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THE INFLUENCE OF FLOREDUX, MAXCEL AND BREVIS ON THE YIELD OF APPLE TREES CV. ŠAMPION

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A b s t r a c t. Flower or fruitlet thinning is one of the cultural practices used for improving the fruit quality and regulation of yield. The effect of ATS (FloreduX), 6-BA (MaxCel) and metamitron (Brevis) on yield and some fruit characteristics of apple trees cv. Šampion/ M.9 T337 was evaluated. Chemical thinning agents were applied alone, as subsequent spraying or as a tank mixture. Due to the possibility of damage to flowers by the announced frosts, a preparation containing sea algae – Goëmar was added in some treatments. Thinning with only MaxCel resulted in an excessive reduction of the total yield expressed in the number of fruits and their mass, but using MaxCel after flower thinning with Floredux gave very good results. The total yield expressed in kg/tree was even bigger than in the control, but the share of fruits with diameter above 7.5 mm was much better. The most promising method of thinning apple trees cv. 'Szampion' was the use of MaxCel+Brevis, at fruitlets diameter of 10-12 mm. The yield expressed by the number of apples on a tree was much smaller than in the control, but total yield did not differ from the total yield of the control trees. Apples in this treatment were characterised by the highest mass and length, as well as large diameters. In the fruits of this treatment, there was no significant reduction in flesh firmness relative to the control, and they had the highest dry matter content.

K e y w o r d s: chemical thinning, hand thinning, cytokinin, fruit quality

INTRODUCTION

The benefits of apple growing depend to the regularity of yield and high external and internal quality of fruit. The condition of annual cropping is a sufficient amount of flowers on a tree, as well as adequate flower setting for the next year. This is possible only with a suitable amount of fruit on the tree. Fruits, through their

seeds, have a negative effect on the formation of flower buds. The hormones contained in the seeds play a major role in this mechanism. Under normal conditions, there are too many flowers and fruit formation is too excessive, therefore, it is necessary to perform thinning. Both for the regularity of yielding and for obtaining big fruits, it is recommended to thin as early as possible (Bergh 1990). Thinning can be done during flowering (flower thinning), but most often it is made later (fruitlet thinning), due to the concerns of farmers about sufficient fruitset. Hand thinning in commercial orchards is impractical and uneconomical. Thus, nowadays, chemical fruit thinning is commonly carried out (Williams and Fallahi 1999). The availability of chemical thinning preparations is variable, as not all of them can remain on the market or be used in a given production system.

A good solution, commonly known among fruit growers, is the use of ammonium thiosulphate (ATS – preparation Floredux) at a suitable concentration. ATS works by desiccating and, therefore, damaging the stigmas and styles of apple flowers and preventing excessive fruitset. In a year when the flowering period is extended, two sprays may be required. Early thinning has a very positive effect on the development of flower buds for the next season. In our climatic conditions there is a high probability of frost during the flowering period. Early thinning with ATS, therefore, carries a risk of too much yield loss. Therefore, fruit farmers prefer to thin a little later. Currently in Poland, the following preparations are registered as approved for apple fruitlet thinning: Brevis 150 SG, Exillis 020 SL, Globaryll 100 SL, and since 2017 also MaxCel. Brevis contains metamitron which is a herbicide and an inhibitor of photosystem II. Metamitron belongs to triazinone chemical group which has recently been reported as an efficient product in the thinning of apple crops (Lafer 2010, Basak 2011). It affects the photosynthetic apparatus for 7 to 10 days after application, reducing electron transport rates by up to 60% (Macartney and Obermiller 2012). Brevis 150 SG is effective in the thinning of apple when applied at the stage from 7 to 15 mm, and its effect may be enhanced when associated with other thinners. Exillis 020 SL, Globaryll 100 SL and MaxCel are based on 6-BA. 6-BA is a cytokinin which not only thins apples, but it also increases fruit size and enhances return bloom for a crop in the following year (Greene 2016). BA improves fruit size or weight by increasing the number of cells per fruit through the stimulation of cell division (Geene *et al*. 1992, Wismer *et al*. 1995).

