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THE RESIDUAL EFFECTS OF VARIOUS BIOPRODUCTS AND SOIL CONDITIONERS APPLIED IN THE ORGANIC NURSERY ON APPLE TREE PERFORMANCE IN THE PERIOD OF TWO YEARS AFTER TRANSPLANTING

Summary

The carry-over effects of bioproducts and soil conditioners used in the nursery production on the growth and fruiting of young apple trees of two scab-resistant cultivars 'Topaz' and 'Ariwa' grown in a commercial orchard were studied. The trees were planted in the spring 2013 and for two consecutive years were not fertilized. In both years a trunk cross-sectional area, the number of shoots and their total length were measured. Total yield and mean fruit weight were recorded in the second year after tree transplanting. Organic fertilizers and soil conditioners such as Micosat, BF Quality, BF Amin and Vinassa used in the nursery resulted in intense growth of cv 'Topaz' shoots. For this cultivar, the type of fertilizers used in the nursery had no effect on fruit yield, but such products as Tytanit and BF Quality increased the mean fruit weight in comparison with other compounds used. In the case of cv 'Ariwa', products such as Humus Active + Aktywit PM, BF Quality, BF Amin, Vinassa and Tytanit intensified tree growth in the orchard. There was a marked increase in the yield from the trees treated in the nursery with Humus Active + Aktywit PM. Also, the average weight of fruit was affected by BF Amin, Vinassa and Tytanit use in the nursery.
Key words: *fertilization, bioproduct, fruit, growth, yield, orchard*

WPŁYW RÓŻNYCH BIOPRODUKTÓW I ULEPSZACZY GLEBOWYCH STOSOWANYCH W SZKÓŁCE EKOLOGICZNEJ NA PÓŹNIEJSZY WZROST I OWOCOWANIE DWULETNICH DRZEW W SADZIE

Streszczenie

W 2013 roku z drzewek jabłoni odmiany 'Topaz' i 'Ariwa' wyprodukowanych w szkółce ekologicznej posadzono sad w celu zbadania następczego wpływu bioproduktów i ulepszaczy glebowych na ich wzrost i owocowanie. W sadzie drzewka nie były nawożone. W każdym roku mierzono ich powierzchnię poprzecznego przekroju pnia oraz liczbę i długość pędów bocznych. Badano także plonowanie drzew i masę ich owoców. Wzrost pędów odmiany 'Topaz' intensyfikowały takie nawozy organiczne i ulepszacze glebowe stosowane wcześniej w szkółce jak Micosat, BF Quality, BF Amin i Vinassa. Rodzaj nawożenia nie miał wpływu na wielkość plonu, natomiast takie produkty jak Tytanit i BF Quality zwiększały średnią masę owocu. U odmiany 'Ariwa' preparaty takie jak Humus Active + Aktywit PM, BF Quality, BF Amin, Vinassa i Tytanit stymulowały wzrost drzewek w sadzie, zaś - Humus Active + Aktywit PM korzystnie wpływały na plonowanie, natomiast takie jak BF Amin, BF Quality, Vinassa i Tytanit zwiększały średnią masę owoców.
Słowa kluczowe: *nawożenie, bioprodukt, owoc, wzrost, plon, sad*

1. Introduction

Many authors [1-7] reported that high-quality young trees are sought, with a suitably well-developed leader and numerous lateral branches for establishing new orchards. Similar rules should be also applied to new organic orchards. Obtaining high-quality trees presents no major problems in conventional nurseries [8-10, 7]. However, organic production of maiden apple [11] or our cherry trees [12] still meets with many difficulties because the number of available growth stimulators is limited. Even if there are such products [13, 14], their effects on plant performance is not known yet. It seems that some bioproducts which have been used in organic nurseries offer a chance to obtain high-quality nursery material required for establishing new ecological orchards [11, 12]. The preliminary studies show, that the quality of trees organically grown are in many cases, not inferior to the nursery stock produced conventionally [15]. We have not encountered in the horticultural literature any substantial data about biological agents used for growth stimulation of organically grown trees with any subsequent effects on the growth and fruiting of trees in the orchard.

