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NAA Thinning of 'Small-Fruited' Apple Cultivars in Combination with CPPU

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K e y w o r d s : Apple thinning, NAA, CPPU.

S u m m a r y

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Forchlorfenuron (CPPU) and naphthaleneacetic acid (NAA) were evaluated as chemical thinners applied at 8 mm king fruit diameter. High volume spray of CPPU (5 ppm) was applied alone or in combination with NAA (10, 15 or 20 ppm) on mature Red 'Jonathan'/M9, 'Gala'/M9 or 'Elstar'/M9 trees, respectively. NAA alone thinned 'Gala' and 'Elstar' effectively. CPPU alone did not enhance fruitlet drop, but increased the incident of asymmetric fruit growth on 'Gala' and 'Elstar'. The combination of CPPU and NAA over-thinned all three cultivars, increased asymmetric fruit growth and reduced seed number.

Introduction

Chemical thinning of apple fruitlets is an indispensable technological practice in contemporary apple production. Thinning increases the percentage of first class fruit and promotes annual cropping (DENNIS 1986). NAA was one of the first products developed for apple fruit thinning and continues to be widely used today (WESTWOOD 1993). NAA application to some 'Delicious' types fails to increase fruit size even though fruit abscission may be induced (GREENE 1943). HOFFMAN & al. 1955 observed an increase in under developed, misshapen fruit in some 'Delicious' cultivars after thinning with NAA. BUKOVAC & al. 1994 attempted to enhance fruit growth in NAA-treated 'Delicious' by addition of 6-benzyladenine (BA). The combination of NAA (15 ppm) and BA (25-100 ppm) on

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Redchief 'Delicious' resulted in excessive production of commercially unacceptable small fruit.

CPPU has been reported to also affect fruit set and size in apple (CURRY & GREENE 1993). Full bloom application of CPPU affected fruit growth similar to that reported for BA. We were interested in determining if CPPU, when combined with NAA, would enhance fruit growth in the small-fruited cultivars of Red 'Jonathan', 'Gala' and 'Elstar' or have a negative effect on fruit size as observed in Red 'Delicious'.

Abbreviations: NAA = 1-naphthaleneacetic acid, CPPU = N-(2-chloro-4-pyridinyl)-N'-phenylurea

Materials and Methods

The trial was conducted in the experimental orchard of the Agricultural Institute of Slovenia located in Brdo near Lukovica in 1996, on 7-year-old apple trees of Red 'Jonathan' and 'Elstar' and on 3-year-old apple trees of 'Gala', all on M9 rootstock. The trees were trained as slender spindle. Statistical design of the trial was a complete randomized block with 5 replications and 5 single tree treatments. At the beginning of bloom, uniform trees of each cultivar were selected according to vigor and bloom density. Flower clusters on selected trees were adjusted so that all trees selected for the experiment in individual blocks had the same number of clusters per cm^2 of trunk. The treatments were as follows:

Control - non-thinned

CPPU - 5 ppm = 5 ml Sitofex (SKW, Trostberk, Germany)/L water, for all cultivars

NAA - 10 ppm = 0.30 ml RP1 (Pinus, Rače, Slovenija)/L water for Red 'Jonathan'

NAA - 15 ppm = 0.45 ml RP1 (Pinus, Rače, Slovenija)/L water for 'Gala'

NAA - 20 ppm = 0.60 ml RP1 (Pinus, Rače, Slovenija)/L water for 'Elstar'

CPPU plus NAA - concentrations as for 2) and 3) above. CPPU application was followed by NAA, after leaves were dry (~ 1 hr)

Hand thinning at June drop

Sprays were applied at 8.4 mm king fruitlet diameter for Red 'Jonathan', 7.5 mm for 'Gala' and 9.1 mm for 'Elstar'. Sprays were applied using hand-sprayer until the leaves were fully wetted (approximately 0.5 L of water/tree) without a surfactant and at a temperature 16 °C and relative humidity of 65 %.

Fruit was harvested at maturity and graded into two size classes: <70 mm and >70 mm diameter. Ten fruit (65-70 mm) were sampled from individual trees and used for rating of quality properties: color (1 = not colored, 10 = 100 % colored), flesh firmness (a hand penetrometer), fruit symmetry (expressed as difference between min. and max. polar and equatorial diameters), seed number per fruit (counting developed seeds in fruit cross-section) and dry matter in juice (using a hand refractometer for reading the value of dry matter in juice obtained during measurement of flesh firmness).

