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Effect of bioregulators and summer pruning on growth and cropping of 'Rubin' apple trees

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ABSTRACT

The effect of spraying with Regalis (prohexadion Ca) and Arbolin (BA + GA_3) and of shoot heading of 'Rubin' trees grafted on P22 rootstocks was investigated in the years 2002 – 2004 on growth and cropping trees. The spraying of trees with Regalis and Arbolin resulted in shortening of terminal shoots on limbs but did not affect the trunk cross-section area. The fruit setting of trees treated with Arbolin was lower in the second year of the research. Cumulative yields of two years and the yield efficiency were lower after Arbolin treatment. A tendency to higher yields and higher yield efficiency was observed after spraying with Regalis at concentration of 1.5 g l^{-1}.

INTRODUCTION

Rubin cultivar was selected of seedlings originated from a 'Lord Labourne' × 'Golden Delicious' crossing. The characteristic features of this cultivar are very strong growth and fruiting, above all, on sub-side shoots 20-40 cm in length ended with flower buds. 'Rubin' produces very few spurs and gives no fruit on long shoots. 'Rubin' apples have excellent taste and are covered with beautiful carmine colour in almost 100%. They can successfully compete with other elite cultivars on both Polish and foreign markets (Mika 1999a).

However, strong growth of trees, specific forms of canopy structure (stripping of the canopy inside) and late beginning of fruit bearing necessitate special treatment. Fruit growers dealing with this cultivar must have profound knowledge concerning selecting proper rootstocks, methods of pruning and canopy formation and also different methods in promoting the earliness of fruit bearing.

One of the methods of to increase the yields of this cultivar is to use properly selected rootstocks (Mika 1999c) such as P22, P59 or M9. Of five apple cultivars grown in Dąbrowice ('Rubin', 'Gloster', 'Sampion', 'Elstar' and 'Lodel') 'Rubin' showed the best yielding efficiency beside 'Gloster' (Mika 1999b). In pruning 'Rubin' trees Mika (2001) recommends the removal of small branches and fruit bearing shoots from the inside of the canopy, leaving small twigs and shoots on its circumference, even if directed upwards.

Apart from this kind of pruning, good results can be obtained from trees pruned after blooming, during the June or July vegetation. In this case all stronger shoots are shortened to 20 cm. Preappearing shoots are short and set flower buds.

An increased number of spurs can also be obtained using bioregulators, such as Arbolin containing benzyladenine (BA) and gibberellic acid (GA_3). However, the gibberellic treatment is sometimes connected with poorer flower bud setting (Jaumień 1999). After growth retardants of the Alar or Cultar type were withdrawn from fruit growing as harmful due to of their residues in plants, a new preparation, recently registered in Poland as Regalis (calcium prohexadion), arouses great interest.

The aim of the study was to improve the structure of the canopy and the earliness of fruit bearing of Rubin apple trees by summer pruning of canopy long shoots and applying preparations of the growth regulators effect.

MATERIAL AND METHODS

The experiment was conducted in the Fruit Growing Experimental Station of Garlica Murowana near Kraków, Poland. Young plants budded on P22 rootstocks were planted in the orchard at the spacing of 4 × 1.2 m in the autumn of 1999.

Pruning and spraying with bioregulators began in 2002, an experiment being established in a randomized block design in four replications of 5 trees each. The canopys of the investigated trees were trained in spindle form. In the tree rows herbicidal belts were maintained, using Roundup at a dose of 4 l ha^{-1} three times during the vegetation season, the grass being left between the rows. Nitrogen fertilization of trees at a dose of 40 kg ha^{-1} was applied every year.

The following treatments of the experiment were compared:

- Control treatment – thinning pruning carried out early in the spring;
- Summer pruning of long shoots carried out in mid-June consisting in the shortening of all shoots above 20 cm in length, five leaves being left;
- Spraying of trees with Arbolin 036 SL at conc. of 30 ml l^{-1} water with a wetting agent;
- Spraying of trees with Regalis 10 WG at conc. of 1.5 g 1^{-1} water;
- Spraying of trees with Regalis 10 WG at conc. of 1.0 g l^{-1} water.

Summer pruning was carried out on 27 May 2002, 5 June 2003, and 10 June 2004. Arbolin spraying was carried out in 2002 on 21 May and repeated on 4 June; in 2003 on 16 May and 5 June, in 2004 on 11 and 18 May.

