EFFECTUL APLICĂRII FERTILIZANȚILOR ECOLOGICI ASUPRA CREȘTERII ȘI FRUCTIFICĂRII LA *ARONIA MELANOCARPA* (Michx.) Elliot, SOIUL AUTOHTON 'MELROM'

THE EFFECT OF ECOLOGICAL FERTILIZATION ON GROWTH AND YIELD OF *ARONIA MELANOCARPA* (Michx.) Elliot, 'MELROM' ROMANIAN CULTIVAR

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Abstract

Nine ecological fertilizer combinations effects on the field response of *Aronia melanocarpa* (Michx.) Elliot, 'Melrom' cultivar was studied. Plants vegetative growth, crop yield, and some fruit quality parameters during a two years experiment (2019 – 2020) performed at the Research Institute for Fruit Growing Pitesti, Arges County, Romania were assessed. The experimental factors studied were A, three different doses of the organic soil fertilizer, Biohumus, and B, the organic foliar treatments in three replication.

On average, on the three graduations of factor B (no fertilizer, Algacifo, Macys foliar fertilizer), the application of 0.3 l of Biohumus fertilizer per plant, compared to the application of the same fertilizer, at a dose of 0.4 l per plant, determined a significant increase with 0.1085 m³ (11.88%) of the aerial part of the plant.

Under the same conditions, the application of 0.2 l Biohumus per plant, compared to the application of 0.3 l Biohumus per plant, determined a distinctly significant increase, by 0.095 g (11.02%), of the average fruit weight, and at the application of 0.3 l per plant, compared to the application of 0.4 l per plant, from the same product, there was a significant decrease, by 0.090 g (10.97%), of the average fruit weight.

Also, the application of higher doses of Biohumus fertilizer (0.3-0.4 l per plant), compared to the variant where only 0.2 l per plant was applied, resulted in a significant and distinctly significant reduction in fruit firmness and values of the fruit juice pH.

Cuvinte cheie: aplicare la sol și foliar, calitate fruct, fermitate, pH, substanță solubilă totală, Biohumus, Algacifo, Macys

Keywords: soil and foliar application, fruit quality, firmness, pH, total soluble content, Biohumus, Algacifo, Macys

1. Introduction

Aronia melanocarpa (Michx.) Elliot (black chokeberry) belonging to the subfamily Maloideae of the Rosaceae family, is a perennial shrub, native to eastern North America and Canada. It was brought to Europe before 1700 (Wiegiers, 1983) and originally cultivated for decorative purposes. Interest in *Aronia* commercial cultivation appeared initially in Russia (around 1900) and then spread in Europe (the mid-1950s). It produces berry-type (false) fruits, smooth, spherical, 6–15 mm in diameter, with an average mass of 0.8–1.5 g, black or black-purple, covered with a thin protective layer of wax, have a dense, juicy, sweet pulp, with an astringent shade. The fruits ripen in August-September, i.e. 80-90 days after the end of the flowering period. *Aronia* berries have high levels of bioactive compounds that maintain and improve human health (Oszmianski and Wojdylo, 2005; Jakobek et al., 2007; Wangenstein et al., 2014; Kulling and Rawel, 2008). The nutritive and non-nutritive compounds concentration differs between species (Vinogradova et al., 2018) and cultivars (Ochmian et al., 2012; Wangenstein et al., 2014), from *Aronia* genus fruits, from one to another location (Hwang and Thi, 2016), depending on soil type (Djuric et al., 2015; Won et al., 2018), climatic factors (Sim, et al., 2017), depending on the fruit ripening stage (Jeppsson, and Johansson, 2000; Yang et al., 2019) and also it changed under the agrotechnical management applied to the crop.

