

Effect of a nanotechnology-based foliar fertilizer on the yield and fruit quality in an apple orchard

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Summary: Nutrient management is a determining element of the technology in fruit production. Significance of foliar fertilization has been increased continuously over the last years, as it can improve directly the vegetative and generative performance of the trees. In this study we aimed to evaluate the effect of a nanotechnology-based foliar fertilizer (Bistep) with 1, 3, and 5 l/ha dosages on the yield and fruit quality parameters in an apple orchard during 2016 and 2018. According to our results, crop load increased with 29% in the third year of the experiment with the application of 5 l/ha Bistep treatment compared to the control treatments. Fruit weight was also improved in each year, as values of fruit weight in all treatments were higher than the control one (3.0-13.0% growth). Fruit surface color increased with 2-18% due to the foliar fertilizer. During the three years, leaf length was 9.5-9.9 mm on the control trees, as 9.8-10.4 mm was measured on the fertilized ones. In conclusion, yield and fruit quality can be improved in apple orchard using a nanotechnology-based foliar fertilizer.

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Introduction

Fertilization of fruit trees is an essential element of the technology due to its significant influence on the quality and quantity of the yield. Nowadays foliar fertilization has become a basic management tool in the intensive orchards. Foliar fertilizers have an interesting potential to improve yield and fruit quality, with relatively low costs and low environmental impact. Application of sprays supplies nutrients to plants more rapidly than the soil fertilization (Tagliavini et al., 2002; Nagy, 2012).

The role of biostimulators is increasing all over the world. Biostimulators can be considered as natural growth regulators, they can contain plant hormones as auxin, gibberellic acid, cytokinins and aminoacids, or some of them contain additive macro and micro nutrients. These preparations increase physiological activities in plants, first of all protein synthesis (Stampar et al., 2003; Nagy et al., 2012). Beneficial effect of the biostimulators on the yield and fruit quality is confirmed by several studies (Hudina et al., 2003; Solar, 2003; Basak & Mikos-Bielak, 2008; Błaszczuk, 2008; Nagy et al., 2009; Csihon et al., 2013).

Researches all over the world focus on developing new technologies which can help the more effective production. Nanotechnology currently belongs to the most promising areas, which has leaped huge achievements during the last decades (Yao et al., 2013; Rao & Gan, 2015; Singh et al., 2016). The technology is based on the synthesis and modulation of nanoparticles, where the molecular are on the nanoscale, typically smaller than 100 nm (Abraham et al., 2008; Auffan et al., 2009). The new properties of nanoscale particles ensure useful functions that are being rapidly exploited in e.g. energy sectors, electronics, material science, medicine and

biotechnology (Parisi et al., 2015). In agriculture, nanotechnology is mainly used to increase food production, aiming to achieve high nutritional value, quality and safety. It can facilitate the transformations of traditional food and agriculture sectors with the utilisation of nanopesticides, nanofertilizers, nanosensors and active packaging (Rao & Gan, 2015; He et al., 2018). Nanotechnology is widely used in modern agriculture to help the spread of precision agriculture (Duhan et al., 2017).

Nanomaterials in crop production aim among others to minimize nutrient losses in fertilization and increase yields by optimized water and nutrient management (Gogos et al., 2012). Nanofertilizers balances the release of main macroelements with their absorption by the plant, as nutrient losses can be prevented and unwanted nutrients interaction with microorganisms, water and air can be avoided (Emadian, 2017). Furthermore nanotechnology is suitable also for helping the availability of micronutrients to plants (Petu et al., 2010).

The aim of this work was to provide data on the effect of three concentrations of nanotechnology-based biostimulator on the yield and fruit quality in an apple orchard.

Materials and methods

Experimental site

The study was performed at the Horticultural Experimental Farm of University of Debrecen from 2016 to 2018. Type of the soil is light sandy loam, the pH of soil is slightly alkaline (pH 7.5-7.6). Humus content varies between 1.2 and 1.6%, the "Arany" number of heaviness is 26-28.

