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Fruit quality and bearing potential of chemically thinned 'Braeburn' and 'Camspur' apples

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Abstract

The objective of this study was to evaluate the effects of 1-naphtaleneacetic acid (NAA) and 6-benzyladenine (BA) on fruit set, quality and the bearing potential of the apple cultivars 'Braeburn' and 'Camspur'. The chemical rates applied were 6, 8, 10 µl l^{-1} NAA, 50, 100 and 150 µl l^{-1} BA to 'Braeburn' and 8, 10, 12 µl l^{-1} NAA, 50, 100 and 200 µl l^{-1} BA to 'Camspur'. Both NAA and BA proved to be effective in reducing fruit set in 'Braeburn'. The average fruit weight was increased, while effects of thinning on fruit quality parameters in 'Braeburn' were not consistent. NAA appeared to be more efficient in reducing fruit set in 'Camspur'. NAA advanced maturity of 'Camspur' fruits, while BA was not effective. Both chemicals improved flower bud formation in 'Braeburn' in the second year of the study, but only NAA increased the number of flower buds in 'Camspur'. Thinning with NAA and BA has a potential risk of oversized fruits in 'Braeburn' and abnormally small (pygmy) fruit occurrence in 'Camspur'.

Key words: 1-aphtaleneacetic acid, 6-benzyladenine, flower buds, fruit set.

Introduction

A prerequisite for a regular bearing of apple trees is an adequate number of flowers per tree, which allows sufficient flower-bud formation in the following year (Wertheim, 2000). Young fruits with immature seeds, as a source of gibberellins, cause inhibition of flower bud initiation (Tromp, 2000; Ramirez et al., 2004). Thus, a heavy crop load reduces flower bud initiation, resulting in low yields in the following year (Keserović et al., 2005). If there are too many fruits per tree, they are small and grouped in clusters (Link, 2000). Chemical thinning with bioregulators decreases fruit set and increases average fruit weight of different apple cultivars (Basak, 2004; Costa et al., 2004; Robinson, 2006; Stern et al., 2006; Stopar, 2006). Thinning with benzyladenine (BA) causes average fruit weight increase which is beyond the effect of thinning alone, by stimulating cortical cell division (Wismer et al., 2002). Indirectly, by reducing fruit number per tree, chemical thinning affects internal fruit quality and return bloom (Link, 2000; Stopar, 2002).

'Braeburn' is a newly introduced cultivar in Serbian apple orchards and little is known about its flowering and fruiting in local growing conditions. It is a highly productive apple, with alternate bearing habit (Hampson, Kemp, 2003). Thinning is needed, especially in young trees with high crop load to avoid growth stunting. Spur types 'Delicious', such as 'Camspur' are difficult to thin, because they are less responsive to bioregulators (Bubán, 2000) and often produce the so-called pygmy fruits, small fruits that persist on trees until harvest (Black et al., 1995). In modern apple growing systems well feathered knip-trees (7+ branches) are planted in spring time with high planting density. Such trees flower and set fruits in the year of planting, and require reduction of fruit set from the first growing season in order to root and develop well and avoid alternative bearing.

The objective of the study was to evaluate the effects of 1-naphtaleneacetic acid (NAA) and 6-benzyladenine (BA) on fruit set, fruit quality and bearing potential of 'Braeburn' and 'Camspur' apple cultivars.

Materials and methods

The trials were conducted during 2009 and 2010 in a commercial apple orchard of the company "Atos Fructum", on three- and four-year-old 'Braeburn' Mariri Red* and Redchief® 'Camspur' (spur type 'Delicious') trees. The orchard is located in Mala Remeta, Irig, Serbia (45º05′ N and 19º44′ E, 215 m a.s.l.). Cv. 'Braeburn' trees are on M9 T337 rootstock, planted in 2007 at 3.2 × 0.8 m distance, and cv. 'Camspur' trees are on M26 rootstock, planted in 2007 at 3.2 × 0.65 m distance. The yield of 32.3 t ha^{-1} of fruits in the third and 50.9 t ha^{-1} in the fourth growing season was recorded in cv. 'Braeburn' in commercial part of the orchard. The yield of 'Camspur' was 20.3 t ha^{-1} in the third and 21.9 t ha^{-1} in the fourth growing season.

Each treatment was tested on six uniform trees, randomly chosen from along the rows, with one tree per replicate. Fruit set was presented with two parameters. Trunk girth was measured 5 cm above the graft union and the number of fruits per cm^2 of trunk cross-sectional areas (TCSA) was calculated. The other fruit set parameter is the number of fruits harvested per 100 flower clusters.

