THE INFLUENCE OF SOME COMPOSTS ON THE GROWTH AND FRUITING PROCESSES IN THE SPECIES *ARONIA MELANOCARPA* (MICHX.) ELLIOT

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Effects of fertilization with two compost types (one produced from vegetal waste and another containing sewage sludge mixed with vegetal waste, respectively) applied in two different doses (30 and 40 t ha^{-1}, respectively 20 and 40 t ha^{-1}) on the growth processes and fruit production at Aronia melanocarpa (Michx.) Elliot, Nero variety were evaluated. The study was at the Research Institute for Fruit Growing Pitesti, Arges County, Romania. The treatments were applied randomized in a block design (RCBD) with 3 replications. After the first experimental year (2020), the aerial parts volume and fruit yield of each bush have been determined. The fruit yield per plant and unit of volume were also calculated. Compost from vegetable waste applied in a dose of 40 t ha^{-1} induced a significant annual increase in plant volume of 0.46 m^3 higher than of unfertilized plants. Compost fertilization produced from sewage sludge at a dose of 20 t ha^{-1} resulted in a high yield of fruit, compared to the yield of untreated plant fruit (fruiting and low growth), and the fruit yield of plants treated with compost produced from vegetable residues at a dose of 30 t ha^{-1} (low fruit yield and average growth) recorded at average increases. Treatments with the highest doses of compost produced from sewage sludge, especially compost from vegetable scraps, were followed by both high yields at medium growth, as well as/ higher increases in plant growth with a small number of fruits. The results obtained revealed that fertilization with compost could be an alternative to the conventional fertilization and its efficiency on growth and fruiting processes of Aronia melanocarpa (Michx.) Elliot, Nero cultivar is closely related to the types of compost and the doses applied.

Keywords: black chokeberry, fertilization, fruit yield, vegetative growing

Nomenclator:

Aronia melanocarpa (*Michx.) Elliot*- name given in 1821 to *Aronia melanocarpa* species of Aronia Medik. (Medikus 1789) genus

'Nero' cultivar - Aronia cultivar obtained in the Czech Republic.

m^3- plant volume measure

plants ha^{-1}- plant density measure

t ha^{-1} – tons ha^{-1} fertilizer doses unit of measure

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kg m^{-3}- fruit yield per unit of plant volume measure
kg $plant^{-1}$- fruit yield per plant

1. Introduction

Aronia melanocarpa (Michx.) Elliott or Black chokeberry is a shrub of the Rosaceae family, originary from North America and transferred to Europe about a century ago [1, 2]. Aronia has gained a huge interest due to its complex biochemical composition that gives it various beneficial effects on health. [3] Fruits of Aronia constitute rich sources of phenolic compounds, organic acids (chlorogenic, ferulic, caffeic), vitamins (B1, B2, C, E, P, PP), mineral substances (Ca, Mg, P, I, K, Fe), carbohydrates, carotenoids, sugars (fructose, glucose) [4, 5, 6]. Polyphenols (anthocyanins and especially procyanidins) are the most important group of biologically active compounds that gives them antioxidant potential and therapeutic properties. [3, 7, 8].

The quality and chemical composition of chokeberry fruits depend on many factors: genotypic factors (species, varieties, types of fruits), climate conditions (temperature, rainfall, and humidity), growing conditions (soil type, compost, geographic location, etc.), picking season, harvest methods, berry maturity, processing, and storage conditions [9, 10, 11, 12, 13].

The Aronia shrub can adapt to a wide range of soil types, but the most balanced growth occurs on well-drained soils with a humus content of 2-3 %, with pH values between 5.5 and 6.5 [6].

Crop fertilization can improve fruit yield and the content of phytonutrients.

Biodegradable waste can be considered a valuable resource for increasing soil fertility. Compost obtained from various biodegradable wastes brings into the soil a remarkable content of nutrients and organic constituents that support crop development by applying according to the soil demand [14].

Compost is a stabilized and sanitized product of composting, which is the biodegradation process of a mixture of organic substrates carried out by a microbial community composed of various populations, both in aerobic conditions and anaerobic [15]. During the composting process, the simple nitrogenous and carbonate compounds are transformed through the activity of microorganisms into more stable complex organic forms, which chemically resemble soil humic substances [16].

