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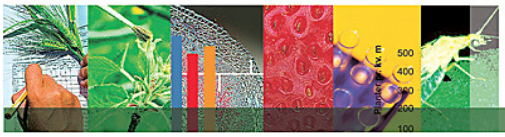
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Small Fruit Appearance on 'Fuji/M.9' Apples Thinned by the Most Known Thinning Agents

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Summary
Mature slender spindle trained 'Fuji/M.9' apple trees were sprayed to the point of drip with the most well-known thinning agents. Ethephon 400 ppm was applied at balloon stage, NAD 100 ppm was applied at 5 mm fruitlet diameter (FD) while NAA 15 ppm, BA 150 ppm or tank-mix combination of both was sprayed at 10 mm FD. Apple trees responded with over thinning when ethephon 400 ppm was used and, consequently, a strong fruit growth succeeded. No thinning was observed if NAD 100 ppm or NAA 15 ppm were sprayed, but the amount of small fruits (<45mm) was increased significantly. Weak thinning was found when BA 150 ppm was applied and fruit growth was lightly increased (not significantly). When NAA 15 ppm was tank mixed with BA 150 ppm no thinning response was seen but the highest amount of small fruits appeared on 'Fuji/M.9' trees.

Introduction

Apple fruit trees frequently form too many flowers and set too much fruit to be able to obtain regular and marketable crops throughout the years. Flower or fruitlet thinning could solve the problems of too heavy fruit set because it improves the fruit appearance and prevents the biennial bearing of apple trees.

The most used thinning compounds registered in Europe are naphthaleneacetic acid (NAA), naphthaleneacetamid (NAD) and ethephon. NAD used alone does not thin strongly enough and ethephon is not the best thinning agent, due to its negative effect on fruit growth (Ebert and Bender, 1986; Stopar, 2000; Link, 2001; Stopar and Lokar, 2003). Some authors reported that the growth of fruit after NAA application was not enhanced enough if the thinning intensity in crown was considered (Greene, 1943; Thomann and Botzner, 1996; Black et al., 1995; Stopar and Lokar, 2003). The synthetic cytokinin 6-benzyladenine (BA) was found to be a good apple thinning agent (Greene et al., 1990; Wismer et al., 1995). Independently of its effects on crop load, BA enhanced the growth of apple fruit additionally (Greene, 1993). When BA was combined with NAA on 'Empire' an independent and additive thinning response was found when tank-mixed (Elfving and Cline, 1993; Bukovac et al, 1994). On the other hand the combination of NAA and BA on 'Delicious' apples resulted in excessive production of commercially unacceptable small (pygmy) fruit (Bound et al., 1991; Bukovac et al., 1994; Greene and Autio, 1994).

'Fuji' apple trees are known as a difficult to thin cultivar. Severe fruit growth inhibition was observed when NAA was used as thinner on 'Fuji' apples while ethephon was presented as the satisfactory thinning agent (Jones et al., 1991). BA showed potential as a thinner for red 'Fuji' apples if applied 20 days after full bloom (Sally et al., 1991).

While 'Fuji' apples are becoming the most marketable cultivar, biennial bearing and small fruit problems still remain the farmer's biggest difficulty. The aim of our study was to test the response of 'Fuji' apple trees to thinners registered in Europe, i.e. NAD, NAA, ethephon and compare their thinning effect with BA, the new thinner shortly coming on the European market.

Materials and methods

The experiments were conducted in the experimental orchard of Faculty of Agriculture at Pohorski Dvor. Eight-year-old apple trees 'Fuji/M.9' of similar flowering intensity and homogenous vigour were selected. The trees were trained as slender spindle. The crowns were about 1 m wide and 2 m high. Pest control and other orchard management were the same as for the production in the rest of this intensive orchard, only the chemical thinning was not performed. The experiments were designed as a randomized block with seven replications and a single tree per plot.

The spraying treatments were as follows:
1) Control – no thin
2) Hand thin – at the time of June drop
3) BA 150 ppm (VBC 30001 - 7.5 ml / L water; Valent Biosciences, Libertyville, IL)
4) NAA 15 ppm (Nokad - 0.375 ml / L water; Isagro, Milano, Italy)
5) Ethephon 400 ppm (0.84 ml Ethrel / L water; Chromos , Zagreb, Croatia)
6) NAD 100 ppm (1.20 g AmidThin / L water; Isagro, Milano, Italy)
7) NAA 15 ppm + BA 150 ppm (tank mix spraying of VBC 30001 and Nokad)

The thinning treatment with ethephon was sprayed at the balloon stage; NAD was applied at 5 mm average fruitlet diameter (FD) while NAA, BA or the combinations of both were applied at 10 mm FD. The chemicals were applied on trees using a hand sprayer to the drip point with 0.5 L water per tree. The yield was estimated at harvesting time. The fruit were divided into three size categories according to the equatorial diameter: smaller than 45 mm, 45 – 70 mm and fruits bigger than 70 mm. Counting of fruits and weighing of yield were done at each tree. Fruit coloration was estimated visually as a percentage of red colour covering the fruit: 1 = 10 % red, 10 = 100 % coloration. Data were subject to statistical analysis using the statistical program Statgraphics 5.0 (STSC, Rockville, USA). Analyses of covariance and Duncan's multiple range test were used for adjusted mean comparisons at P = 0.05. The number of flower clusters per single tree counted before setting the experiment was used as the cofactor for the analyses of covariance.