The aim of these studies was to investigate the residual effects of different forms of fertilization applied to maiden trees in the organic nursery on the growth and fruiting of these trees during the first years after transplanting in the IPM orchard.

2. Materials and Methods

Maiden apple trees of the scab resistant cultivars 'Topaz' and 'Ariwa' grafted on M.26 rootstock planted in new orchard were produced by an organic nursery in Mokra Lewa, 51°58'11.8"N 20°05'27.5"E (Central Poland). During their growth in the nursery, both the rootstocks and the maidens were treated twice with various biopreparations: the rootstocks – the first time at the beginning of May and the second time in early June, and the maidens – in mid-May and in mid-June. NPK-trees (treatment 1) were produced by the same nursery.

The trees prepared for an orchard experiment, while in the nursery were treated with the following compounds:

1. NPK fertilization: at dose of 17.64 g m^{-2} NH_4NO_3 (Zakłady Azotowe Puławy PLC, Poland), 6.52 g m^{-2} triple super phosphate ("Fosfory" LLC, Poland), and 16.0 g m^{-2} K_2SO_4 (KALI GmbH, Germany), which were the equivalents of 60 kg ha^{-1} N, 30 kg ha^{-1} P, and 80 kg ha^{-1} K, respectively;
2. Fertigo (Ferm-O-Feed, the Netherlands) – granulated sheep and poultry manure containing 55% C, 1% N, 0.3% P and 1% K, and microelements and soil micro-organisms. The product was applied at a dose of 150 g m^{-2} (1500 kg ha^{-1}), and was the equivalent of 45 kg ha^{-1} N, 13 kg ha^{-1} P and 17 kg ha^{-1} K;
3. Micosat (CCS Aosta Srl, Italy) – microbial inoculum consisting of mycorrhizal fungi (*Glomus mosseae* and *G. intraradices*) and plant growth promoting bacteria (*Pseudomonas fluorescence* and *Bacillus subtilis* strains). The product contains 40% C, 0.15% N, 431 mg kg^{-1} P and 9558 mg kg^{-1} K, and a granular formulation Micosat F12 WP was applied to the soil at planting at a dose of 10 g m^{-2} (100 kg ha^{-1}), and a second application was carried out in liquid form (Micosat F MS 200) at a dose of 1 g m^{-2} (10 kg ha^{-1})
4. Humus UP (Ekodarpol, Poland) – an extract from vermicomposts containing 0.65% C, 0.03% N, 30.8 mg kg^{-1} P and 4535 mg kg^{-1} K. The product was applied to the soil as a 2% solution (2 ml m^{-2}) (20 l ha^{-1}).
5. Humus Active + Aktywit PM (Ekodarpol, Poland) – an extract from vermicomposts based on a product derived from molasses. Humus Active is a soil improver with active humus and population of beneficial microorganisms containing 0.78% C, 0.03% N, 1050 mg kg^{-1} P and 4119 mg kg^{-1} K. Aktywit PM is a soil improver containing 20.5% C, 0.92% N, 81.2 mg kg^{-1} P and 42990 mg kg^{-1} K. (Humus Active was applied to the soil as a 2% solution (2 ml m^{-2}) (20 l ha^{-1}) and Aktywit PM was applied to the soil as a 1% solution – 1 ml m^{-2} (10 l ha^{-1}).
6. BioFeed Amin (Agrobio Products B.V., the Netherlands) – an extract supplemented with amino acids – an extract of vegetal amino acids containing 1.12% C, 0.14% N, 347 mg kg^{-1} P. The product was applied to the soil as a 0.5% solution (0.5 ml m^{-2}) (5 l ha^{-1}).
7. BioFeed Quality (Agrobio Products B.V., the Netherlands) – an extract from several seaweed species reinforced with humic and fulvic acids containing 0.6% C, 0.07% N, 32.6 mg kg^{-1} P (applied to the soil as a 0.5% solution (0.5 ml m^{-2}) (5 l ha^{-1}).
8. Tytanit (Intermag, Poland) – titanium (Ti) applied to the leaves as a 0.05% solution (0.05 ml m^{-2}) (0.5 l ha^{-1}).
9.Vinassa (Józefów LLC, Poland) – molasses residue from yeast production containing 12.0% C, 1.86% N, 949 mg kg^{-1} P, 17615 mg kg^{-1} K. The product was applied to the soil as a 0.5% solution (0.5 ml m^{-2}) (5 l ha^{-1}).
10. Untreated (without fertilization) maiden trees served as the control.