The chemicals used were Dirager, containing 3.3% active ingredient (a.i.) NAA and Gerba 4LG, containing 4% a.i. BA ("L-Gobbi", Italy). The treatments were applied as a single chemical application at the rates of 0.18, 0.24 and 0.30 ml l^{-1} of the commercial product Dirager (which corresponds to 6, 8, and 10 µl l^{-1} of a.i. NAA) and 1.25, 2.5 and 3.75 ml l^{-1} of the commercial product Gerba 4LG (corresponding to 50, 100 and 150 µl l^{-1} of a.i. BA) on cv. 'Braeburn'. The chemical rates applied on cv. 'Camspur' were 0.24, 0.30 and 0.36 ml l^{-1} of Dirager (8, 10 and 12 µl l^{-1} of a.i. NAA) and 1.25, 2.5 and 5.0 ml l^{-1} Gerba 4LG (50, 100 and 200 µl l^{-1} of a.i. BA). Untreated control trees were included in both cultivars.

NAA was applied when the mean diameter of king fruits was in the range of 9.5–10.9 mm in 'Braeburn' and 8.3–12.0 mm in 'Camspur'. The trees were treated with BA when king fruits were in the range of 9.4–12.3 mm diameter in 'Braeburn' and 10.3–12.4 mm in 'Camspur'. The trees were sprayed with a backpack sprayer ("Stihl SR-420") until run-off, at a spray volume of 1000 l ha^{-1}. To each treatment a surfactant, Trend® 90 ("DuPont", USA), was added at the rate of 1 ml l^{-1}.

Apples from the treatments were harvested at commercial harvest time. 'Braeburn' fruits were picked on 29th September in 2009 and 7th October in 2010. 'Camspur' fruits were picked on 11th September in 2009 and 16th September in 2010. A mean sample of 30 fruits per replicate was used to assess fruit quality. Average fruit weight and length/diameter (L/D) ratio were calculated. Fruit flesh firmness was measured using a FT 327 penetrometer ("Winopal Forshchungsbedarf", Germany), with an 11 mm probe. Two measurements were made on the opposite sides of each fruit. The starch index was evaluated using the starch iodine test (Vaysse, 2002). Total soluble solids (TSS) were determined using a hand refractometer (0–32%). Titratable acidity (TA) was measured by titration with 0.1 N NaOH to pH 8.1. The results were expressed as a percentage of malic acid in fruits.

A mean sample of 100 flower buds per treatment was collected to assess bearing potential of thinned trees during the winter period. Buds were cut longitudinally, and flower primordia were detected under a binocular (12.5^x). Bearing potential was presented as the percentage of buds with flower primordia in the total number of buds in the sample.

The data were analyzed using analysis of variance (*ANOVA*). Duncan's multiple range test was used to compare the means ($P < 0.05$) with *Statistica 9* (StatSoft Inc., USA).

Results and discussion

Number of fruits per cm^2 trunk cross-sectional area (TCSA) of cv. 'Braeburn' was significantly decreased following 100 and 150 µl l^{-1} BA treatments in 2009 and all thinning treatments in 2010 compared to the control (Table 1). A similar thinning level was achieved by both chemicals. The number of fruits per 100 flower clusters was reduced in both years of the study, but the differences were not statistically significant at the highest rates of BA and 8 µl l^{-1} NAA in 2010. The total yield of fruits is a function of the number of fruits per tree and the average fruit weight thus may be decreased by chemical thinning due to reduction of fruit number (Stopar, 2002; Milić et al., 2011 a). The yields similar to the control were achieved by the lowest rates of NAA and BA in 2009, due to the highest fruit set in these treatments (Table 1). The highest yield of cv. 'Braeburn' in 2010 was recorded at the highest rate of BA where fruit set and average fruit weight were the highest among treatments. All thinning treatments affected average fruit weight of cv. 'Braeburn' compared to the control (Table 1). The largest fruits were obtained with 150 µl l^{-1} BA treatment, and were 224.7 and 207.6 g in 2009 and 2010, respectively. Similar fruit set decrease and average fruit weight increase in 'Braeburn' was achieved by thinning with Accel containing BA as an active ingredient (Ouma, Matta, 2003). Thinning cv. 'Braeburn' with NAA and BA may be of greater significance in practice than early flower and fruit thinning. Early thinning of 'Braeburn' flowers with caustic chemicals can cause oversized fruits (Milić et al., 2011 b). The average fruit weight of 224.7 g, obtained with 150 µl l^{-1} BA treatment in 2009 would not be recommended in practice in cv. 'Braeburn', because oversized fruits may have lower storage ability. Thus, it might be concluded that 'Braeburn' fruits should be thinned with lower BA rates than 150 µl l^{-1}. NAA appeared to be similarly efficient as BA in thinning 'Braeburn' fruitlets considering fruit set parameters and the average fruit weight increase (Table 1).