The apple orchard was planted in spring of 2011. Trees were grafted on M.9 rootstock and designed with spacing of 4 x 1 meter. Trees were trained to slender spindle with the height of 3.5 m. The study was performed on cultivar 'Pinova'. Orchard has drip irrigation system. Plant protection refers to the principles of integrated pest management.

Applied treatments

The main objective of this study was to evaluate the effect of a nanotechnology-based biostimulator (Bistep) on the yield and fruit quality in an apple orchard. The trial was consisted of four treatments (control, 1, 3 and 5 l/ha concentrations). First treatment was applied at full bloom in each year, then treatments were repeated 6-7 times (**Table 1**). Each treatment was consisted of 10 trees.

Table 1. Time of treatments (Debrecen, Pallag, 2016-2018)

2016	2017	2018
14 April	5 April	9 April
27 April	26 April	25 April
23 May	10 May	17 May
6 June	25 May	31 May
22 June	12 June	19 June
7 July	29 June	6 July
27 July	3 August	31 July
10 August		

Applied materials

'Pinova' is a German apple cultivar, hybrid of 'Clivia' and 'Golden Delicious'. It has high fruit yield, with little tendency towards biennial bearing. It is tolerant to the scab, but sensitive to powdery mildew. Fruit is juicy and crisp, red skin color is about 50-70% (Fischer et al., 2000).

Bistep is a nanotechnology-based plant conditioner preparation (Manufacturer: UAB ALJARA, LT-11219 Vilnius, Geniu Str. 16-38., Lithuania). It contains microhumatates, macronutrients, active salts of organic acids, amino acids, fulvic acid, vitamins, phytohormones, soil microflora and trace elements (**Table 2**). The main active ingredients, microhumatates are formed by physical disassembly of natural humic substances.

Table 2. Active ingredients of Bistep

Parameter	Value
Dry matter content (w/w%)	1.3
Organic matter content (w/w%) d.m.	25
N content (w/v%)	0.02
P ₂ O ₅ content (w/v%)	0.03
K ₂ O content (w/v%)	0.3
MgO content (w/v%)	0.02
B content (w/v%)	0.0002
Fe content (w/v%)	0.01

Assessed parameters

During harvest, fruit yield (kg/tree) was measured. For the better comparability these data were compared also to the trunk thickness and expressed as crop load (kg/cm²). Fruit quality parameters were assessed based on 100 fruits/treatments.

Diameter (mm) and weight (g) of the fruits were determined. Fruit surface color was evaluated with a visual estimation in percentage form. The intensity (darkness) of the fruit surface color was assessed with similar method on a scale ranging from 1-5. Leaf size (length, width) was measured based on 100 leaves/treatments. Two parameters of the leaf size were multiplied, which is proportional to the leaf area. Statistics were performed by ANOVA at P=0.05 level using LSD test.

Results and discussion

Effect of the treatments on the yields is concluded in **Table 3**. Data shows that the lowest yield was harvested from the control trees in each year (21.9-33.4 kg/tree). Crop load (yield/trunk thickness) was also the lowest with the untreated trees (0.64-0.92 kg/cm²), while sprayed trees presented values between 0.62 and 1.14 kg/cm².

Crop load of the fertilized trees was nearly equal in 2018 (1.08-1.19 kg/cm²), the highest value was observed for 5 l/ha treatment (1.19 kg/cm²), while data of control trees was lower with 29% (0.92 kg/cm²). However, this notable difference is presumably due not only to the treatments performed in 2018, but also to the fact that this was the third consecutive year that the trees received plant conditioner.

