration as Ca(NO₃)₂·4H₂O.

^y and ^x Significantly different from control at 5% and 1% level by a normal distribution test, respectively.

^w LSD (5% level)=1.057.

^v Significantly different from control at 5% level by the LSD test. LSD (5% level)=1.23.

Fig. 2. The cumulative percentages of cracked fruits in immersion treatment as affected by Ca, NAA and the combined treatments in 'Napoleon'.

ture of cherry fruit prior to harvest. They hypothesized that the main factor in the cracking of sweet cherries is water absorption through the cuticular fracture and the part of fruit apex without cuticle, and not through the stomata. If that is the case, the effect of the NAA on the reduction of fruit cracking could be attributed to the smooth increase of fruit and flesh volumes accompanied by a reduction of cuticular fractures. As NAA markedly reduced cracking, other auxins may serve the same purpose and became a common practice applicable on cherry trees under open culture. More detailed studies are needed to elucidate the mechanism of cracking.

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オウトウの裂果指数と樹上裂果に及ぼす Ca 剤とナフタレン酢酸の散布の影響

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摘 要

オウトウの裂果に及ぼす硝酸カルシウムとナフタレン酢酸 (NAA) の単用散布および併用散布の効果を調査した。

1. ‘ナポレオン’に対する0.5%の硝酸カルシウムの散布は、薬害や薬剤残留による果面汚れを伴わずに裂果発生を大幅に減少させた。

2. 3段階の濃度 (0.5, 1 および 2 ppm) の NAA 単用散布により、‘佐藤錦’の裂果指数および樹上裂果率

はそれぞれ対照区の約15~30%および約13~40%に減少した。また、‘ナポレオン’への同様な散布処理により、裂果指数および樹上裂果率はそれぞれ対照区の約20~38%および約26~66%に減少した。

3. ‘ナポレオン’への両薬剤の併用散布により、裂果指数および樹上裂果率はともに単用散布より減少した。これらの最小値は対照区の約8分の1にまで達した。