Aronia can grow in a wide range of soil types and, therefore, needs modest amounts or no fertilizers. To stimulate plant growth, it is recommended a fertilizer with high nitrogen content. On the other hand, less fertile soils have the advantage of keeping the plants smaller. The application of fertilizers increases yield and growth and can change the chemical composition of chokeberry fruits

(Skupień and Oszmiański, 2007). Through its nitrogen/carbon ratio, fertilization could be an important instrument to ensure the optimal culture traits exploitation in intensive production systems.

The basic way of providing plants with essential nutrients is soil fertilization in which mineral elements are taken up by the plant root system. Previous studies have indicated that the application of organic fertilizer fulfills the requirements of sustainable agriculture, and organic fertilizer has apparent advantages over chemical fertilizer in many aspects. (JASIM et al., 2019). It can also improve soil biological and biochemical properties and optimize soil microbial community structure (Diacono and Montemurro 2010 cited by JASIM et al., 2019). By building a soil environment favorable for the organism growth while improving aeration and nutrient-holding capabilities, organic fertilizers become a more advantageous option than a conventional chemical one. Moreover, while non-organic fertilizers temporarily add nutrients to the soil, they are unable to have a lasting impact on soil health, which can lead to depletion of valuable growth-enhancing soil qualities over time (Choi et al., 2020).

Without minimizing the soil fertilizer (be it organic or not) importance, it is necessary to agree that the foliar fertilization of crops offers also specific advantages over soil-applied fertilizers because the nutrients are applied and taken-up directly by their target organs, providing a specific and fast response. Often the soil through its chemical, physical, and biological complexity acts as a barrier and a buffering medium canceling or delaying the fertilizer effects.

There are just a few studies regarding *Aronia melanocarpa* ecological fertilization and, their principal purpose was to evaluate the fruit quality, especially the therapeutic involved compounds (i.e. polyphenolic classes). According to Skender et al. (2017), the combination of mineral and organic nitrate fertilizers gave the best results in morphometric characteristics of fruit, yield, and vegetative characteristics of the growth of *Aronia melanocarpa*.

The purpose of this study was to investigate the effect of organic soil Biohumus different doses and foliar fertilization with Algacifo and Macys products on vegetative growth, yield, and fruit quality of *Aronia melanocarpa* 'Melrom' cultivar.

2. Material and methods

The study was carried out at Research Institut for Fruit Growing Pitești Argeș county (44°54'N, 24°52'E), Romania in 2019 and 2020. Pitești meteorological station weather data (global solar radiation (MJ m⁻² · day⁻¹), air temperature (°C), relative air humidity (RH, %), rainfall (mm), VPD (kPa), wind speed at the height of 2 m (m · s⁻¹), and ETo (mm · day⁻¹), were recorded by an automatic weather station (WatchDog Weather Station 2900ET, Spectrum Technologies, Aurora, Illinois) at 10-min intervals and averaged hourly. The station is located at a distance of about 500 m from the experimental plot.

The experimental plot was established in the spring of 2017. The plant material consisted of a 3-year-old Melrom cultivar of *Aronia melanocarpa*, planted at 3 m inter-row spacing and 1 m in-row distances (resulting in 3333 plants ha⁻¹ density), being drip irrigated.

In this area in 2019 was established a bifactorial experiment to study the effects of soil fertilization with Biohumus and two foliar fertilizer treatments.

The experience was arranged according to the block method, in three replications to the following scheme:

- the A experimental factor.

Consisted of three Biohumus doses, applied with the following graduations: a₁= Biohumus 0.2 L plant⁻¹; a₂= Biohumus 0.3 L plant⁻¹; a₃= Biohumus 0.4 L plant⁻¹;

- the B experimental factor.

Consisted of foliar fertilizer type, with the following graduations: b₁=Unfertilized by foliar application; b₂= Algacifo 3 L ha⁻¹; b₃=Macys 2 L ha⁻¹.

All 3 repetitions of each graduation of A factor (a₁, a₂, a₃), with the afferent graduations of B factor (b₁, b₂, b₃), were arranged on a row of plants in the experimental plot. The 3 repetitions within the same row were separated from each other by leaving one untreated plant (isolation).