There is a lack of studies concerning the *Aronia melanocarpa* growth and yielding when cultivated using compost. This is why our experiment purpose was to study the vegetative growth and the yielding capacity of four years plants of Aronia, ′Nero′ cultivar shrubs in the field.

2. Materials and methods

The study was carried out at the Research Institute for Fruit Growing Pitesti, Arges County Romania (44°54′N, 24°52′E), during 2020. The experimental plot was established in the spring of 2016, having a planting density of 3,333 plants ha^{-1} (3 x 1 m), and the cultivar studied in the experiment was ′Nero′. The methods for determining main parameters for soil and composts characterisation are shown in Table 1.

Table 1.

The methods and devices used for determination of the main characteristic parameters for soil and composts.

No. crt.	Parameters	Methods	Devices
1	Moisture, %	ISO 16586:2003	Precisa XB 120a Digital Analytical Balance, Precision 10 ^{4}, Etuva –Ed- Binder
2	Total Mineral Salts, %	ASTM D2974 - 20e1	Precisa XB 120a Digital Analytical Balance, Precision 10 ^{4} Caloris L1206 Calcination Oven
3	Total Organic Carbon, TOC, %	Device Method Nondispersive Infrared Absorption Detector	Multi N/C 2100/2100s, Analytik Jena.
4	Total Nitrogen, Nt Azot, %	Device Method Chemiluminescent Detectors	Multi N/C 2100/2100s, Analytik Jena.
5	pH	SR ISO 10390:2015	pH -meter JENWAY 370

The influence of composts of *Aronia melanocarpa* growth in four compost variants in three replications variants of testing is followed according to the data from Table 2. The two types of compost, M and A have provided respectively from composting station Mioveni - Arges county, obtained from mixture vegetable waste and sludge from municipal wastewater treatment station, and from composting station Albota - Arges county, obtained from mixture of vegetable waste.

Table 2

The variants of testing of *Aronia melanocarpa* growth

No. crt.	Variant	Compost Types	Compost Doses, t ha^{-1}
1	V1	**Untreated Plants**	0
2	V2	**M**	20
3	V3	**M**	40
4	V4	**A**	30
5	V5	A	40

Plant's vegetative growth and the fruit yield parameters were assessed. The plants' vegetative growth was quantified by calculating the volume occupied by each Aronia shrub in the experiment, which has been assimilated with a reverse pyramid trunk.

Plants' height and width were measured after the vegetative growth cessation. The ratio between fruit production per plant and the plant volume was calculated to obtain the fruit yield per volume unit (kg m^{-3}), as well as the ratio of crop yield to vegetative growth (considering the difference between aerial plant volume in spring and autumn as the vegetative growth).

Microsoft Excel and SPSS 14 Software (IBM SPSS Statistics) were used to process the experimental data. Treatment effects on fruit yield and plant growth were determined by two-tail analyses of variance (ANOVA). Differences between treatment variants were rated by Duncan's multiple range test, at the 95% confidence level. Data were expressed as mean ± standard deviation. Pearson's correlation was used to analyse the association between all studied parameters. The values $P < 0.05$ were considered statistically significant.

For the association between all studied parameters analyse was used Pearson's correlation. The $P < 0.05$ values were considered statistically significant.

3. Results and discussion

The average values of characteristic parameters for compost and soil are shown in Table 3.

A one-way between-subjects ANOVA was conducted to compare the effect of composts types and doses on the bush volume, the annual increase in bush volume, the fruit yield per plant, fruit yield per bush unit of volume (kg m^{-3}) ratio, and fruit yield per annual increase in bush volume ratio.

Table 3.

The average values of characteristic parameters for compost and soil

No. Crt.	Parameters,	Compost M	Compost A	Soil, Average Value, Deep 0-30 cm
1	Moisture, %	31.38	26.06	13.13
2	Mineral salts, g/kg wet substance	716.2	769.3	978.5
3	Total Organic Carbon, TOC, g/kg wet substance	283.9	232.7	21.5
4	Nitrogen Total, Nt, g/kg wet substance	0.583	1.224	0.103
5	pH	6.09	6.59	6.03

The mean volume of the aerial part of the shrubs was 1.41 m^3, with an oscillation between 0.74 and 2.22 m^3 (Table **4**) and was not significantly influenced by the compost type and dose ($p>0.05$) (as shown in Table **5**).