The aim of this study on apple trees cv.'Šampion' was to estimate the effectiveness of chemical thinning of flowers and fruitlets with Floredux, Brevis and MaxCelalone, as a subsequent spraying or in a mixture. Due to the possibility of damage to flowers by announced frosts, a preparation containing sea algae – Goëmar was added in some treatments.

MATERIAL AND METHODS

The experimental material in 2016 was apple trees of the 'Šampion'/M.9 T337 cultivar, planted in a commercial orchard in Stryjno. The trees were planted in 2010 in rows directed from north to south, with spacing of 3.3 × 1.2 m. The trees were trained as slender spindles. Orchard floor management consisted of grass in the interrows and 1-m wide herbicide strip in the intrarow space. Protection of trees against pests was carried out in accordance with current recommendations for fruit orchards. Fertilisation was carried out according to the YARA fertiliser program. For each combination of thinning flowers or fruitlets, 10 intensely flowering trees were selected. The apple trees were thinned according to the following scheme:

1. Control (without any thinning practices);
2. Control (without any thinning practices) + 3 × Goëmar 2 l ha^{-1} in 1000 l of water;
3. Hand thinning (after the June fruit drop)
4. Hand thinning (after the June fruit drop) + 3 × Goëmar 2 l ha^{-1} a in 1000 l of water;
5. Ammonium thiosulphate (during flowering) + BA 300 ppm (with 10-12 mm diameter of royal buds on older wood) (Floredux 15 l ha^{-1}, 500 l water ha^{-1}) + MaxCel 7.5 l ha^{-1}; 500 l water ha^{-1});
6. Metamitron 495 ppm (king fruit diameter 8-10 mm) (Brevis 1.65 kg; 500 l water ha^{-1});
7. Metamitron 660 ppm (king fruit diameter 8-10 mm) (Brevis 2.2 kg; 500 l water ha^{-1});
8. BA 300 ppm (king fruit diameter 10-12 mm) (MaxCel 7.5 l ha^{-1}; 500 l water ha^{-1});
9. Ammonium thiosulfate (during flowering) (Floredux 15 l ha^{-1}, 500 l water ha^{-1}) + Metamitron 495 ppm/ BA 300 ppm (king fruit diameter 10-12 mm) (Brevis 1.65 kg + MaxCel 7.5 l ha^{-1}; 500l water ha^{-1});
10. Metamitron 495 ppm/ BA 300 ppm (king fruit diameter 10-12 mm) (Brevis 1.65 kg + MaxCel 7.5 l ha^{-1}; 500l water ha^{-1}).

At harvest time (29th of September, 2016) samples of 100 fruits per treatment were randomly collected for fruit quality determinations. Quality was determined by assessing the following features:

- Total yield expressed in number of fruit $tree^{-1}$ (No.) and mass $tree^{-1}$ (kg);
- Proportion of fruit in individual size classes – on a sample of 100 fruits from every treatment that were divided in three classes: < 65 mm; 65-75 mm and > 75 mm of fruit diameter.
- Mean fruit mass determined with a digital balance (g);
- Diameter and length of fruits determined with digital caliper (mm);
- Skin colour assessed with an arbitrary scale: 1-5 (1: no blush, 2: 1-25% of skin with blush, 3: 26-50% of skin with blush, 4: 51-75% of skin with blush, 5: 76-100% of skin with blush);

• Flesh firmness with Magness-Taylor penetrometer (mod. FT 327) with 11 mm probe;
• Soluble solids content (%) with an Abbé refractometer;
• Dry matter content (%) with the oven-drying method.

The data were statistically evaluated by analysis of variance (ANOVA) by Tukey's test at P = 0.05). Data were analysed using 'STATISTICA' software.