Table 1. Fruit set and average fruit weight of cv. 'Braeburn' treated with 1-naphtaleneacetic acid (NAA) and 6-benzyladenine (BA)

Treatment	No. of fruits per cm² TCSA³	No. of fruits per 100 flower clusters	Yield kg per tree	Yield t per hectare⁴	Average fruit weight g
		2009			
Control	8.3b²	56.5b	11.3bc	44.1	171.6a
6 µl l⁻¹ NAA¹	6.8ab	25.5a	11.6bc	45.3	205.3b
8 µl l⁻¹ NAA	5.1ab	24.0a	8.5abc	33.2	213.3bc
10 µl l⁻¹ NAA	5.2ab	20.8a	8.4abc	32.7	200.7b
50 µl l⁻¹ BA	7.0ab	29.8a	11.8c	46.1	203.5b
100 µl l⁻¹ BA	4.2a	20.4a	6.8ab	26.7	199.7b
150 µl l⁻¹ BA	3.6a	19.4a	6.4a	25.1	224.7c
		2010			
Control	11.4b	69.7ab	17.0ab	51.2	162.1a
6 µl l⁻¹ NAA	6.5a	47.7cd	17.5ab	52.7	182.1bc
8 µl l⁻¹ NAA	6.3a	50.8bcd	14.1ab	42.3	197.1cd
10 µl l⁻¹ NAA	5.5a	39.5d	12.6a	37.8	183.9bc
50 µl l⁻¹ BA	6.2a	46.0cd	14.7ab	44.2	180.4bc
100 µl l⁻¹ BA	6.5a	55.8a	19.4ab	58.3	177.9b
150 µl l⁻¹ BA	6.6a	62.5abc	21.4b	64.4	207.6d

Notes. [1] The chemical rates given in tables correspond to the amount of active ingredients NAA or BA in the spraying solution. [2] Means followed by the same letter do not differ significantly according to Duncan's multiple range test at $*P < 0.05$. [3] TCSA – trunk cross-sectional area. [4] Yield per hectare is calculated as yield per tree × number of trees per hectare (3906 trees per hectare).

All thinning treatments had an effect on reducing the number of fruits per cm² TCSA in 'Camspur' in both years of the study (Table 2). NAA had an effect on reducing the number of fruits per 100 flower clusters in both years of the study, while BA was effective at the rate of 100 µl l⁻¹ in 2010 only. The yields were the highest in the controls in the both years of the study (Table 2). Bound (2006) stated that BA did not affect fruit set of 'Delicious' apple, but reported the occurrence of pigmy fruits. Pygmy fruits occur when thinning 'Delicious' with NAA (Black et al., 1995) or in combination with BA (Robinson, 2006). In the present study, pygmy fruits occurred both after NAA and BA application. The largest number of pygmy fruits was detected at 10 µl l⁻¹ NAA and 200 µl l⁻¹ BA. Despite the pygmy fruit problem NAA could be used for thinning 'Delicious' apple fruits (Black et al., 1995). As previously reported by Bound and Wilson (2007), thinning with BA did not affect fruit weight of 'Camspur' apples in 2010, except at the highest rate of NAA (Table 2). However, fruit weight in 'Camspur' was significantly increased at 8 and 12 µl l⁻¹ NAA treatments and at the highest rate of BA in 2009.

Table 2. Fruit set, average fruit weight and number of pygmy fruits of cv. 'Camspur' treated with NAA and BA