The annual increase in bush volume (m^3) had a mean value of 0.56 m^3 and ranked between 0.21 and 1.03 m^3 (Table 4). The values of the parameter lower than average values have been prevailing, simultaneously with the presence of a small number of much higher values. According to the ANOVA test, the experimental factor (compost type and dose) significantly influenced the Aronia vegetative growth.

Table 4.

Statistical descriptors for growing and fruiting processes of *Aronia melanocarpa* (Michx.) Elliot, \`Nero\` cultivar, Pitesti, Arges County (2020)

	Bush volume (m^3)	The annual increase in bush volume (m^3)	Fruit yield (kg $plant^{-1}$)	Fruit yield/bush unit of volume (kg m^{-3})	Fruit yield/annual increase in bush volume (kg m^{-3})
Mean	1.4083	0.5573	4.2917	3.1230	8.6587
Median	1.3850(a)	0.5250(a)	4.1333(a)	3.1250(a)	8.4050(a)
Mode	1.59	0.21(b)	4.90	1.90(b)	2.25(b)
Std. Deviation	0.36246	0.20716	1.47860	0.91236	3.87370
Skewness	0.307	0.354	0.765	-0.368	0.728
Std. Error of Skewness	0.427	0.427	0.427	0.427	0.427
Kurtosis	-0.152	-0.449	1.469	-0.001	0.537
Std. Error of Kurtosis	0.833	0.833	0.833	0.833	0.833
Range	1,48	0.82	6.98	3.81	15.71
Minimum	0.74	0.21	1.42	1.05	2.25
Maximum	2.22	1.03	8.40	4.86	17.96

(a) Calculated from grouped data.
(b) Multiple modes exist. The smallest value is shown.

By performing Duncan's multiple comparison procedure based on the Studentized range test (Table 5), the parameter values were divided into three homogeneity classes. The plants treated with the highest dose of compost type A (40 t ha^{-1}) had an annual increase in volume (M=0.78 m^3, SE=0.62) significantly higher when compared with than that of the untreated plants (M=0.32, SD=0.62). Although there were no significant differences between the plants treated with the lowest dose of the type A compost (30 t ha^{-1}), (M=0.52, SD=0.62), type M compost in a 20 t ha^{-1} dose, (M=0.56, SD=0.62) and type M compost in a 40 t ha^{-1} dose (M=0.61, SD=0.62), all the three treatments significantly differed when compared to the untreated plants (M and SD are used to represent mean and standard deviation, respectively). Also, no significant difference was noticed between the effects caused by the composts M, 40 t ha $^{-1}$, and A 40 t ha $^{-1}$.

By corroborating all the data, these results suggest that, in 2020, the plants' growth was significantly stimulated by the application of compost type A in a 40 t ha^{-1} dose. The fruit yield per plant ratio varied from 1.42 to 8.40 kg plant^{-1}, with a mean value of 4.29 kg plant^{-1}. As the ANOVA test confirms, the compost doses and types taken together did not influence the fruit yield in the first experimental year (Table 5). Considering only the compost type as an experimental factor, it could be noted that M type compost led to a significantly higher fruit yield, led to a fruit yield of 1.47 kg plant^{-1} higher than that of the untreated plants (Table 6).

The fruit yield per bush unit of volume (kg m^{-3}) ratio was not significantly influenced by the experimental fertilization variants (Table 5). The mean value of the indicator was of 3.12 kg m^{-3}, with a minimum of 1.05 and a maximum of 4.86 kg m^{-3} (Table 4). Fruit yield per annual increase in bush volume ratio (kg m^{-3}), with an average of 8.66 kg m^{-3}, varied between 2.25 and 17.95 kg m^{-3} (Table 4) and was not significantly influenced by the compost fertilization.

Table 5.