The trees selected for experimental planting were characterized by similar trunk diameter of about 12 mm measured at the height 20 cm above the graft union. The orchard study was conducted in 2013 and 2014 at the Fruit Experimental Station in Dąbrowice (51°54'57.3"N 20°06'16.2"E) near Skierniewice, on a podzolic soil. The trees for the experiment were planted in the spring at a spacing of 2.0 x 4.0 m. The soil for the orchard was prepared for three consecutive years by growing buckwheat and green manure plants. Based on the analysis of the soil, nutrient deficiencies were supplemented to the optimum level, i.e. N (0.1% - dry weight ADW), K (6.7 mg 100 g^{-1} of soil), P (4.9 mg 100 g^{-1} of soil), Mg (3.4 mg 100 g^{-1} of soil). Soil pH was 6.1.

After planting, the trees were uniformly pruned according to generally applicable rules. Pruning was performed every year to train the crowns in the shape of a spindle. For two consecutive years, the trees were grown without any mineral or organic fertilization. However, they were protected against pests and diseases according to the rules applicable to orchards with integrated production.

Measurements carried out in the orchard:
- diameter of the tree trunk after planting and every year was measured at the height of 20 cm above the graft union;
- number and length of shoots in the crown recorded in year-1 and -2
- fruit yield, per tree, and mean fruit weight recorded in year-2.

The orchard experiment was designed in randomized blocks with four three-tree replications. The results were subjected to one-way analysis of variance using Statistica 10 program. Multiple comparisons of mean values for the combinations were performed using Tukey's test at significance level of $p < 0.05$.

3. Results

The measurements of the growth characteristics of 'Topaz' and 'Ariwa' apple trees in the first two years in the orchard are shown in Tables 1-4.

The type of fertilizer applied to maiden trees of the cultivar 'Topaz' in the nursery had no significant effect on the size of the increase of TCSA. All treatments contributed to a significant increase in the number of laterals as compared with the controls. There were no significant differences among such treatments as NPK, Manure, Micosat, BF Quality and BF Amin. The highest value for this characteristic was accomplished by BF Quality, and the lowest one by Humus UP and Tytanit. In case of total length of lateral shoots all treatments increase this parameter in comparison to control plots. The highest level for this data was in plots treated in the nursery by Micosat and BF Quality (Table 1).

Table 1. The trunk cross-sectional area (TCSA) and the number and total length of lateral shoots of apple trees of cv 'Topaz' in year-1, 2013

Tab. 1. Pole poprzecznego przekroju pnia (PPPP), liczba i długość pędów bocznych jabłoni odmiany 'Topaz' w pierwszym roku po posadzeniu (2013)

Treatment	TCSA [cm^2]	Number of lateral shoots per tree	Total length of lateral shoots[#] per tree [cm]
Control	3.3 a[x]	6.7 a	179.2 a
NPK	3.7 a	9.5 c-e	243.5 b-d
Manure	2.9 a	9.1 b-e	244.7 b-d
Micosat	3.9 a	9.5 c-e	278.5 d
Humus UP	2.7 a	8.0 b	214.7 a-c
Humus Active + Aktywit PM	5.0 a	8.2 bc	235.2 a-d
BF Quality	5.4 a	10.4 e	281.0 d
BF Amin	5.3 a	9.6 de	272.2 cd
Tytanit	3.7 a	8.1 b	200.9 ab
Vinassa	5.0 a	8.5 b-d	227.1 a-d