Treatment	No. of fruits per cm² TCSA	No. of fruits per 100 flower clusters	Yield kg per tree	Yield t per hectare[1]	Average fruit weight g	Number of pygmy fruits[2]
2009						
Control	9.4c	130.2b	9.0c	43.3	183.8a	–
8 µl l⁻¹ NAA	5.5ab	75.3a	6.1ab	29.3	219.6c	–
10 µl l⁻¹ NAA	5.3ab	79.9a	4.4a	21.2	193.4ab	–
12 µl l⁻¹ NAA	4.6a	73.4a	5.7ab	27.4	225.4c	–
50 µl l⁻¹ BA	7.0b	129.8b	6.5ab	31.3	185.3a	–
100 µl l⁻¹ BA	7.2b	128.8b	7.4bc	35.6	201.8abc	–
200 µl l⁻¹ BA	5.2ab	99.4ab	7.0bc	33.7	216.4bc	–
2010						
Control	11.9b	113.0c	9.7b	46.6	164.3a	0a
8 µl l⁻¹ NAA	6.3a	67.9ab	6.7a	32.2	155.4a	11.3bc
10 µl l⁻¹ NAA	6.8a	74.0ab	7.2a	34.6	155.1a	17.8b
12 µl l⁻¹ NAA	5.2a	57.0a	7.2a	34.6	201.8b	5.6ac
50 µl l⁻¹ BA	6.7a	97.3bc	7.9ab	38.0	161.7a	3.0a
100 µl l⁻¹ BA	7.9a	73.4ab	8.5ab	40.9	164.4a	11.2bc
200 µl l⁻¹ BA	6.3a	81.4abc	8.7ab	41.8	171.0a	13bc

Notes. [1] Yield per hectare is calculated as yield per tree × number of trees per hectare (4808 trees per hectare). [2] Pygmy fruits were detected in 2010 only.

Thinning showed no effect on fruit shape of apple cultivars 'Fuji', 'Gala', 'Delicious', 'Golden Delicious' and 'Braeburn' (Ouma, Matta, 2003; Costa et al., 2004; Stern et al., 2006). The present research confirms that NAA and BA do not affect fruit shape in 'Braeburn' (Table 3), but is in contrast with the results presented by Bound and Wilson (2007) that BA caused fruit flattening in 'Delicious' (Table 4).

Table 3. Fruit quality of cv. 'Braeburn' treated with NAA and BA

Treatment	L/D[1] ratio	Fruit firmness kg cm⁻²	Starch index (1–10)	TSS[2] %	TA[3] %
2009					
Control	0.89a	9.5c	5.6a	13.3c	0.37b
6 µl l⁻¹ NAA	0.90a	9.2abc	6.2b	12.0a	0.31a
8 µl l⁻¹ NAA	0.89a	9.4bc	6.3b	12.4ab	0.33a
10 µl l⁻¹ NAA	0.90a	9.1ab	6.3b	13.2c	0.31a
50 µl l⁻¹ BA	0.90a	9.0a	6.5b	12.9bc	0.32a
100 µl l⁻¹ BA	0.90a	9.3abc	6.5b	12.0a	0.36b
150 µl l⁻¹ BA	0.92a	9.2abc	6.6b	13.1c	0.38b
2010					
Control	0.90a	9.1a	5.4a	11.5a	0.48a
6 µl l⁻¹ NAA	0.92ab	9.5b	5.6ab	11.6ab	0.50a
8 µl l⁻¹ NAA	0.91a	9.8c	6.1b	12.2b	0.59c
10 µl l⁻¹ NAA	0.91a	9.3ab	6.0ab	11.7ab	0.51a
50 µl l⁻¹ BA	0.92ab	9.2ab	5.8ab	11.8ab	0.49a
100 µl l⁻¹ BA	0.92ab	9.5b	5.7ab	11.8ab	0.56bc
150 µl l⁻¹ BA	0.95b	9.3ab	5.7ab	11.9ab	0.52ab

[1] L/D – length/diameter ratio, [2] TSS – total soluble solids content, [3] TA – titratable acidity

In most cases thinning increases fruit firmness, but a decrease in firmness could also be observed (Link, 2000). The effect on firmness depended on the cultivar and application time. The effects of growth regulator treatments on flesh firmness at harvest were not consistent in the present research, similarly to the results of McArtney et al. (2007). In the case of cv. 'Braeburn' in 2009, fruit firmness was generally decreased in thinning treatments as previously reported by Costa et al. (2004), with significant differences in 10 µl l^{-1} NAA and 50 µl l^{-1} BA, but increased compared to the control in 2010 (Table 3). In the case of cv. 'Camspur', fruit firmness was generally decreased by NAA and unaffected by BA treatments, except for the lowest rate of BA in 2010 where firmness was increased (Table 4). The starch index was significantly increased by all thinning treatments in cv. 'Braeburn' in 2009, but only in 8 µl l^{-1} NAA in 2010 (Table 3). In cv. 'Camspur', starch index was increased at higher rates of NAA in 2009 only (Table 4). Fruit firmness reduction associated with advanced starch degradation confirms that thinning may advance fruit maturity (Link, 2000; McArtney et al., 2007).