Table 3. Fruit yield and crop load (Debrecen – Pallag, 2016-2018)

	Fruit yield (kg/tree)			Crop load (kg/cm ²)		
	2016	2017	2018	2016	2017	2018
Control	21.9	21.7	33.4	0.79	0.64	0.92
1 l/ha	23.0	33.5	39.4	0.96	1.01	1.14
3 l/ha	29.5	22.2	37.8	1.11	0.62	1.08
5 l/ha	26.3	28.8	51.5	0.84	0.73	1.19
LSD _{5%}	7.2	6.6	8.3	0.25	0.21	0.36

Fruit size was between 76 and 78 mm in the first two year, while in 2018 diameter changed between 72-75 mm (**Table 4**). Differences are more evident regarding fruit weight, as treatments resulted in 3.0-13.0% increase in 2016 (206-224 g), compared to the control (200 g). The largest fruits were picked in 5 l/ha treatment (224 g). In 2017, fruit weight was larger with 3.6-5.2% (201-204 g) for 3 l/ha and 5 l/ha treatments, compared to the untreated trees (194 g). In 2018, fruit size of the control trees was 72.3 mm, while fruits of the sprayed ones ranged from 73.1 to 75.1 mm.

Table 4. Fruit size and fruit weight (Debrecen – Pallag, 2016-2018)

	Fruit size (mm)			Fruit weight (g)		
	2016	2017	2018	2016	2017	2018
Control	78.6	78.4	72.3	200	194	160
1 l/ha	78.8	75.7	73.1	206	192	163
3 l/ha	76.2	76.9	75.1	211	201	179
5 l/ha	78.2	77.8	73.8	224	204	168

The most spectacular changes can be seen in the coloration of the fruits (**Table 5**), as Bistep treatments had unequivocal positive effect on the fruit surface colour and fruit colour intensity in each year. In 2016, fruit surface colour of control trees was 29%, while surface colouration of sprayed fruits was 45-53%. One year later colour improvement compared to the

control varied up 2% to 10% due to the treatments. In 2018, untreated trees presented only 31% skin coloration, while foliar fertilizing resulted in 46–49% fruit surface colour.

In the case of the fruit color intensity, which means the darkness of the red color, untreated trees presented also the lowest values. During three years fruits of control trees produced weaker coloration on a scale ranging from 1-5 fruits presented values between 2.9-3.1, while fertilized fruits reached values of 3.9-4.6.

Table 5. Fruit surface colour and fruit colour intensity (Debrecen – Pallag, 2016-2018)

	Fruit surface colour (%)			Fruit colour intensity (1-5)		
	2016	2017	2018	2016	2017	2018
Control	29	37	31	3.1	3.7	2.9
1 l/ha	45	39	46	4.0	3.9	4.4
3 l/ha	47	40	49	4.4	4.0	4.3
5 l/ha	53	50	47	4.4	4.6	4.5

Leaf size is a determining factor regarding the assimilation performance of the trees (**Table 6**). Data shows that leaf length and leaf width were increased by the treatments in each year. During 3 years leaf length was 9.5-9.9 mm on the control trees, as 9.8-10.4 mm was measured on the fertilized ones. Leaf width varied between 5.1 and 5.4 mm for the untreated trees, while fertilized trees presented 5.8-6.2 mm values. When the two parameters are multiplied, it can be seen that 5 l/ha Bistep treatment caused 7.4% increase (61.0) in leaf area compared to the control (56.8).

Table 6. Leaf size (Debrecen – Pallag, 2016-2018)

	Length (cm)			Width (cm)			Length(cm) x width(cm)		
	2016	2017	2018	2016	2017	2018	2016	2017	2018
Control	9.5	9.9	9.8	5.1	5.9	5.8	49.0	58.8	56.8
1 l/ha	9.6	9.8	9.7	5.4	5.9	5.8	51.6	57.5	56.3
3 l/ha	9.6	10.4	9.9	5.2	6.2	5.9	49.9	64.1	58.4
5 l/ha	9.9	10.3	10.0	5.2	6.0	6.1	50.8	62.2	61.0

Conclusions

Based on our study, it can be stated that yield and fruit quality can be improved effectively in apple orchard using nanotechnology-based foliar fertilizer. During three years, crop load increased with 29% in 5 l/ha Bistep treatment. Fruit size and weight were also improved, as values of all treatments were higher than the control. Fruit surface color increased with 2-18% due to the plant conditioner.