Each graduation of A factor, with its 3 replications, was disposed of on a separate row of plants. Taking into account the large distance between the rows of plants (3 meters), it was considered that it isn't an influence of Biohumus dose fertilizers from one row to another. Therefore, no isolation rows were left between the rows on which the A factor graduations were placed.

To highlight the effects of the experimental treatments on the growth and fruiting processes of the plants and also on some indicators regarding the quality of the fruit production, the following indicators were determined:

- the shrub aerial part volume (m³) was quantified by calculating the volume occupied by each *Aronia* plant in the experiment, which we assimilated with a reverse pyramid trunk. The calculation of this volume was made by measuring the height and width of each plant before and after the cessation of

growth;

- fruit yield (g plant^{-1}) was measured by weighing the production on each plant;
- the report between the yield of each plant (Kg) to its volume (m^3).

For the assessment of the influence of experimental factors on the production quality, the following indicators were registered:

- the fruit medium mass (g fruit^{-1}) was achieved by individually weighing 20 fruits in 2019 and 30 fruits in 2020 for each B factor graduation;
- the fruit's firmness (Bareiss HPE II-FFF units) was achieved by measuring the resistance to penetration for each fruit whose individual weight was determined;
- the total soluble solids (TSS) content ($^{\circ}$ Brix) and the juice pH were determined for 10 fruits from each B factor graduation with a Kern digital refractometer (with Brix grades units) and, respectively, with a mini Lab pH - meter;
- chlorophyll fluorescence (to support the harvest moment election) was evaluated using a FluoroPen FP 100 fluorimeter.
- the analysis of the experimental factors influence on the different indicators regarding the *Aronia melanocarpa* behavior was performed by using the ANOVA statistic test.

3. Results and discussions

The nearest meteorological station (Pitesti, Arges County) reported multiannual average values e precipitation of 678 mm (1969-2020), as well as mean minimum temperatures of -5.1°C in January and a maximum temperature mean of 27.9°C in July, with an annual average of 10.0°C .

The climatic characteristics in 2019 justify *Aronia melanocarpa* 'Melrom' cultivar to start its vegetative growing season on March 1, 2019, and, respectively, on March 14, 2020, and then finish it on August 8, 2019, and, respectively, on September 9, 2020.

All the *Aronia* shrubs included in the experiment went through the phenological stages without a significant difference between fertilization treatments. A similar result was reported by Kawecki and Tomaszewska (2006) related to the *Aronia melanocarpa* cultivated under various soil management techniques in Poland condition. Our fertilization plans visibly influenced *Aronia melanocarpa* 'Melrom' cultivar vegetative and productivity indicators.

On the average of the three-factor B graduations (b_1 , b_2 , b_3), the treatment with 0.3 l plant^{-1} Biohumus organic fertilizer (see table 3.1), contrary to the treatment with the same fertilizer in the 0.4 l plant^{-1} dose, induced a significant increase of the aerial plant part with 0.1085 m^3 (11.88%) (Figure 1).

In the same conditions, the fertilization with 0.2 l plant^{-1} Biohumus, contrary to the 0.3 l plant^{-1} dose treatment, induced a very significant increase, with 0.095 g (11.02%) of medium fruit weight (Figure 2). The treatment with a Biohumus fertilizer dose of 0.3 l plant^{-1} , contrary to the fertilization with 0.4 l plant^{-1} with the same product, resulted in a very significant decrease with 0.090g (10.97%) of the fruit medium weight.

The increase of the organic fertilizer (Biohumus) applied on plants to $0.3\text{-}0.4 \text{ l plant}^{-1}$, compared to the 0.2 l plant^{-1} dose, determined some fruit yield per plant rapport increasing (Kg plant^{-1}) and also the increasing of fruit yield to the plant volume unit report (Kg m^{-3}), without statistically assured differences between them.