Regalis spraying was conducted on 8 and 27 May 2002, 8 and 16 May 2003, and 11 and 18 May 2004.

Tree growth parameters were determined every year on the basis of the following measurements:

- Trunk diameter measured at 30 cm above the soil level, calculated per cross-section area of the trunk and annual growth;
- Height and width of the canopy, used in computing the canopy volume;
- Length of 10 selected shoots that lengthened the axis of branches and the computation of the average length.

The earliness of fruit bearing and the yields were determined on the basis of the following observations:

- Percentage of fruit setting;
- Total yield (total yield from five trees calculated in kg per one tree);
- Productivity index calculated on the basis of total yield and cross-section area of the trunk [kg cm^{-2}].

The quality of fruit was established on the basis of:

- Average weight of a fruit [g];
- Degree of fruit coloration in a scale from 1 to 5 where I = 20% of coloration of the fruit surface; II = 21-40%; III = 41-60%; IV = 61-80% and V = above 80%;
- Flesh firmness was measured on 10 apples from each treatment on the side of the basic colour and on that of the flush. Since no significant difference was assessed between the opposite sides of the apples,

means from two measurements on each apple were taken into consideration. The results are given in kilograms, fruit firmness at the harvest time [KG cm^{-2}];

– Titratable acidity and soluble solids content at the time of fruit harvest. The measurement of pH of juice sampled from the apples was performed using potentiometric method according to PN-90/A-75101/07. Soluble solids content was determined using ATAGO refractometer at 22°C in juice squeezed from the homogenate of apples previously sampled for the flesh firmness measurement. The results are given in percentages. Acidity was determined in the homogenate in the solution adjusted to pH 8.1 with 0.1 n NaOH, this value being accepted as the neutrality level. The results are given in percentage values calculated as malic acid.

The content of mineral constituents (N, P, K, Ca and Mg) in dry matter of leaves was determined on the basis of chemical analyses of the leaves. Samples of 50 leaves for analysis were taken in July from each plot (treatment) from the central part of a long shoot. The leaves were air-dried and chemical analyses were conducted in the Central Laboratory of the Skierniewice Fruit Growing Institute.

The results were verified using variance method. The differences between the means were evaluated using the Duncan test at $p = 0.05$ coefficient.

RESULTS AND DISCUSSION

The trunk cross-section area was uniform at the time when the experiment was established. The treatments did not affect increases in the cross-section area or in the dimensions of this area in the autumn of 2004 (Table 1). Summer pruning in 2002 increased the average length of shoots that lengthened the axis of branches. However, in the following two years the length of these shoots was smaller owing to the applied pruning. Similar effect was observed in the trees treated with Regalis. An analysis of the total length of shoots in the years 2002 – 2004 confirmed distinct suppression of growth brought about by Regalis (Table 2). This result is corroborated by the literature (Evens et al. 1997). No stimulating effect of Arbolin on the growth of shoots was observed contrary to the effect of a similar preparation recorded by Watanabe et al. (2003). The size of the canopy was similar in all the years of the experiment irrespective of the applied treatments.

Table 1. Trunk cross-section area of 'Rubin' apple trees depending on pruning and bioregulators treatment

Treatments	Trunk cross-section area	Increase in trunk cross-section area [cm^2]			Final trunk area
	Spring 2002	2002	2003	2004	Autumn 2004
1. Control	3.17 a*	3.73 a	2.60 a	4.77 a	14.27 a
2. Summer pruning	2.43 a	3.51 a	3.16 a	3.60 a	12.70 a
3. Arbolin 30 ml l^{-1}	2.58 a	2.05 a	2.48 a	4.29 a	11.40 a
4. Regalis 10 WG 1.5 g l^{-1}	2.89 a	2.98 a	2.24 a	2.88 a	10.99 a
5. Regalis 10 WG 1.0 g l^{-1}	2.87 a	3.38 a	2.48 a	4.23 a	12.96 a

*Means marked with the same letter do not differ significantly at p = 0.05

Table 2. The results of pruning and bioregulators on growth of 'Rubin'apple trees