Results and discussion

When the experiment was set and the flower clusters were counted a relatively big variability was found and this was the reason for non-homogeneous number of flower clusters per tree (Tab.1). To avoid the misinterpretation of the thinning data, analyses of covariance were performed to adjust the means of final fruit number, fruit weight and coloration estimations by using the original flower cluster number as a covariate.

Table 1: Analyses of covariance for 'Fuji' flowering and fruit thinning data determined at harvest 2004.

Treatment	No. of flower clusters / tree	Yield (kg / tree)	No. of fruits / tree	No. of fruits / 100 clusters
Control	148 c*	14,2 b	103 bcd	81 bc
Hand thin	139 bc	14,3 b	82 b	66 b
BA 150 ppm	127 abc	13,8 b	89 bc	69 b
NAA 15 ppm	121 ab	14,8 b	118 cd	94 c
Ethephon 400 ppm	124 ab	5,4 a	29 a	22 a
NAD 100 ppm	110 a	16,2 b	123 d	100 c
NAA 15 ppm + BA 150 ppm	122 ab	14,2 b	114 cd	96 c

* Mean separation within columns by Duncan's multiple range test *P*=0.05

Looking the final fruit number per tree or per 100 clusters, only the balloon stage application of ethephon 400 ppm thinned significantly (Tab.1). The yield on ethephon treated trees was very small and below the commercial need for this tree size. Due to the insufficient crop load the mean fruit weight was very good and the coloration of the fruit was better, too (Tab. 2). Similar consequences of low crop load on fruit quality enhancement were well known and proved on 'Jonagold' apple trees (Stopar et al., 2002). Jones et al. (1991) reported on proper thinning when 'Fuji/MM106' was sprayed with ethephon 400 ppm. A strong interdependence between ethephon action and outside temperature is a well known phenomenon (Olien and Bukovac, 1982). The application of BA 150 ppm at 10 mm FD thinned 'Fuji' similarly to the hand thinning treatment. The fruit weight was increased (not significantly) and came near (still below) the commercial standard. When NAD 100 ppm was sprayed just after petal fall or NAA 15 ppm at 10 mm FD no thinning was observed (Tab. 1), although the concentrations used were the highest recommended /registered for the application of these growth regulators. The fruit size distribution at harvest after NAD or NAA spraying shows a significant increase of number of small fruits (< 45 mm, 'pygmy') comparing to control or other treatments (Tab.

2). The share of middle or bigger size fruits and mean fruit weight stayed comparable to the control, i.e. the non-thinned trees. Reports of NAA suppression on apple fruit growth were found on 'Delicious' or 'Summerred' apples at the rate of 15 or 10 ppm, respectively (Black et al., 1995; Stopar et al., 2003).

Table 2: Analyses of covariance for 'Fuji' fruit quality data determined at harvest 2004.

Treatment	No. of fruits < 45mm	No. of fruits 45-70mm	No. of fruits >70mm	Mean fruit weight (g)	Fruit coloration (1-10)**
Control	0 a*	53 cd	50 b	135 a	6,9 ab
Hand thin	0 a	14 ab	68 b	170 b	6,8 a
BA 150 ppm	2 a	32 bc	55 b	153 ab	6,6 a
NAA 15 ppm	9 b	61 d	48 b	128 a	6,6 a
Ethephon 400 ppm	0 a	5 a	24 a	202 c	7,8 b
NAD 100 ppm	10 b	55 cd	58 b	134 a	6,1 a
NAA 15 ppm + BA 150 ppm	20 c	43 cd	51 b	125 a	6,4 a

* Mean separation within columns by Duncan's multiple range test P=0.05
** Color estimation: 1= 10 % red color, 10 = 100 % of fruit covered by red color

When NAA 15 pm and BA 150 ppm was tank mixed and applied at 10 mm (FD) no fruit thinning was observed (Tab. 1). The results are in contradiction with the findings on 'Empire' in which the tank-mix spraying of NAA+BA act on an extraordinary thinning effect (Elfving and Cline, 1993; Bukovac et al, 1994). In contrast, when Stopar (2002) sprayed 'Gala' or 'Golden delicious' apples with the combinations of BA 50 ppm + NAA 5 ppm no additive thinning response was observed comparing to alone applications of both agents. Fruitlet growth inhibition after NAA+BA spraying is a phenomenon known on 'Delicious' apples (Bound et al., 1991; Bukovac et al., 1994; Greene and Autio, 1994). Our 'Fuji' trees show similar symptoms when relatively high concentrations of both agents were tank mixed. The combination spraying of NAA 15 ppm + BA 150 ppm provoke a very high number of small fruits (< 45 mm), and even significantly higher if compared to NAD or NAA alone applications.

We could say in conclusion that hard to thin 'Fuji' apple trees responded with over thinning when ethephon 400 ppm was used at balloon stage. Light thinning was observed when BA 150 ppm was applied at 10 mm FD and no thinning was seen if NAD 100 ppm or NAA 15 ppm were sprayed at 5 mm or 10 mm FD, respectively. Applications of NAD or NAA induced a higher share of small fruits (<45 mm). When NAA 15 ppm was tank mixed with BA 150 ppm, no thinning response was seen but for the highest amount of small fruits appearing on 'Fuji/M.9' trees.

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