The higher Biohumus dose treatment ($0.3\text{-}0.4 \text{ l plant}^{-1}$), compared to the lower Biohumus dose of 0.2 l plant^{-1} treatment, induced a very significant decrease of the fruit firmness (Figure 3) and very significant increase of the fruit juice pH values (Figure 4). Although the total soluble solids content increased and the chlorophyll fluorescence values had a decreasing trend at higher Biohumus dose ($0.3\text{-}0.4 \text{ l plant}^{-1}$), contrary to the 0.2 l plant^{-1} dose, these differences were not statistically assured.

On average, the three organic Biohumus fertilizer dose levels, compared to the experimental variants where no foliar treatment was applied, the Algacifo foliar fertilizer induced a significant decrease of total soluble solids content with 0.8383 (10.4%) and significantly decreased with 0.12333 (10.3%) the juice pH values (see table 3.2 and Figure 6). In the same conditions, Macys foliar fertilizer treatment determined a significant decrease of total soluble content with 0.9270 (Figure 7). The two foliar fertilizer treatments, compared to the untreated with foliar fertilizer variant, did not induce a significant change of the other analyzed indicators.

On average of the three organic Biohumus fertilizer dose levels, compared to the experimental variants where no foliar treatment was applied, Macys foliar fertilizer treatment significantly decreased the fruit firmness with 4.7560 (Figure 5). When compared with Algacifo, Macys also significantly decreased the fruit firmness with 3.8934 (see table 3.2). The two foliar fertilizer treatments, compared to the untreated with foliar fertilizer variant, did not induce a significant change of the other analyzed indicators.

The data presented in Table 3.3 showed that medium fruit weight values correlated distinct significant negative ($r=-0.364^{00}$) with the aerial plant part volume. This result can be explained by the fact

that, in the case of the existence of a larger volume of the aerial part of the plant, there was also a higher number of fruits per plant. Or, it is generally known that a higher number of fruits per plant results in a lower fruit average weight. A logical explanation also exists in the case of the negative correlation, distinctly significant, between the values of the fruit's average mass and the total soluble solids content.

The positive correlations between the aerial parts volume and the fruit production per plant ($r=0.605^{**}$), as well as, the distinctly significant positive correlation between the fruit production on the bush and the ratio between the fruit production and the plant aerial part volume ($r=0.598^{**}$) also have a biological explanation, as expected, the larger the plants, the more fruit they produce.

Figure 8 describes the intensity of the correlation between fruit production on the bush (y) and the volume of the aerial part of the plants (x) for each applied variant of the Biohumus, in part (factor A), in other words, how the assimilates are distributed for the two important processes, growth and fruiting, depending on the quantities of Biohumus fertilizer applied in the first year after administration.

It is observed that in all three graduations, the correlations between the growth and fruiting processes are very significantly positive, but the slope of the regression lines differs. In other words, in general, the most vigorous plants ensured the highest production.

In the case of the minimum dose of Biohumus, 62.45% of the oscillation of fruit production was determined by the variation of the volume of the bushes ($R^2 = 0.6245^{***}$), 61.92% in the case of the dose of 0.3 l / Biohumus plant ($R^2 = 0.6192^{***}$) and 56.83% in the case of the maximum fertilizer dose ($R^2 = 0.5683^{***}$).

The influence of the Biohumus fertilization appears in the slope of the regression lines and also in the fruit yield increase obtained for the volume unit increasing of the bushes. Thus, the lowest slope for the fruit yield increasing for an increase in bush volume of 1 m³, was recorded when applying only 0.2 l Biohumus plant⁻¹ (1.809 Kg fruits), the maximum range limit of the bush volume variation being close to the other graduations, 1.02 m³.

At the second graduation (0.3 l / plant), the higher the volume of the plants was in the range 0.36 - 1.14 m³, the more the fruit production increased by 2.8977 kg / m³ of the volume of the bushes, in the range 0.88 - 3.74 kg / plant.