RESULTS AND DISCUSSION

Table 1. Total yield of apple trees cv. 'Šampion' in 2016

Treatment	N° of fruit tree^{-1}	Total yield (kg tree^{-1})
1. Control	183.0 d[1]	29.79 d-f
2. Control+Goëmar	171.0 d	31.32 ef
3. Hand thinning	96.0 ab	21.91 a-c
4. Hand thinning + Goëmar	101.88 ab	19.49 ab
5. Floredux+MaxCel	149.50 cd	34.22 f
6. Brevis 1.65 kg	125.25 bc	26.33 b-e
7. Brevis 2.2 kg	124.13 bc	27.51 c-f
8. MaxCel	76.13 a	17.82 a
9. Floredux + MaxCel/Brevis	113.25 b	22.24 a-c
10. MaxCel/Brevis	96.63 ab	23.75 a-d

[1]Different letters in columns indicate a significant difference in Tukey's Multiple Comparison Test ($p < 0.05$)

Each thinning method resulted in a significant reduction in the total yield expressed as the number of apples per tree, apart from the combination where Floredux+MaxCel were used (Tab. 1). In some cases a significant decrease in the total yield expressed as kg tree^{-1} in comparison to the control trees was noted (treatments 3,4,8,9). Only the trees where Floredux+MaxCel, Brevis 2.2 kg, Brevis 1.65 kg and MaxCel/Brevis were used (treatments 5,6,7,10) had a similar mass of total yield to the control trees. Overthinning occurred after using MaxCel alone. According to McArtney and Obermiller (2014), high concentrations of metamitron can promote excessive fruit drop, requiring some care during application. In this study the total yield at the dose of Brevis of 1.65 and 2.2 kg ha^{-1} was similar.

Each of the thinning methods improved the share of large fruits (75-85 mm in diameter) and very large (above 85 mm in diameter), as compared to the control where there was a fruit class with a diameter of less than 6.5 cm (Fig. 1). In the treatment with only MaxCel, the whole crop was apples with diameters of more than 7.5 cm. The largest share of very large fruits (more than 8.5 cm in diameter) was recorded in the treatment with MaxCel/Brevis. Assessing the structure and quantity of the crop, excellent results were obtained after the application of Floredux+MaxCel. The total yield expressed in kg tree^{-1} was even higher than in the control, but the share of fruit with diameter above 75 mm was much better.

The explanation of this may be that early thinning of apple trees during flowering reduces the competition within the tree for carbohydrates produced during photosynthesis and improves cell division in the persisting fruitlets. Most cell division occurs in the first 3-4 weeks following fruit set (Denne 1960). In addition, cytokinins promote cell division in young fruitlets (Letham 1966, Greene *et al*. 1992). As a result, a slight reduction in the number of fruit as compared to the control resulted in an increase in the mass of the crop. However, this was not observed in a similar treatment where after the previous flower thinning the mixture of BA and metamitron was used (Floredux+Maxcel/Brevis). This could be explained by a different mechanism of fruitlets drop. 6-BA application results in reduced polar auxin transport across the fruit pedicel and enhances the sensitivity of the abscission zone to ethylene, eventually leading to activation of the abscission zone (Botton *et al*. 2011). This causes the drop of the weakest fruits. Metamitron is an PSII inhibitor and in this way reduces fruit set in apples. Byers *et al*. (1984) stated that photosynthetic inhibitors might also enhance the activity of other thinning agents applied to apples. Perhaps this caused a greater thinning effect than in the treatment with Floredux+MaxCel, as a result, not only the smallest fruits have fallen.