Data were subjected to statistical analysis using the statistical program Statgraphics 5.0 (STSC, Rockville, USA) and LSD for mean comparisons at $p = 0.05$.

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Results and Discussion

Red 'Jonathan'

CPPU at 5 ppm did not induce significant fruit thinning, but average fruit size was increased (insignificantly). Fruit in the 65-70 mm size class showed a statistically significant effect of CPPU on fruit deformation expressed as the difference between max. and min. polar and equatorial diameters (Tables 1, 2).

NAA (10 ppm) in combination with CPPU (5 ppm) resulted in over thinning and increased mean fruit weight. Fruit deformation was significantly greater than for NAA or CPPU alone. Fruit from all chemical treatments contained fewer seeds than the nontreated control (Tables 1,2).

'Gala'

CPPU alone did not result in significant thinning, fruit deformation was small but significant and fewer seeds were produced per fruit. CPPU treated fruit were poorly colored also (Tables 3, 4).

NAA (15 ppm) alone thinned significantly and increased mean fruit size. The combination of CPPU and NAA caused strong fruitlet thinning and increased average fruit weight. Analyses of fruit characteristics showed significant deformation, fewer seeds per fruit, greater firmness and less red color than non thinned controls (Tables 3, 4).

'Elstar'

CPPU did not cause significant fruitlet thinning, but had a slight effect on fruit size at harvest.

NAA (20 ppm) alone induced significant fruitlet thinning. This resulted in an increase in percentage of larger fruit which did not, however, differ from the control as to their external and internal characteristics.

The combination of CPPU and NAA resulted in over thinning. The fruit were significantly longer in the polar diameter than control, they had fewer seeds and more dry matter in juice (Tables 5, 6).

NAA at 10 ppm on Red 'Jonathan' did not significantly reduce fruit load, but 15 ppm NAA on 'Gala' or 20 ppm NAA on 'Elstar' caused significant fruitlet thinning and enhanced return bloom. The reduced fruit number resulted in larger fruit size, but, the amount of fruit in the larger size class (> 70 mm) did not fully compensate reduced fruit load.

Application of synthetic cytokinin CPPU (5 ppm) did not promote fruit thinning or influence return bloom in any of the three cultivars. This is the difference between forchlorfenuron and synthetic cytokinin BA which thins the apple tree fruitlets successfully (SALLY & al. 1991, ELFVING 1998). It is interesting that CPPU alone generally increased fruit size, similar to BA, which enhanced fruit size independently of fruit set (GREENE 1993). This effect may be related to an increase in cell division in the fruit cortex (WISMER & al. 1995). Sampling of CPPU treated fruit showed slightly more asymmetrical fruit development in 'Gala'

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and 'Elstar'. This was similar, but less severe, than that observed by GREENE 1989 on 'McIntosh' at concentrations greater than 10 ppm CPPU.

The combination of CPPU and NAA caused over-thinning of fruitlets in all three cultivars, but increased return bloom only on 'Elstar'. Similar over-thinning of fruitlets was observed by BUKOVAC & al. 1994 in a trial of NAA 10 ppm combined with BA 25 or 50 ppm on 'Empire'. In this study, the combined CPPU and NAA application induced strong deformation of fruits which was probably the result of significantly smaller seed number in all three cultivars.

Table 1. Yield of Red 'Jonathan' and the return bloom in the CPPU x NAA trial.

Treatment *	Flower clusters / cm^2	Fruits no. / cm^2	Yield (kg / tree)	Fruits > 70 mm (kg / tree)	Mean fruit weight (g)	Return bloom Fl. cluster/cm^2
Control	15.3 a	7.7 c	10.2 bc	5.7 a	126 a	26.9 a
CPPU	15.4 a	8.1 c	11.0 c	7.4 a	133 a	26.7 a
NAA	15.3 a	6.9 bc	10.1 bc	6.4 a	129 a	32.1 a
CPPU + NAA	15.4 a	4.0 a	6.9 a	6.0 a	155 b	30.8 a
Hand thinning	15.4 a	6.0 b	7.9 ab	5.2 a	134 a	29.7 a

*Mean separation within columns by LSD multiple range test, P = 0.05.

Table 2. Fruit quality of Red 'Jonathan' in the CPPU x NAA trial.