Note: [x]- Data followed by the same letter do not differ significantly according to Tukey's test $p < 0.05$
[#]- shoots longer than 5 cm

Source: own work / Źródło: opracowanie własne

The growth and fruiting of cv 'Topaz' trees in the second year after planting is shown in Table 2. The data shows that each type of fertilizer used in the nursery of maidens, except Tytanit, significantly increased the TCSA in comparison with the controls. The largest TCSA was found in trees previously treated with the preparations BF Amin and Vinassa. The use of Tytanit on the plants in the nursery had no significant effect on the number of emerging shoots in year-2 as compared with other treatments. However, the application of NPK, BF Amin and Vinassa significantly affected the number of new shoots in year-2. The other preparations had little effect on this process. The smallest increase in the growth of lateral shoots was in the two-year-old trees from Tytanit treated maidens, and the highest increase was in Vinassa treated. There were no significant differences in tree yields among the treatments, and there were some significant differences in average fruit weight with the heaviest and lightest fruit produced by trees treated by BF Quality and Humus Active + Aktywit PM, respectively (Table 2).

The type of products used to fertilize cv. 'Ariva' maiden trees in the nursery had a significant impact on the subsequent growth of young trees in the orchard (Tables 3 and 4). In year-1 the largest increase in TCSA was shown by trees treated with Humus Active + Aktywit PM, and BF Quality (Table 3). In this respect, the trees of the above mentioned treatments differed significantly from the trees of the control and the other types of nursery treatment. A relatively large increase in TCSA was also observed in trees whose maidens had been fertilized in the nursery with the preparations BF Amin and Vinassa, while the lowest TCSA in trees treated in the nursery with the preparation Tytanit (Table 3).

The trees treated with the preparations BF Amin and Tytanit resulted in a significant increase in the number of shoots to 13.0 and 11.5, respectively. The other preparations, with the exception of NPK, also stimulated this process, but to a lesser extent. Total length of shoots in year-1 significantly increased in all treatment combinations where the bioproducts were used, except for those with NPK and granulated manure application. The largest increase in the total length of shoots was shown by the trees treated with BF Amin. Significant increases were also observed in maidens treated with the bioproducts Humus Active + Aktywit PM, BF Quality, Tytanit and Vinassa (Table 3).

Table 3. The trunk cross-sectional area (TCSA) and the number and total length of lateral shoots of apple trees of cv 'Ariwa' in year-1, 2013

Tab. 3. Pole poprzecznego przekroju pnia (PPPP), liczba i długość pędów bocznych jabłoni odmiany 'Ariwa' w pierwszym roku po posadzeniu (2013)

Treatment	TCSA [cm^2]	Number of lateral shoots per tree	Total length of lateral shoots# per tree [cm]
Control	2.9 bc	7.9 a	224.4 a
NPK	1.9 ab	8.6 a	210.0 a
Manure	2.0 ab	10.1 bc	244.7 ab
Micosat	2.4 a-c	9.9 b	269.8 bc
Humus UP	2.9 bc	10.4 b-d	287.9 c
Humus Active + Aktywit PM	5.5 e	11.2 de	331.0 de
BF Quality	5.9 e	11.2 de	334.7 de
BF Amin	4.0 d	13.0 f	362.1 e
Tytanit	1.5 a	11.5 e	304.6 cd
Vinassa	3.3 cd	11.1 c-e	345.3 de

Explanations as for Table 1.

Source: own work / Źródło: opracowanie własne

The residual effects of the bioproducts used in the organic nursery on cv 'Ariva' trees grown in year-2 are presented in Table 4. A significant increase in TCSA was observed only in trees fertilized in the nursery with the preparations BF Amin, Tytanit and Vinassa. There were no significant differences among the other treatments. The increase in the number of lateral shoots was significantly affected by granulated manure and biopreparations such as BF Amin, Tytanit and Vinassa- being the most effective. The preparations such as BF Amin and Tytanit also significantly increased their total length of shoots. NPK fertilization and treatment with Humus Active + Aktywit PM did not have any significant effect on increasing the length of shoots in year-2 (Table 4).