When applying the maximum Biohumus dose of 0.4 l / plant, although the slope of the regression line was lower than when applying 0.3 l / plant, of 2.4831 kg fruit / m³ of bush volume, the level of the fruit production was generally superior especially for shrubs with lower volume of the aerial plant part.

A further study of shows the correlation between fruit production and the volume of the aerial part of the plants on B factor graduations (Figure 9) shows that fertilization with Algacifo, unlike the other two variants, induced an increase in production per plant at a higher rate. Plants of the same average size produce more abundantly in the variants in which Algacifo was applied. Also the yield ranged wide in this chart area.

4. Conclusions

Aronia melanocarpa 'Melrom' cultivar is a valuable crop for its fruit quality. It could be grown under the Arges county climatic conditions and responds to the ecological fertilization treatments. On average, on the three graduations of factor B (b_1 , b_2 , b_3), the application of 0.3 l of Biohumus fertilizer per plant, compared to the application of the same fertilizer, at a dose of 0.4 l per plant, determined a significant increase with 0.1085 m³ (11.88%) of the aerial part of the plant.

Under the same conditions, the application of 0.2 l Biohumus per plant, compared to the application of 0.3 l Biohumus per plant, determined a distinctly significant increase, by 0.095 g (11.02%) of the average fruit weight, and at the application of 0.3 l Biohumus per plant, compared to the application of 0.4 l per plant from the same product, there was a significant decrease, by 0.090 g (10.97%), of the average weight of the fruit.

Also, the application of higher doses of Biohumus fertilizer (0.3-0.4 l per plant), compared to the variant where only 0.2 l per plant was applied, resulted in a significant and distinctly significant reduction in fruit firmness and values of the fruit juice pH.

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Tables and Figures

Table 3.1. The soil fertilizer Biohumus dose influence on fruit medium mass, fruit firmness, the juice pH, total soluble solids, chlorophyll fluorescence, the shrub aerial part volume, fruit yield per shrub, and the plant productivity index on *Aronia melanocarpa* (Michx.) Elliot, 'Melrom' cultivar, Maracineni – Arges (2019 – 2020)

Bio-humus doze	The shrub aerial part volume (m ³)	Fruit yield per shrub (kg)	Productivity index (kg/m ³)	Fruit medium mass (g)	Fruit firmness (Bareiss HPE II-FFF units)	Fruit juice pH	Total soluble solid (°Brix)	Chlorophyll fluorescence (QY)
0.2 l plant ⁻¹	0,6267	1,4594	2,7792	1,0194	64,2467	4,0733	21,3167	0,2720
0.3 l plant ⁻¹	0,6863	1,8817	3,2600	0,9249	58,0907	4,1617	21,7183	0,2319
0.4 l plant ⁻¹	0,5778	1,7961	2,8499	1,0150	56,9440	4,1426	21,3459	0,2500
LSD 5%	0.105	NS	NS	0.041	4.305	0.046	NS	NS
LSD 1%	0.165			0.058	6.119	0.066		
LSD 0.1%	0.239			0.084	8.860	0.095

Fig. 1. The soil fertilizer Biohumus dose influence on the shrub aerial part volume on *Aronia melanocarpa* (Michx.) Elliot, 'Melrom' cultivar, Maracineni – Arges (2019 – 2020)

Fig. 2. The soil fertilizer Biohumus dose influence on the fruit medium mass on *Aronia melanocarpa* (Michx.) Elliot, 'Melrom' cultivar, Maracineni – Arges (2019 – 2020)

Fig. 3. The soil fertilizer Biohumus dose influence on the fruit firmness on *Aronia melanocarpa* (Michx.) Elliot, 'Melrom' cultivar, Maracineni – Arges (2019 – 2020)

Fig. 4. The soil fertilizer Biohumus dose influence on the fruit juice pH on *Aronia melanocarpa* (Michx.) Elliot, 'Melrom' cultivar, Maracineni – Arges (2019 – 2020)