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References

- Abraham, A., Kannangai, R., Sridharan, G., (2008):** Nanotechnology: a new frontier in virus detection in clinical practice. *Indian J. Med. Microbiol.* 26(4) 297–301.
- Auffan, M., Rose, J., Bottero, J. Y., Lowry, G. V., Jolivet, J. P., Wiesner, M. R. (2009):** Towards a definition of inorganic nanoparticles from an environmental, health and safety perspective. *Nat. Nanotechnology* 4. 634–664.
- Baptista, F. R., Belhout, S. A., Giordani, S., Quinn, S. J. (2015):** Recent developments in carbon nanomaterial sensors. *Chem. Soc. Rev.* 44(13): 4433–4453.
- Basak, A., Mikos-Bielak, M. (2008):** The use of some biostimulators on apple and pear trees. In: Z.T. Dabrowski (ed.): *Biostimulators in modern fruit agriculture.* 7–17.
- Błaszczak, J. (2008):** Quality of ‘Conference’ pears as affected by Goëmar BM 86 and Fruton. In: *Biostimulators in modern agriculture: Fruit crops.* Ed.: Dabrowski, Z. T.) 18–24.
- Csihon, Á., Illés, A., Szabó, A., Bicskei, D. K. (2013):** Biostimulátor készítmények összehasonlító vizsgálata intenzív almaültetvényben. *Kertgazdaság* 45(4): 20–27.
- Duhan, J. S., Kumar, R., Kumar, N., Kaur, P., Nehra, K., Duhan, S. (2017):** Nanotechnology: The new perspective in precision agriculture. *Biotechnology Reports* 15. 11–23.
- Emadian, S. E. (2017):** Physiological Responses of Loblolly Pine (*Pinus taeda* L.) to Silicon and Water Stress, Texas A & M Univ, college station, TX, 2017, pp. 27–37 (Ph.D. Thesis, Diss. Abst.AAC8815865).
- Fischer, H. M., Schmadlak, J., Fischer, C. M. (2000):** Apple Tree Named ‘Pinova’. United States Patent. Pub. N°.: US00PP11601P. Patent Number: 11,601
- Ghormade, V., Deshpande, M. V., Paknikar, K. M., (2011):** Perspectives for nano-biotechnology enabled protection and nutrition of plants. *Biotechnol. Adv.* 29. 792–803. <https://doi.org/10.1016/j.biotechadv.2011.06.007>.
- Gogos, A., Knauer, K., Bucheli, T. D. (2012):** Nanomaterials in Plant Protection and Fertilization: Current State, Foreseen Applications, and Research Priorities. *J. Agric. Food Chem.* 60. 9781-9792. <https://doi.org/10.1021/jf302154y>
- He, X., Deng, H., Hwang, H. (2018):** The current application of nanotechnology in food and agriculture. *Journal of Food and Drug Analysis* 27. 1-21. <https://doi.org/10.1016/j.jfda.2018.12.002>
- Hudina, M., Solar, A., Stampar, F. (2003):** Does foliar nutrition influence the pear fruit quality? *International Journal of Horticultural Science.* 9(2): 25-28. <https://doi.org/10.31421/IJHS/9/2/386>
- Khot, L. R., Sankaran, S., Maja, J. M., Ehsani, S., Schuster, S. W. (2012):** Applications of nanomaterials in agricultural production and crop protection: A review. *Crop Prot.* 35. 64–70. <https://doi.org/10.1016/j.cropro.2012.01.007>
- Nagy, P. T. (2012):** Bioregulátor kísérletek eredményei és gyakorlati hasznosítási tapasztalatai a gyümölcsstermesztésben. Debreceni Egyetem. AGTC MK Kertészettudományi Intézet. 97 p.
- Nagy, P. T., Ambrus, A., Nyéki, J., Soltész, M., Szabó, Z. (2012):** Effect of foliar spraying with algae suspension on leaf and fruit quality parameters of apple varieties. *International*