Table 2. The trunk cross-sectional area (TCSA), number and total length of lateral shoots, total yield and mean fruit weight of apple trees of cv 'Topaz' in year-2, 2014)

Tab. 2. Pole poprzecznego przekroju pnia (PPPP), liczba i długość pędów bocznych oraz wielkość plonu i średnia masa owoców jabłoni odmiany 'Topaz' w drugim roku po posadzeniu (2014)

Treatment	TCSA [cm^2]	Number of lateral shoots per tree	Total length of lateral shoots# per tree [cm]	Yield per tree [kg]	Mean fruit weight [g]
Control	21.5 a	20.7 b-d	452.7 b	1.1 a	146.1 ab
NPK	33.3 bc	27.0 e	572.5 e	1.3 a	155.6 ab
Manure	34.9 c	24.5 de	517.2 cd	1.0 a	166.4 bc
Micosat	36.5 c	21.2 b-d	474.8 bc	1.1 a	143.8 a
Humus UP	32.3 bc	20.3 bc	536.3 de	1.0 a	166.4 bc
Humus Active + Aktywit PM	36.2 c	18.2 b	443.5 b	1.5 a	141.9 a
BF Quality	35.7 c	20.0 bc	542.0 de	1.9 a	195.8 d
BF Amin	45.5 d	26.7 e	703.5 g	1.6 a	161.8 ab
Tytanit	25.7 ab	14.3 a	267.2 a	1.9 a	184.5 cd
Vinassa	44.8 d	23.8 c-e	623.2 f	1.4 a	165.2 bc

Explanations as for Table 1.

Source: own work / Źródło: opracowanie własne

Table 4. The trunk cross-sectional area (TCSA), number and total length of lateral shoots, total yield and mean fruit weight of apple trees of cv 'Ariwa' in year-2, 2014

Tab. 4. Pole poprzecznego przekroju pnia (PPPP), liczba i długość pędów bocznych oraz wielkość plonu i średnia masa owoców jabłoni odmiany 'Ariwa' w drugim roku po posadzeniu (2014)

Treatment	TCSA [cm^2]	Number of lateral shoots per tree	Total length of lateral shoots# per tree [cm]	Yield per tree [kg]	Mean fruit weight [g]
Control	22.1 a	11.5 a	361.0 a	0.6 a	147.4 ab
NPK	22.6 a	13.0 ab	356.0 a	0.8 a	142.8 ab
Manure	24.6 a	17.7 c	471.5 b	0.6 a	196.9 c
Micosat	25.1 a	13.7 a-c	463.3 b	0.3 a	133.9 a
Humus UP	25.8 a	14.5 a-c	446.0 b	0.3 a	146.8 ab
Humus Active + Aktywit PM	24.6 a	15.3 a-c	373.8 a	2.1 b	173.6 bc
BF Quality	25.9 a	14.3 a-c	461.8 b	0.5 a	152.9 ab
BF Amin	38.2 b	18.0 c	580.4 c	0.7 a	198.6 c
Tytanit	34.2 b	16.3 bc	558.3 c	1.5 ab	198.8 c
Vinassa	37.6 b	24.5 d	767.0 d	1.5 ab	180.7 bc

Explanations as for Table 1.

Source: own work / Źródło: opracowanie własne

Most of the fertilizers used in the nursery, except Humus Active + Aktywit PM, had no significant effect on the size of fruit yield of apple trees of the cultivar 'Ariwa', two years after transplanting. A tendency to improve the fruit yield in the orchard was observed only in the trees, which were treated with the preparations Tytanit and Vinassa (Table 4).

A significant effect on fruit weight was found only in trees whose maidens in the nursery had been fertilized with organic manure and the biopreparations BF Amin, Tytanit, Humus Active + Aktywit PM, and Vinassa with the average fruit weight equal to 189.7 g (Table 4).