The fertilizer influence on growing and fruiting processes of *Aronia melanocarpa* (Michx.) Elliot, \`Nero\` cultivar, Maracineni – Arges (2020)

Fertilizer Treatment	Bush Volume (m^3)	The Annual Increase in Bush Volume (m^3)	Fruit Yield (kg plant^{-1})	Fruit Yield/Bush Volume (kg m^{-3})	Fruit Yield/Annual Increase in Bush Volume (kg m^{-3})
Not Treatment	1.2383^{A}	0.3150^{C}	3.4300^{A}	2.8900^{A}	11.4467^{A}
Compost Type M - 20 t ha^{-1}	1.3483^{A}	0.5617^{B}	4.8417^{A}	3.6583^{A}	9.6733^{AB}
Compost Type M – 40 t ha^{-1}	1.5833^{A}	0.6100^{AB}	4.9500^{A}	3.1833^{A}	8.7700^{AB}
Compost Type A 30 t ha^{-1} ^{1}	1.2150^{A}	0.5217^{B}	3.4533^{A}	2.8783^{A}	6.8383^{AB}
Compost Type A 40 t ha^{-1}	1.6567^{A}	0.7783^{A}	4.7833^{A}	3.0050^{A}	6.5650^{B}

*Means followed by A, AB or B letter (s) differed significantly with P values ≤ 0.05 (according to Duncan MRT).

A significant difference between the highest ratio value (11.44 kg m^{-3}) and the lowest one (6.57 kg m^{-3}), calculated for the untreated plants, as well as, for the plants treated with compost type A, respectively, in a 40 t ha^{-1} dose was observed (Table 5**).**

Table 6.

The fertilizer type influence on growing and fruiting processes of *Aronia melanocarpa* (Michx.) Elliot, `Nero` cultivar, Maracineni – Arges (2020)

The fertilizer type	Bush volume (m^3)	The annual increase in bush volume (m^3)	Fruit yield (kg $plant^{-1}$)	Fruit yield/bush volume (kg m^{-3})	Fruit yield/annual increase in bush volume (kg m^{-3})
Not compost treatment	1.2383[a]	0.3150[b]	3.4300[b]	2.8900[a]	11.4467[a]
A type compost	1.4358 [a]	0.6500[a]	4.1183[ab]	2.9417 [a]	6.7017[b]
M type compost	1.4658 [a]	0.5858[a]	4.8958[a]	3.4208 [a]	9.2217[ab]

*Means followed by A, AB or B letter (s) differed significantly with P values ≤ 0.05 (according to Duncan MRT).

Table 7.

The correlation matrix between the growing and fruiting processes indicators of *Aronia melanocarpa* (Michx.) Elliot, `Nero` cultivar, Maracineni – Arges (2020)

		Bush volume (m^3)	The annual increase in bush volume (m^3)	Fruit yield (kg $plant^{-1}$)	Fruit yield/bush unit of volume (kg m^{-3})	Fruit yield/annual increase in bush volume (kg m^{-3})
Bush volume (m^3)	Pearson Correlation	1	0.733**	0.366*	-0.338	-0.276
The annual increase in bush volume (m^3)	Pearson Correlation	0.733**	1	0.116	-0.406°	-0.690°°
Fruit yield (kg $plant^{-1}$)	Pearson Correlation	0.366*	0.116	1	0.730**	0.540**
Fruit yield per bush unit of volume (kg m^{-3})	Pearson Correlation	-0.338	-0.406°	0.730**	1	0.769**
Fruit yield per annual increase in bush volume (kg m^{-3})	Pearson Correlation	-0.276	-0.690°°	0.540**	0.769**	1

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

According to Table 7, there was a significant correlation between plant aerial part volume and fruit yield (r=0.366*). This means that plants with a higher volume produced a higher yield. Moreover, plant volume correlated negatively, distinct significantly, with the yield to plant growth ratio (r=-0.276°°), indicating that the plant invested more in its vegetative growth. This aspect was also suggested by a significant negative correlation between fruit yield and fruit yield to the unit of volume ratio (r=-0.406°°), and the distinct significant negative correlation between fruit yield and the ratio yield to vegetative growth (r=-0.690**).