Table 4. Fruit quality of cv. 'Camspur' treated with NAA and BA

Treatment	L/D ratio	Fruit firmness kg cm^{-2}	Starch index (1–10)	TSS %	TA %
		2009			
Control	0.93a	8.8de	4.5a	11.4a	0.21ab
8 µl l^{-1} NAA	0.93a	8.4bc	4.3a	11.6ab	0.24c
10 µl l^{-1} NAA	0.96b	8.2b	6.2b	13.0bc	0.28e
12 µl l^{-1} NAA	0.96b	7.8a	6.0b	13.6c	0.27e
50 µl l^{-1} BA	0.96b	8.5bcd	4.5a	12.3abc	0.21a
100 µl l^{-1} BA	0.99b	8.6cd	4.8a	13.6c	0.22b
200 µl l^{-1} BA	1.00b	9.0e	4.1a	12.6abc	0.26d
		2010			
Control	0.96ab	7.8bc	4.5a	10.8a	0.27ab
8 µl l^{-1} NAA	0.96ab	7.6ab	4.5a	10.8a	0.28ab
10 µl l^{-1} NAA	0.97b	7.8bc	4.8a	10.2a	0.27ab
12 µl l^{-1} NAA	0.96ab	7.5a	5.1a	10.4a	0.29b
50 µl l^{-1} BA	0.95ab	8.2d	4.7a	10.8a	0.29b
100 µl l^{-1} BA	0.95a	7.9bc	4.8a	10.4a	0.24a
200 µl l^{-1} BA	0.98b	8.0cd	4.5a	10.4a	0.27ab

Note. Explanations of abbreviations under Table 3.

Thinning can increase fruit TSS content by 2% to 3% and TA by 10% to 20% (Link, 2000). Thinning with NAA and BA decreased TSS content in fruits of 'Braeburn' but increased in 'Camspur' in 2009. There was no significant effect of thinning on TSS content in fruits of both cultivars in 2010, except for 8 µl l^{-1} NAA in 'Braeburn' where an increase in TSS was recorded. The effects of thinning on TA were not consistent in both cultivars and years of the study.

Removing a certain number of young fruits by chemical thinning with NAA and BA, creates favourable conditions for flower bud formation and increases the return bloom, which is reported in cvs 'Gala', 'Golden Delicious' and 'Fuji' (Stopar, 2002; Basak, 2004; Costa et al., 2004). In the present study, bearing potential was calculated as the percentage of buds with flower primordia in the sample (Keserović et al., 2005). The bearing potential was calculated before winter pruning and frost damages occurrence, thus is considered a more objective method for assessing direct effects of chemical thinning on flower bud formation then visually estimating flowering intensity. The number of buds with flower primordia was slightly increased in all treatments compared to the controls in both cultivars in 2009, but the increase was statistically significant only at the highest rate of NAA in 'Camspur' (Figs 1 and 2). In 2010, the bearing potential was increased by NAA and BA applications in cv. 'Braeburn' and 8 and 10 µl l^{-1} NAA treatments in cv. 'Camspur'. These two apple cultivars showed the different reaction to the applied thinning chemicals considering the bearing potential. BA did not affect the number of buds with flower primordia in cv. 'Camspur' (Fig. 2).

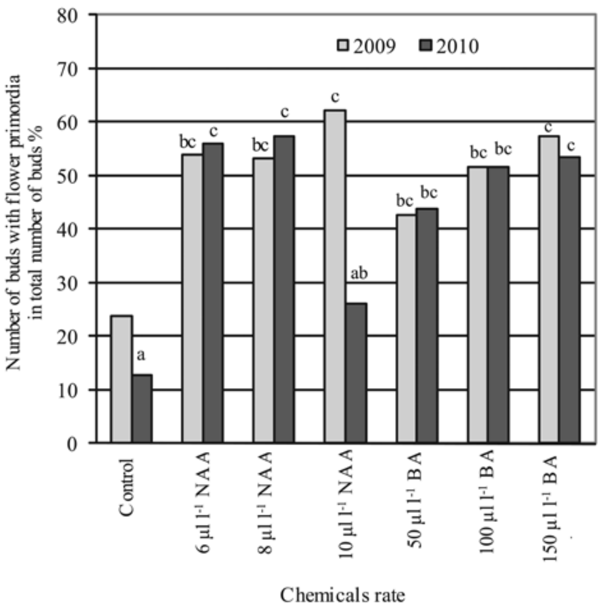

Figure 1. The effects of thinning with NAA and BA on bearing potential of cv. 'Braeburn'