- Journal of Horticultural Science. 18(1): 35-38. p. <https://doi.org/10.31421/IJHS/18/1/991>
- Nagy, P. T., Csihon, Á., Szabó, A. (2019):** Effects of algae products on nutrient uptake and fruit quality of apple. National resources and sustainable development 9(1): 80-91. p. <https://doi.org/10.31924/nrsd.v9i1.026>
- Parisi, C., Vigani, M., Rodríguez-Cerezo, E. (2015):** Agricultural Nanotechnologies: What are the current possibilities? Nano Today 10. 124-127. p. <https://doi.org/10.1016/j.nantod.2014.09.009>
- Peteu, S.F., Oancea, F., Sicuia, O.A., Constantinescu, F., Dinu, S. (2010):** Responsive polymers for crop protection. Polymers 2(3): 229–251. <https://doi.org/10.3390/polym2030229>
- Rao, P. V., Gan, S. H. (2015):** Recent advances in nanotechnology-based diagnosis and treatments of diabetes. Curr. Drug Metab.16, 371–375. <https://doi.org/10.2174/1389200215666141125120215>
- Santoso, D., Lefroy, R.D.B., Blair, G. J. (1995):** Sulfur and phosphorus dynamics in an acid soil/crop system. Aust. J. Soil Res. 33. 113–124. <https://doi.org/10.1071/SR9950113>
- Shojaei, T. B., Salleh, M. A. H., Tabatabaei, M., Mobli, H., Aghbashlo, M., Rashid, S. A., Tan, T. (2019):** Applications of Nanotechnology and Carbon Nanoparticles in Agriculture. In Micro and Nano Technologies, Synthesis, Technology and Applications of Carbon Nanomaterials, Editor(s): Rashid, S. A., Othman, R. N. I. R., Hussein, M. Z. 247-277. p. <https://doi.org/10.1016/B978-0-12-815757-2.00011-5>.
- Sing, P., Kim, Y. J., Zhang, D., Yang, D. C. (2016):** Biological Synthesis of Nanoparticles from Plants and Microorganisms. Trends in Biotechnology 34(7): 588-599. p. <https://doi.org/10.1016/j.tibtech.2016.02.006>
- Solar, A. (2003):** The effects of foliar nutrition containing various macro and microelements on the growth and development of young grafted walnut (*Juglans regia* L.) plants. International Journal of Horticultural Science, 9(2): 33-37. <https://doi.org/10.31421/IJHS/9/2/388>
- Stampar, F., Solar, A., Hudina, M. (2003):** Influence of foliar nutrition on apple production. International Journal of Horticultural Science. 9(2): 15-18. <https://doi.org/10.31421/IJHS/9/2/384>
- Tagliavini, M., Drahorad, W., Dalla Via, J. (2002):** Preface. Acta Horticulturae 594. <https://doi.org/10.17660/ActaHortic.2002.594>.
- Zheng, L., Hong, F., Lu, S., Liu, C. (2005):** Effect of nano-TiO₂ on strength of naturally aged seeds and growth of spinach. Biol. Trace Elem. Res. 104. 83–91. <https://doi.org/10.1385/BTER:104:1:083>
- Yao, D., Chena, Z., Zhao, K., Yang, Q., Zhang W. (2013):** Limitation and challenge faced to the researches on environmental risk of nanotechnology. 2013 International Symposium on Environmental Science and Technology. 149-156. p. <https://doi.org/10.1016/j.proenv.2013.04.020>
- Wilson, M.A., Tran, N.H., Milev, A.S., Kannangara, G.S.K., Volk, H., Lu, G.Q.M., (2008):** Nanomaterials in soils. Geoderma 146. 291–302. <https://doi.org/10.1016/j.geoderma.2008.06.004>