Starting from the finding of several researchers [17, 18], who developed models to simulate the growth and development of crops, according to which the plant grows and develops as a group of interacting semi-autonomous organs, we can expect a negative correlation between growth and fruiting. In this experiment, the compost effect should mask the negative interaction between fruiting and growth by the appearance in the fertilized plants, unlike the control, of some intense growth processes as well as of high production. Since the phenotypic plants' response to the application of experimental variants is integrative (through growth and fruiting processes), the use of growth-fruiting correlation graphs to study the effect of an experimental factor is necessary. Therefore, in the graphs presented below we did not use the average values of the parameters per fertilization variants, but the raw values for each individual.

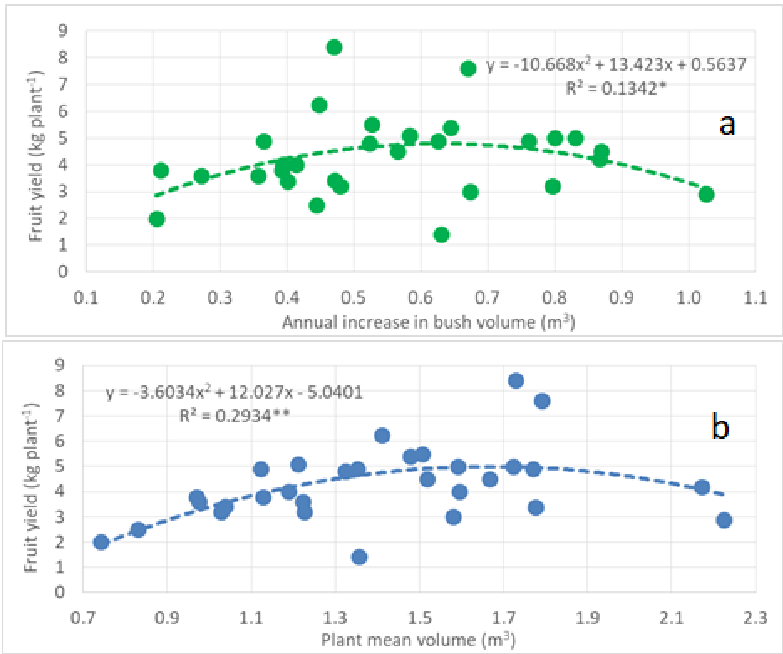

Fig. 1.a and 1.b. Correlation between fruit yield (kg plant^{-1}) and the annual increase in bush volume (the upper side) and between fruit yield (kg plant^{-1}) and plant mean volume (m^3) (the downside), on all compost types and doses, Maracineni, Arges, 2020

Fig. 1.a and 1.b present the significant correlation (R^2=0.1342*) between fruit yield and the annual increase in bush volume, respectively, the distinct significant correlation between fruit yield and the plant mean volume (R^2=0.2934**). A 13.42 percent of the fruit yield oscillation in the 1.42-8.40 kg plant^{-1} range was determined by the variation of the annual increase in bush

volume between 0.21-1.03 m^3 and 29.34% was determined by the plant average volume variation in the 0.74-2.22 m^3 interval. According to Fig 1.a, the compost fertilization allowed the plants to sustain both the fruit yield and the vegetative growth, but only for the shrubs with low to medium vegetative growth. The increase in the annual plant volume occurred in plants that had a low fruit load and whose growth was intensely stimulated by the application of fertilizers. The left and bottom part of the curve corresponds to low vegetative growing and small crop yield. This situation characterizes plants that were either not fertilized or fertilized did not have a significant effect on assimilation processes.

As the slope of the curve decreases, the plants belonging to this area accentuate their vegetative growth in the absence of a large number of fruits on the bush, being stimulated, however, by the effects of the fertilizers applied. The upper, middle, zone of the curve corresponds to the plants with mean annual growth but higher fruit production. It is a favourable situation when these plants used fertilizers mainly for fruit production and less for growth.

The largest increase in the volume of bushes was due to the presence of a small number of fruits on the plants, in the conditions of a significant positive effect of the compost application. On a short term, the situation does not seem favourable, but on a long term, the activation of growth processes may bring the plants to another state of growth-fruiting balance, followed by the gradual increase of the productive potential of the plants.