Table 3.2. The foliar fertilizers variants influence on fruit medium mass, fruit firmness, the juice pH, total soluble solids, chlorophyll fluorescence, the shrub aerial part volume, fruit yield per shrub, and the plant productivity index on *Aronia melanocarpa* (Michx.) Elliot, 'Melrom' cultivar, Maracineni – Arges (2019 – 2020)

Foliar fertilizer	The shrub aerial part volume (m3)	Fruit yield per shrub (kg)	Productivity index (kg/m3)	Fruit medium mass (g)	Fruit firmness (Bareiss HPE II-FFF units)	Fruit juice pH	Total soluble solid (°Brix)	Chlorophyll fluorescence (QY)
No foliar fertilizer	0.6265	1.6278	2.8046	0.9879	61.6333	4.1750	22.0500	0.2309
Algacifo	0.5885	1.7711	3.1744	0.9873	60.7707	4.0517	21.2117	0.2722
Macys	0.6758	1.7383	2.9102	0.9843	56.8773	4.1508	21.1230	0.2508
LSD 5%	NS	NS	NS	NS	3.918	0.123	0.807	NS
LSD 1%					5.282	0.112	1.088	
LSD 0.1%					7.010	0.149	1.443

Fig. 5. The foliar fertilization influence on the fruit firmness on *Aronia melanocarpa* (Michx.) Elliot, 'Melrom' cultivar, Maracineni – Arges (2019 – 2020)

Fig. 6. The foliar fertilization influence on the fruit juice pH on *Aronia melanocarpa* (Michx.) Elliot, 'Melrom' cultivar, Maracineni – Arges (2019 – 2020)

Fig. 7. The foliar fertilization influence on the total soluble solids content on *Aronia melanocarpa* (Michx.) Elliot, 'Melrom' cultivar, Maracineni – Arges (2019 – 2020)

Table 3.3. The correlation matrix of fruit medium mass, fruit firmness, the juice pH, total soluble solids, chlorophyll fluorescence, the shrub aerial part volume, fruit yield per shrub, and the plant productivity index *Aronia melanocarpa* (Michx.) Elliot, 'Melrom' cultivar, Maracineni – Arges (2019 – 2020)

	Productivity index (kg/m ³)	Fruit yield per shrub (kg)	The shrub aerial part volume (m ³)	Chlorophyll fluorescence (QY)	Total soluble solid (°Brix)	Fruit juice pH	Fruit firmness (Bareiss HPE II-FFF units)	Fruit medium mass (g)
Fruit medium mass (g)	-0.008	-0.247	-0.364**	0.018	-0.225**	0.027	0.344**	1
Fruit firmness (Bareiss HPE II-FFF units)	-0.286*	-0.644**	-0.460**	0.061	0.154*	-0.050	1	
Fruit juice pH	0.166	0.030	-0.065	-0.073	0.079	1		
Total soluble solid (°Brix)	0.095	0.159	0.011	0.020	1			
Chlorophyll fluorescence (QY)	-0.076	-0.144	-0.007	1				
The shrub aerial part volume (m ³)	-0.226	0.605**	1					
Fruit yield per shrub (kg)	0.598**	1						
Productivity index (kg/m ³)	1							

** . Correlation is significant at the 0.01 level (2-tailed).

* . Correlation is significant at the 0.05 level (2-tailed).

Fig. 8. The correlation between fruit yield and the shrub aerial part volume distributed on A factor graduation on *Aronia melanocarpa* (Michx.) Elliot, 'Melrom' cultivar, Maracineni – Arges (2019 – 2020)

Fig. 9. The correlation between fruit yield and the shrub aerial part volume distributed on B factor graduation on *Aronia melanocarpa* (Michx.) Elliot, 'Melrom' cultivar, Maracineni – Arges (2019 – 2020)