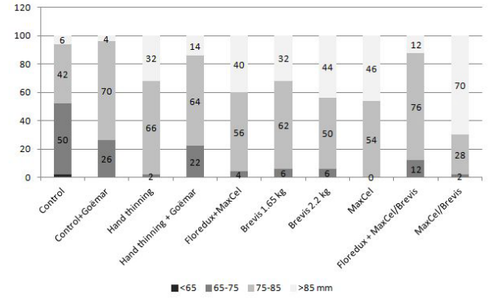

Fig. 1. Proportion of fruit in individual size classes expressed as percentage of fruit number

Each of the thinning methods resulted in a significant increase in the mean fruit mass as compared to the control trees (Tab. 2). Apples with the highest weight were recorded in the MaxCel/Brevis treatment. In the present experiment, a greater weight of fruit was obtained, with crop load of 100 fruits per tree, as compared to the results of Kapłan and Baryła (2006). In the treatment Hand thinning + Goëmar the crop load was close to 100 pieces per tree and mean fruit mass was 191 g, while in the work of Kapłan and Baryła (2006), 171-175 g were obtained. In most of the thinning methods an increase in fruit diameter was observed, compared to the control. Only apples from the trees where Brevis was applied at a dose of 1.65 kg ha^{-1} had a similar diameter as the control apples. The largest diameter was observed in fruits from trees where only MaxCel was used. Each

of the thinning methods resulted in an increase in the length of apples in relation to the control. Apples from trees where the fruitlets were thinned with MaxCel/Brevis were characterised by the highest values of the mentioned feature. Colour and size of apple are very important criteria for consumers (Dobrzański and Rybczyński 2002). There was no significant effect of thinning on the skin colour of apple cv. 'Szampion'. Only fruits from trees where hand thinning was applied showed skin blush more intensive than the control fruits. This is consistent with findings of Maas and Meland (2016) who evaluated thinning response of 'Summer red' apple and noted that blush colour was significantly higher for apples of hand-thinned trees compared to all other treatments. Thinning achieved by the Brevis treatment did not improve the intensity of blush.

Table 2. Some external fruit quality indicators: Mean fruit mass, diameter of fruit, length of fruit, skin colour and skin russeting

Treatment	Mean fruit mass (g)	Diameter of fruit (mm)	Length of fruit (mm)	Skin colour (scale 1-5)
1. Control	162.78 a[1]	71.60 a	63.00 a	3.72 a
2. Control+Goëmar	183.16 ab	75.70 b	67.10 b	3.92 ab
3. Hand thinning	228.28 d-f	80.29 cd	70.91 cd	4.44 b
4. Hand thinning + Goëmar	191.34 bc	78.20 bc	69.07 b-d	4.08 ab
5. Floredux+MaxCel	228.90 d-f	84.32 e	72.80 de	3.88 a
6. Brevis 1.65 kg	210.21 cd	76.96 ab	69.61 b-d	3.56 a
7. Brevis 2.2 kg	221.67 de	81.69 de	70.89 cd	3.84 a
8. MaxCel	234.12 ef	81.24 d	70.45 b-d	3.84 a
9. Floredux + MaxCel/Brevis	196.41 bc	76.04 b	68.22 bc	3.96 ab
10. MaxCel/Brevis	245.81 f	81.84 de	76.22 e	4.04 ab

[1] Different letters in columns indicate a significant difference in Tukey's Multiple Comparison Test ($p < 0.05$)

Apples from trees where thinning was done by hand, Hand thinning + Goemar and Brevis 2.2 kg, were characterised by much lower flesh firmness in relation to control apples (Tab. 3).

Table 3. Some internal fruit quality indicators: flesh fruit firmness, soluble solids content and dry matter content

Treatment	Flesh firmness kG cm^{-2}	Soluble solids content	Dry matter content (%)
1. Control	6.87 de[1]	11.95 ab	14.50 ab
2. Control+Goëmar	6.76 cd	11.8 a	13.90 a
3. Hand thinning	6.44 ab	12.15 ab	14.95 ab
4. Hand thinning + Goëmar	6.42 a	12.75 ab	14.37 ab
5. Floredux+MaxCel	6.63 a-d	12.00 ab	14.69 ab
6. Brevis 1.65 kg	7.09 e	11.90 ab	14.18 ab
7. Brevis 2.2 kg	6.52 a-c	12.20 ab	14.32 ab
8. MaxCel	6.58 a-d	12.95 b	15.65 b
9. Floredux + MaxCel/Brevis	6.73 b-d	12.50 ab	14.65 ab
10. MaxCel/Brevis	6.74 b-d	12.45 ab	15.81 b