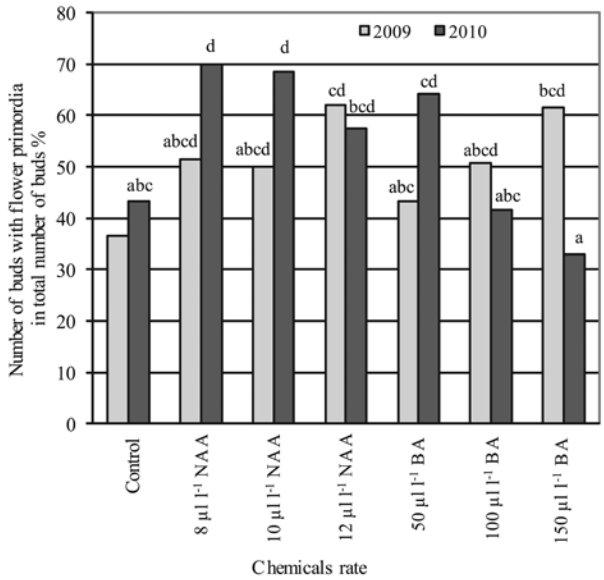

Figure 2. The effects of thinning with NAA and BA on bearing potential of cv. 'Camspur'

NAA and BA proved to be efficient chemical thinning agents for apple cultivars 'Braeburn' and 'Camspur', but problems considering oversized fruits in cv. 'Braeburn' and pygmy fruits in 'Camspur' may occur.

Conclusions

1. Both 1-naphtaleneacetic acid (NAA) and 6-benzyladenine (BA) proved to be effective thinning chemicals for cv. 'Braeburn'. The highest yields were achieved in the treatments with week thinning effects and increased fruit weight. The highest BA rate of 150 µl l^{-1} resulted in oversized fruits, which may be prone to storage disorders.

2. Effects of thinning on fruit quality parameters were not consistent. Starch index increase with decrease in fruit firmness in some treatments points at advanced fruit maturity on chemically thinned 'Braeburn' trees.

3. Thinning improved flower bud formation in 'Braeburn' in the second year of the study.

4. NAA appeared to be a more efficient chemical in reducing the fruit set in Redchief® 'Camspur Delicious'. The highest yields were recorded for control trees. Pygmy fruits occurred both after NAA and BA application.

5. Both thinning chemicals caused fruit elongation and an increase in total soluble solids (TSS) content and titratable acidity (TA) in the first year of the study. NAA advanced maturity of 'Camspur' fruits, while BA was not effective. Fruit quality was not affected by thinning in the second year of the study.

6. Only NAA increased the number of flower buds in cv. 'Camspur'.

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Chemiškai retintų 'Braeburn' bei 'Camspur' obelų vaisių kokybė ir produktyvumas

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Santrauka

Tyrimo tikslas – įvertinti 1-naftilacto rūgšties (NAR) ir 6-benziladenino (BA) įtaką veislių 'Braeburn' bei 'Camspur' obelų vaisių užmezgimui, kokybei ir produktyvumui. Veislės 'Braeburn' augalams naudoti 6, 8, 10 µl l^{-1} NAR bei 50, 100, 150 µl l^{-1} BA, veislės 'Camspur' – 8, 10, 12 µl l^{-1} NAR bei 50, 100, 200 µl l^{-1} BA koncentracijų tirpalai. Veislės 'Braeburn' obelų vaisių užmezgimą efektyviai mažino ir NAR, ir BA. Šios veislės obelų vaisių vidutinė masė padidėjo, o retinimo poveikis vaisių kokybės rodikliams buvo nenuoseklus. NAR efektyviai mažino veislės 'Camspur' obelų vaisių užmezgimą, paankstino jų brandą, o BA buvo neefektyvus. Antraisiais tyrimų metais abu chemikalai pagerino veislės 'Braeburn' obelų žiedinių pumpurų formavimąsi, bet tik NAR padidino veislės 'Camspur' jų kiekį. Žiedams retinti naudojant NAR ir BA, yra rizika išaugti per dideliems veislės 'Braeburn' ir nenormaliai mažiems (nykštukiniams) veislės 'Camspur' obelų vaisiams.

Reikšminiai žodžiai: 1-naftilacto rūgštis, 6-benziladeninas, žiedų pumpurai, vaisių užmezgimas.