4. Discussion

The regulations (834/2007 and 889/2008) applicable in all EU countries do not allow the use of mineral fertilizers in nurseries producing organically grown fruit trees. To improve the quality of the nursery stock, including the intensification of tree growth and the formation of lateral shoots, a variety of natural products are used, including mineral fertilizers, extracts from marine algae and terrestrial plants, vermicomposts resulting from the biological activity of living organisms, mycorrhizal fungi, products obtained by the fermentation of yeast and others [16-25, 13].

The influence of most of the above-mentioned bioproducts on the growth and development firstly the rootstocks, and then the maiden apple and sour cherry trees were studied in detail in recent years [26, 27, 24]. Bioproducts such as Humus UP, BF Amin, BF Quality and Vinassa were applied to stimulate the growth of young apple trees expressed by formation of lateral shoots, increasing their length and development of root system [27, 28, 12]. These compounds contributed to produce young trees of quality comparable to the trees produced by conventional methods, i.e. fertilized with mineral fertilizers [15].

The presented studies demonstrated that nursery application of BF Quality and BF Amin positively influenced the growth of apple trees after transplanting in the orchard. Tytanit did not belong to the group of products that intensified the growth of maidens in the nursery, but the trees treated with it showed a tendency to set more fruit in the orchard than those treated with other bioproducts. The beneficial effects of Tytanit on the growth and fruiting of fruit trees and shrubs have been described by other authors [29, 30, 19, 13].

Positive residual effects could also be seen with the biopreparation Vinassa applied to maiden trees at the nursery stage. In the orchard, the trees of both apple cultivars formed the crown with significantly more annual shoots than in trees treated with other bioproducts. This probably created conditions for better fruiting of the trees in contrast to those from the other treatments.

The carry-over effects of vermiculites varied in the orchard, depending on tested apple cultivar. In spite of that, the combination of Humus Active +Aktywit PM, which additionally contained beneficial microorganisms, produced more positive effect in orchard trees than Humus UP used by itself.

It has been shown in previous works by the author, that Micosat in sour cherry, and BF Quality, BF Amin and Vinassa in apple used in the organic nursery stimulated growth of lateral shoots in the crown, and also had a significant impact on the increase in the thickness of the trunk. However, different cultivars of the same species of sour cherry and apple responded differently to the same fertilizers.

The effects of biofertilizers used in organic nurseries on the quality of maiden trees produced by them are, according to the publications cited above, already fairly well understood. However, there are no reports in the available literature describing the interdependence between the type of fertilization applied to maidens in the nursery and the character of their subsequent growth and fruiting in the orchard. The present research is in an early stage and should be continued if more reliable results are to be obtained. Thus, the presented results, will continue, as far as possible, not only with apple, but also with other species of fruit trees.

5. Conclusions

1. Organic fertilizers and soil conditioners such as Micosat, BF Quality, BF Amin and Vinassa, used in the nursery of maiden apple trees of cv. 'Topaz', increased the ability of tree branching and the length of lateral shoots. The positive residual effects of fertilization in the nursery with BF Amin and Vinassa on tree vegetative growth were still evident in the orchard two years after transplanting.
2. The fertilizer regime in the nursery of maiden trees cv 'Topaz' had no effect on the intensity of fruiting, but

bioproducts and soil conditioners such as Tytanit and BF Quality caused a small but significant increase in mean fruit weight.

3. The application of Humus Active + Aktywit PM, BF Quality, BF Amin, Vinassa and Tytanit in the nursery exhibited strong residual impact on 'Ariwa' tree growth during the first two years after transplanting.

4. Treatment of 'Ariwa' maidens with Humus Active + Aktywit PM in the nursery had a beneficial effect on tree fruiting in the second year after planting in the orchard. The application of granulated manure, BF Amin, BF Quality, Vinassa and Tytanit also positively affected the mean fruit weight.

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The work has been supported by a grant from the EU Regional Development Fund through the Polish Innovation Economy Operational Programme, contract No. UDA-POIG01.03.01-10-109/08-00.