Treatments	Canopy volume [m^3]			Total length of limb leader [cm]			
	2002	2003	2004	2002	2003	2004	2002 – 2004
1. Control	1.213 b*	1.488 a	1.86 a	342.3 a	293.3 b	263.2 a	898.7 c
2. Summer pruning	1.136 ab	1.409 a	1.80 a	427.8 b	176.0 a	253.5 a	857.2 abc
3. Arbolin 30 ml l^{-1}	0.818 a	1.012 a	1.62 a	362.8 ab	264.3 b	256.7 a	883.7 bc
4. Regalis 10 WG 1.5 g l^{-1}	0.834 a	1.025 a	1.26 a	338.5 a	191.5 a	250.5 a	780.5 ab
5. Regalis 10 WG 1.0 g l^{-1}	0.877 ab	0.993 a	1.58 a	350.0 a	189.0 a	230.7 a	770.0 a

*see Table 1

In the second and third year of the investigation Arbolin reduced the percentage of set fruits, showing the thinning effect of this preparation (Table 3). This result also suggests that Arbolin should not be used on trees, which have not yet entered the full fruit bearing stage. In the first year of fruit bearing no treatment affected the yields of trees in comparison with the control. Summer pruning did not affect the total yield from the years of the experiment and a certain tendency to yield reduction was even observed. The application of Arbolin had a distinctly limiting effect on the yield and also on the size of fruit expressed by the average weight of apples (Table 4). Decreases in the percentage of flower buds setting and hence the reduction of yield due to the pruning, which has the character of top plucking, is in agreement with our earlier results (Poniedziałek et al. 2000). Irrespective of the applied dose the effects of Regalis were similar and did not differ from the control treatment.

The lowest productivity index was found for the trees treated with Arbolin but an increasing tendency appeared after the spraying with Regalis at the dose of 1.5 g l^{-1}.

Table 3. The effect of pruning and bioregulators on fruiting of 'Rubin' apple trees

Treatments	Total yield [kg per tree]			Cumulative yield [kg]	Efficiency index [kg cm^{-2}]	Fruit-set [%]			
	2002	2003	2004	2002 – 2004	2004	2002	2003	2004	2002 – 2004
1. Control	0.48 ab*	4.68 b	10.46 b	15.62 b	1.34 b	3.3 a	6.5 b	8.5 bc	6.1 b
2. Summer pruning	0.14 a	5.22 b	7.10 ab	12.46 ab	1.03 b	2.1 a	8.7 b	9.1 c	6.6 b
3. Arbolin 30 ml l^{-1}	0.58 b	0.92 a	3.76 a	5.26 a	0.57 a	3.4 a	2.0 a	4.6 a	3.3 a
4. Regalis 10 WG 1.5 g l^{-1}	0.50 ab	5.54 b	9.38 ab	15.42 b	1.41 b	2.1 a	8.4 b	6.5 ab	5.7 b
5. Regalis 10 WG 1.0 g l^{-1}	0.34 ab	4.51 b	10.65 b	15.50 b	1.27 b	2.3 a	7.1 b	7.2 bc	5.5 b

* see Table 1

Table 4. The effect of pruning and bioregulators on fruit quality features of 'Rubin' apple trees

Treatments	Mean mass of fruit [g]				Fruit colour degree 1-5		
	2002	2003	2004	2002 – 2004	2003	2004	2003 – 2004
1. Control	208 ab*	174 a	233 a	205 b	4.24 b	5.0 b	4.6 c
2. Summer pruning	230 ab	178 a	212 a	207 b	3.43 ab	4.2 a	3.8 b
3. Arbolin 30 ml l^{-1}	156 a	157 a	207 a	173 a	2.63 a	3.7 a	3.1 a
4. Regalis 10 WG 1.5 g l^{-1}	230 ab	157 a	207 a	198 b	3.8 b	5.0 b	4.4 c
5. Regalis 10 WG 1.0 g l^{-1}	251 b	162 a	239 a	217 b	3.4 ab	5.0 b	4.2 b

* see Table 1

Table 5. Firmness and soluble solids of 'Rubin' apples depending on pruning and bioregulators (at harvest)

Treatments	Fruit firmness [KG cm^{-2}]				Soluble solids [%]			
	2002	2003	2004	2002 – 2004	2002	2003	2004	2002 – 2004
1. Control	7.6 a*	7.5 a	6.4 a	7.2 a	14.0 ab	13.6 a	13.8 a	13.8 a
2. Summer pruning	7.6 a	7.5 a	7.1 b	7.4 a	13.6 ab	12.9 a	13.8 a	13.4 a
3. Arbolin 30 ml l^{-1}	7.9 a	7.6 a	6.8 ab	7.4 a	13.5 a	13.7 a	14.3 b	13.8 a
4. Regalis 10 WG 1.5 g l^{-1}	7.6 a	7.5 a	6.7 ab	7.2 a	14.1 b	13.4 a	13.5 a	13.7 a
5. Regalis 10 WG 1.0 g l^{-1}	7.6 a	7.7 a	6.4 a	7.3 a	13.9 ab	13.8 a	13.6 a	13.8 a