Treatment *	Polar diff. (mm)	Equat. diff. (mm)	Fruit color (1-10)	Firmness (kp cm^{-2})	Seed number	Soluble solids (%)
Control	5.0 a	2.5 a	7.7 a	9.43 ab	4.6 b	14.3 a
CPPU	6.7 b	3.1 b	8.1 a	9.17 a	4.1 ab	14.4 a
NAA	5.6 ab	2.7 a	8.5 a	9.76 b	4.4 ab	14.3 a
CPPU + NAA	9.0 c	3.5 c	7.9 a	9.71 b	3.6 a	14.7 a
Hand thinning	6.1 ab	2.5 a	7.8 a	9.44 ab	4.2 ab	14.2 a

*Mean separation within columns by LSD multiple range test, P = 0.05.

Table 3. Yield of 'Gala' and the return bloom in the CPPU x NAA trial.

Treatment *	Flower clusters / cm^2	Fruits no. / cm^2	Yield (kg / tree)	Fruits > 70 mm (kg / tree)	Mean fruit weight (g)	Return bloom Fl. cluster/cm^2
Control	17 a	15.2 d	5.9 b	0.6 a	115 a	32.0 ab
CPPU	17 a	12.9 cd	4.4 a	1.3 ab	122 ab	29.1 a
NAA	17 a	9.5 ab	4.1 a	1.4 b	130 b	46.7 b
CPPU + NAA	17 a	7.6 a	3.9 a	2.3 c	145 c	35.0 ab
Hand thinning	17 a	11.5 bc	4.7 ab	1.2 ab	131 b	42.3 ab

*Mean separation within columns by LSD multiple range test, P = 0.05.

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Table 4. Fruit quality of 'Gala' in the CPPU x NAA trial.

Treatment *	Polar diff. (mm)	Equat. diff. (mm)	Fruit color (1-10)	Firmness (kp cm^{-2})	Seed number	Soluble solids (%)
Control	5.1 a	2.0 a	5.9 bc	9.92 a	6.9 c	12.4 ab
CPPU	7.9 b	3.3 bc	3.9 a	10.35 ab	5.2 ab	11.7 a
NAA	6.5 ab	2.3 ab	6.5 c	10.13 ab	5.9 bc	12.7 b
CPPU + NAA	10.1 c	4.0 c	4.5 ab	10.60 b	4.5 a	12.4 ab
Hand thinning	5.3 a	2.6 ab	6.2 bc	10.07 ab	6.4 bc	12.4 ab

* Mean separation within columns by LSD multiple range test, P = 0.05.

Table 5. Yield of 'Elstar' and the return bloom in the CPPU x NAA trial.

Treatment *	Flower clusters / cm^2	Fruits no. / cm^2	Yield (kg / tree)	Fruits > 70 mm (kg / tree)	Mean fruit weight (g)	Return bloom Fl. cluster/cm^2
Control	10.5 ab	10.1 b	16.7 b	6.5 a	117 a	2.9 a
CPPU	11.2 b	8.4 b	14.9 b	9.9 ab	134 ab	2.7 a
NAA	10.6 ab	3.6 a	8.5 a	6.7 a	140 b	5.9 b
CPPU + NAA	10.0 a	2.7 a	8.1 a	7.6 ab	175 c	9.1 c
Hand thinning	10.7 ab	7.8 b	17.0 b	11.5 b	134 ab	6.7 bc

* Mean separation within columns by LSD multiple range test, P = 0.05.

Table 6. Fruit quality of 'Elstar' in the CPPU x NAA trial.

Treatment *	Polar diff. (mm)	Equat. diff. (mm)	Fruit color (1-10)	Firmness (kp cm^{-2})	Seed number	Soluble solids (%)
Control	4.5 a	1.9 a	6.3 a	8.8 a	7.0 b	13.2 a
CPPU	5.4 ab	1.9 a	6.1 a	8.6 a	7.4 b	13.2 a
NAA	4.8 ab	1.8 a	7.0 a	9.1 a	6.7 b	14.2 ab
CPPU + NAA	6.0 b	2.6 a	6.0 a	9.2 a	3.8 a	14.6 b
Hand thinning	4.3 a	1.9 a	6.5 a	8.8 a	6.9 b	14.4 b

* Mean separation within columns by LSD multiple range test, P = 0.05.

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