As Fig 1.b shows, there is a tendency for fruit yield increasing while the plants' mean volume increases (the left and the middle curve area). Also, the fruit production was limited by the flowering bud number (set up in the previous vegetative year). Therefore, the plants could achieve higher aerial part volume without yield increasing. The only significant correlation between the fruit yield and annual increase in bush volume, for each type of compost studied in the experiment (Fig. 2), occurred for the plants treated with type A compost, in 40 t ha^{-1} dose, V_5, (R^2=0.5203*). A decreasing fruit yield trend as the vegetative growth increased could be observed for this fertilization variant.

In this variant (V_5), the plants with the highest fruit load achieved the highest yields, and those with low fruit load, the largest increases in bush volume. The intense effect of compost application is noticeable, either through high yields or through the largest growth increases.

The untreated plants (V_1) produced low fruit yield (between 2 and 4 kg $plant^{-1}$), and also had a low vegetative growth (0.21-0.41 m^3). With a comparable fruit yield (1.42-4.8 kg $plant^{-1}$), V_4 plants grew more (0.39-0.63 m^3). Therefore, the V_4 compost (A type compost, 30 t ha^{-1}) effect materialized only in plants vegetative growth. The higher yield was obtained in V_2, V_3, and V_5, especially for the plants with medium annual volume increase. The V_2 treated plants yielded higher than the control variant (3.6-6.25 kg plant^{-1}), but also had a higher annual volume increase (0.36-0.87 m^3).

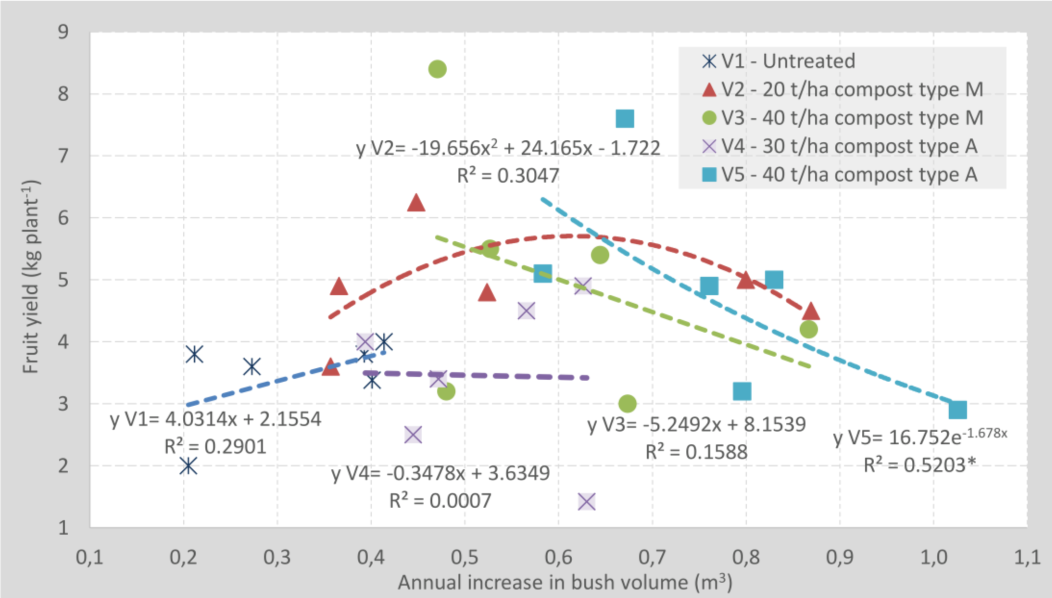

Fig. 2. Correlation between the fruit yield (kg plant^{-1}) and the annual increase in bush volume (m^3), for each compost type and dose, Maracineni, Arges, 2020