* see Table 1

Table 6. Titratable acidity and pH of 'Rubin' apples depending on pruning and bioregulators (at harvest)

Treatments	pH				Titratable acidity [g 100 g^{-1}]			
	2002	2003	2004	2002 – 2004	2002	2003	2004	2002 – 2004
1. Control	3.14 b*	3.2 bc	3.24 a	3.19 a	0.75 a	0.67 a	0.71 ab	0.71 a
2. Summer pruning	3.14 b	3.3 c	3.26 a	3.23 a	0.73 a	0.67 a	0.72 ab	0.71 a
3. Arbolin 30 ml l^{-1}	3.09 a	3.2 bc	3.25 a	3.18 a	0.84 b	0.61 a	0.77 b	0.74 a
4. Regalis 10 WG 1.5 g l^{-1}	3.08 a	3.1 a	3.31 b	3.16 a	0.79 ab	0.65 a	0.65 a	0.70 a
5. Regalis 10 WG 1.0 g l^{-1}	3.10 ab	3.1 a	3.31 b	3.17 a	0.78 ab	0.70 a	0.64 a	0.71 a

* see Table 1

Table 7. Content of nitrogen, phosphorus and potassium in leaves depending on pruning and bioregulators [mg 100 g^{-1}] (dry matter basis)

Treatments	N			P			K		
	2002	2003	2004	2002	2003	2004	2002	2003	2004
1. Control	2.52 a*	2.69 b	2.54 b	0.20 a	0.18 b	0.21 a	1.69 a	1.65 a	1.51 ab
2. Summer pruning	2.74 b	2.79 b	2.51 b	0.23 a	0.19 b	0.20 a	1.62 a	1.58 a	1.38 a
3. Arbolin 30 ml l^{-1}	2.66 ab	2.34 a	2.20 a	0.19 a	0.16 a	0.18 a	1.63 a	2.10 b	1.81 c
4. Regalis 10 WG 1.5 g l^{-1}	2.54 a	2.66 a	2.48 b	0.23 a	0.18 b	0.21 a	1.73 a	1.73 a	1.44 ab
5. Regalis 10 WG 1.0 g l^{-1}	2.57 ab	2.64 b	2.48 b	0.21 a	0.19 b	0.19 a	1.76 a	1.75 a	1.61 b

* see Table 1

The firmness of fruit flesh did not change after the applied treatments (Table 5). In 2004 only a tendency to a greater firmness appeared due to the summer pruning of trees. In 2004 the greatest content of soluble solids in fruit juice was recorded in trees treated with Arbolin, however, no differences were found in the means from the years (Table 6). The pH value of the fruit juice changed in the years of the experiment. In the first year of the investigation higher pH was recorded in the control and in trees after summer pruning. This tendency was also maintained in the second year. However, in the third year higher pH was found in the case of Regalis application. The mean from the years was not differentiated.

The treatments did not affect the content of organic acids in apple homogenate.

The effect of the applied treatments on the content of nitrogen in leaves was not unequivocal (Tables 7 and 8). The pruning increased the percentage of nitrogen in leaves. Arbolin reduced the content of this constituent in leaves. In the case of the remaining treatments the content was maintained at the same level. Arbolin decreased the percentage of phosphorus, magnesium and calcium in leaves but increased the content of potassium.