[1]Different letters in columns indicate a significant difference in Tukey's Multiple Comparison Test ($p < 0.05$)

No significant effect of thinning methods on soluble solids content was found. The values of the mentioned feature were in the range from 11.8 to 12.95%. There was no significant effect of thinning on dry matter content in the fruit. The smallest values of the mentioned feature were noted for Control+Goëmar treatment, and the largest after the application of MaxCel/Brevis and MaxCel alone. Greene (2014) observed that the application of metamitron in combination with BA determined slight changes in variables related to flesh firmness and soluble solids.

CONCLUSIONS

1. Thinning of apple trees cv. 'Šampion' with only MaxCel resulted in an excessive reduction of the total yield expressed in the number of fruit and its mass, but using MaxCel after flower thinning with Floredux gave very good results. The total yield expressed by kg/tree was even bigger than in the control, but the share of fruit with diameter above 7.5 mm was much better.

2. The most promising method of thinning apple trees cv. 'Šampion' was the use of MaxCel+Brevis, at fruitlet diameter of 10-12 mm. The yield expressed by the number of apples on a tree was much smaller than in the control, but the mass of the total yield did not differ from the total yield of the control trees. Apples in this treatment were characterised by the highest mass and length, as well as large diameter. In the fruits of this combination, there was no significant reduction in flesh firmness relative to the control and they had the highest dry matter content.

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WPŁYW PREPARATÓW FLOREDUX, MAXCEL I BREVIS NA PLON JABŁONI ODMIANY ŠAMPION

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S t r e s z c z e n i e. Przerzedzanie kwiatów lub zawiązków jest jednym z podstawowych zabiegów wykorzystywanych dla poprawy jakości owoców i wielkości plonu. Badano wpływ ATS (FloreduX), 6-BA (MaxCel) i metamitronu (Brevis) na plon i wybrane cechy jakościowe owoców jabłoni odmiany Šampion/ M.9 T337. Przerzedzanie chemiczne wykonano aplikując preparaty w kolejnych zabiegach lub w mieszaninie. Ze względu na niebezpieczeństwo uszkodzeń kwiatów przez zapowiadane przymrozki w niektórych kombinacjach zastosowano dodatkowo preparat zawierający algi – Goëmar. Przerzedzanie z użyciem tylko preparatu MaxCel spowodowało nadmierną redukcję plonu wyrażonego liczbą sztuk na drzewo oraz jego masą. Jednakże użycie preparatu MaxCel po wcześniejszej aplikacji w czasie kwitnienia preparatu Floredux okazało się korzystne. Plon całkowity wyrażony w kg·drzewo^{-1} był nawet większy niż w kontroli, ale udział owoców o średnicy powyżej 7,5 cm był znaczniejszy. Najkorzystniejszą metodą przerzedzania jabłoni odmiany ‚Šampion' było zastosowanie MaxCel+Brevis, przy średnicy 10-12 mm. Plon wyrażony liczbą owoców na drzewo był dużo niższy niż w kontroli, ale

plon całkowity (kg·drzewo^{-1}) różnił się od kontrolnego. Jabłka w tej kombinacji charakteryzowały się najwyższą masą i długością, jak również średnicą. Ponadto jędrność owoców w tej kombinacji nie obniżyła się istotnie w stosunku do kontroli, a zawartość suchej masy była największa.

S ł o w a k l u c z o w e: przerzedzanie chemiczne, przerzedzanie ręczne, cytokininy, jakość owoców