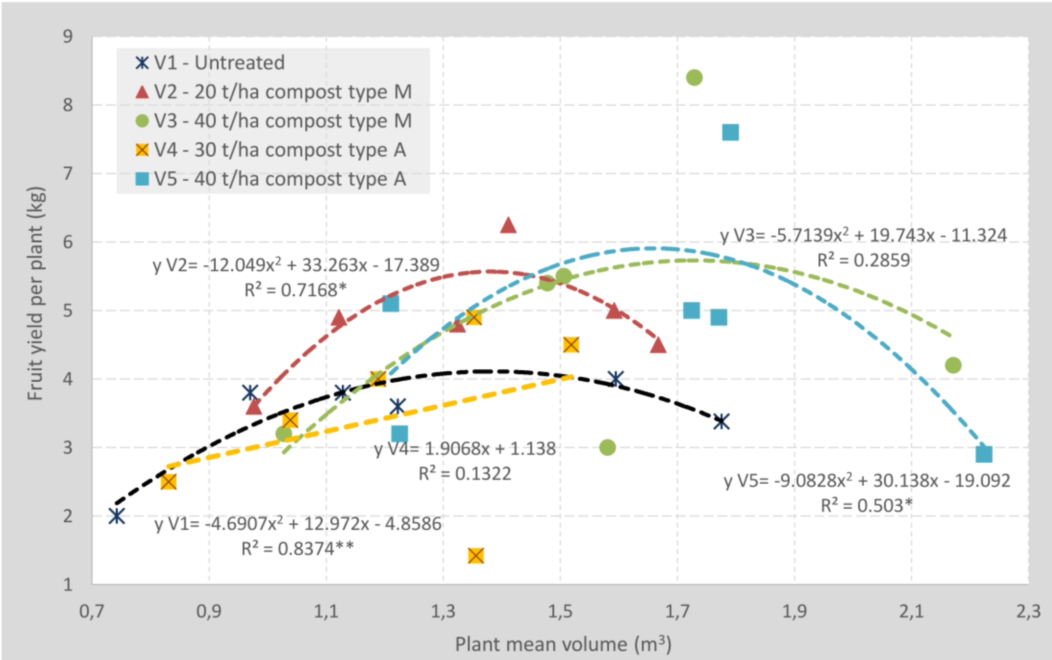

Fig. 3. Correlation between the fruit yield (kg plant^{-1}) and bush volume (m^3), on each compost type and dose, Maracineni, Arges, 2020

As Fig. 3 presents, the fruit yield distinctly significant correlated with the plant mean volume in V_1 (R^2=0.8374**). Also, there was a significant correlation between these two variables in V_2 (R^2=0.7168*) and, respectively, in V_5 (R^2=0.503*). The V_2 treated plants (M type compost, 20 t ha^{-1}) gave superior fruit yield, compared with V_1 (3.6-6.25 kg $plant^{-1}$) and V_4 in approximately the same range of variation of the bush mean volume: 0.98-1.67 m^3. The higher fruit yield in V_5, in the range of 2.9-7.6 kg $plant^{-1}$, and V_3, in the range of 3-8,4 kg $plant^{-1}$, was obtained from plants with larger volume (1.21-2.22 m^3), comparing with V_1, V_2, and V_4.

4. Conclusions

In the first year of the compost fertilization experiment conducted on 4-year-old *Aronia melanocarpa* plants, ′Nero′ cultivar, the mean fruit yield per plant was of 4.29 kg and varied between 1.42 and 8.40 kg $plant^{-1}$. The annual increase in bush volume (m^3) had a mean value of 0.56 m^3 and oscillated between 0.21 and 1.03 m^3. The compost significantly increased fruit production and vegetative growth of shrubs. Thus, comparing the effects of the two compost types with the control variant, it resulted that fertilization with type M compost significantly increased fruit production per plant, with 1.47 kg, compared to unfertilized plants.

The fertilization of the plants with the type A compost significantly increased the annual increase in bush volume with 0.335 m^3, thus significantly reducing the ratio between the fruit production and the annual increase in the volume of the plants, with 4.75 kg m^{-3}, compared to the non-fertilized variant. Also, type A compost in a 40 t ha^{-1} dose induced a significant annual increase in plant volume with 0.46 m^3, compared with the unfertilized plants. The fertilization with M type compost in a 20 t ha^{-1} dose led to high fruit yield, when compared with untreated (low fruiting and growth), and with the A type compost applied in 30 t ha^{-1} dose variants (low fruit yield and medium growth) registered at medium growth increases. The highest dose of M compost, especially of A compost treatments, were followed both by high yields at medium growth, and by higher growth increases in plants with small fruit numbers.

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