Table 8. Content of calcium and magnesium in leaves depending on pruning and bioregulators [mg 100 g^{-1}] (dry matter basis)

Treatments	Ca			Mg		
	2002	2003	2004	2002	2003	2004
1. Control	0.89 a*	1.10 b	1.15 b	0.19 a	0.22 a	0.27 a
2. Summer pruning	0.83 a	1.32 c	1.35 b	0.20 a	0.23 a	0.25 a
3. Arbolin 30 ml l^{-1}	0.86 a	0.81 a	0.96 a	0.17 a	0.19 a	0.21 a
4. Regalis 10 WG 1.5 g l^{-1}	1.01 a	1.27 bc	1.21 b	0.20 a	0.23 a	0.22 a
5. Regalis 10 WG 1.0 g l^{-1}	0.93 a	1.14 b	1.24 b	0.18 a	0.22 a	0.24 a

*see Table 1

CONCLUSIONS

1. Treatments did not the effect growth of the trees, only shoots on the trees sprayed with Regalis were slightly shorter.
   - Arbolin decreased the percent of setting fruits so it can be consider as thinning agent. It should not be used before full fruiting of trees.
   - Arbolin decreased the yield and the mass of fruit.
   - The trees sprayed with Arbolin had the lowest index of yield or productivity efficiency. Regalis (1.5 g l^{-1}) showed tendency to increase the index.

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REFERENCES

EVENS R.R, EVENS J.R., RADEMACHER W., 1997. Prohexadione calcium for suppression of vegetative growth eastern apples. Acta Hort. 451: 663-666.

JAUMIEŃ F., 1999. Wpływ giberelin na tworzenie się pąków kwiatowych. Ogrodnictwo 1/1: 6-8. [In Polish]

MIKA A., 1999a. Sto pytań do Instytutu Sadownictwa i Kwiaciarstwa w Skierniewicach. Sad Now. 8: 5-6. [In Polish]

MIKA A., 1999b. Rubin w ocenie agrotechnika. Sad Now. 5: 12. [In Polish]

MIKA A., 1999c. Planting density of apple trees as related to rootstocks. Proc. of the Intl. Seminar. August 19-21, Warsaw-Ursynów: 77-78.

MIKA A., 2001. Jak regulować nadmierny wzrost jabłoni. Sad Now. 8: 6-7. [In Polish]

PONIEDZIAŁEK W., GĄSTOŁ M., BIENIASZ M., 2000. Efect of heading summer sprouts on the growth and fruiting of apple trees. Folia Hort. 12/1: 3-11.

WATANABE M., SUZUKI A., KOMORI S., SATO M., 2003. Effect of plant growth regulators on shoot growth of a columnar type apple tree. Hort. Res. 2/2: 97-100.

WPŁYW BIOREGULATORÓW I CIĘCIA LETNIEGO NA WZROST I OWOCOWANIE DRZEW JABŁONI ODMIANY ‘RUBIN’.

Streszczenie: Badano wpływ Regalisu (proheksadion wapnia), Arbolinu (BA + GA_3) i ogławiania pędów na wzrost i owocowanie drzew jabłoni odmiany ‘Rubin’ rosnących na podkładce P.22. Zastosowane zabiegi nie wpłynęły w sposób istotny na wzrost drzew. Nieznaczne osłabienie wzrostu pędów zaobserwowano jedynie u drzew opryskiwanych preparatem Regalis. Arbolin zmniejszył procent zawiązanych owoców, co świadczy o przerzedzającym działaniu tego związku na zawiązki jabłek. Wskazuje również na to, że preparat ten nie powinien być stosowany przed wejściem drzew w pełnię owocowania.

Zastosowanie Arbolinu ograniczało wielkość plonu i powodowało również drobnienie owoców. Wskaźnik produktywności drzew był najniższy u drzew, na

których zastosowano Arbolin, natomiast wykazał tendencję do wzrostu w wyniku opryskiwania drzew Regalisem w dawce 1,5 g l^{-1}. Jędrność owoców nie uległa zmianie pod wpływem zastosowanych kombinacji. Jedynie w 2004 roku zaznaczyła się tendencja do zwiększenia jędrności owoców w wyniku cięcia letniego drzew. Również inne parametry takie jak zawartość ekstraktu, pH soku i zawartość kwasu w soku była podobna. Wpływ badanych kombinacji na zawartość azotu w liściach nie był jednoznaczny. Cięcie zwiększyło zawartość azotu, ale tylko w roku 2002, Arbolin obniżył go w 2003 i 2004 r. Regalis zastosowany w stężeniu 1,5 g l^{-1} wody obniżył zawartość azotu tylko w roku 2003. Opryskiwanie preparatem Arbolin wpłynęło na zmniejszenie zawartości fosforu w liściach, a w dwóch ostatnich latach zmniejszyło w liściach zawartość wapnia przy równoczesnym zwiększeniu koncentracji potasu. Zawartość magnezu nie uległa zmianie.

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