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EFFECTS OF ORGANIC AND INORGANIC FOLIAR FERTILIZERS ON THE NUTRITIONAL AND PRODUCTIVE PARAMETERS OF FOUR HIGHBUSH BLUEBERRIES CULTIVARS

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Abstract

To evaluate the effect of some organic or chemical fertilizers on the nutritional and productive parameters of blueberries (Vaccinium corymbosum L.), an experiment was carried out on a farm in the Argeş meadow in a loam-clay soil with four blueberry varieties: 'Duke', 'Blueray', 'Hannah's Choice' and 'Elliott'. Treatments with two foliar organic fertilizers were applied: Algacifo 3000 (2 L/ha) and ERT 23 Plus (1 L/ha) and one conventional treatment: Poly-Feed 19-19-19 + ME (10 kg/ha) along with a control treatment without fertilization in the years 2020-2021 in a four-year blueberry plantation. Results indicate that the nitrogen or phosphorus content of the leaves and fruits was significantly influenced by the variety and fertilization options. The highest concentration of nitrogen and phosphorus in leaves and fruits was recorded in 'Blueray' variety, the variant fertilized with Poly-Feed 19-19-19 + ME. The potassium content showed significant differences between varieties and variants of leaf fertilization. Finally, the chemical fertilizer obtained the highest values for most of the evaluated parameters in all the blueberry varieties studied.

Key words*: blueberry, organic and inorganic fertilizers, plant nutrition, yield.*

INTRODUCTION

The highbush blueberry, *Vaccinium corymbosum* L., belonging to the Ericaceae family, is native to North America and is found in the spontaneous flora of the Northeastern United States and Southeastern Canada. If until the 1900s, blueberries were only known as a North American native shrub with delicious fruit, then it became an international commercial crop (Retamales and Hancock, 2012). In Romania, in the mountainous areas, the species *Vaccinium myrtillus* and *Vaccinium vitis-idaea* grow spontaneously. The first varieties of highbush blueberry (*Vaccinium corymbosum* L.), were cultivated in our country, in 1968 at the Research-Development Institute for Pomiculture in Pitesti and at the Research Station for Pomiculture in Bilceşti (Ancu, 2014).
Soil is the most important factor for the success of blueberry cultivation. Acid soils with a pH between 4.5 and 5.5 are preferred (Alt et al., 2017), with medium texture, well drained and rich in organic matter. Lowering the pH of the soil is done by adding and incorporating into the soil substances with potential for acidification: granular sulfur, dust (approximately 250 kg/ha for the descent by one unit), acid peat (3 t/ha), resinous sawdust. To maintain the acidity of the soil, a dose of powdered sulfur of 100 kg is applied every year for sandy soils or 150 kg for clay soils (Chițu et al., 2016). In organic farms, acetic acid or citric acid and topically applied elemental sulfur are used to lower the pH of the soil in irrigated water (Sadowsky, 2010).
Compared to other fruit species, blueberries have low nutritional requirements (Zidlik et al., 2019). In intensive crops to maintain high yields, it is recommended to keep at a constant level the content of macro and micronutrients in the soil and leaves (Pormale et al., 2009). The supply of blueberries with nutrients is done on the ground, foliar or by fertigation, the doses being established following the foliar diagnosis (Ancu, 2014). Blueberry fertilization has been the focus of many studies. The dose of fertilizer varies depending on the age of the plantation, the vigor of the bushes, the location, the type of soil, the mulching of the soil (organic or inorganic), the fertility of the soil (Hanson, 2006). In the first years 20g N/plant is recommended, in the following years it can reach about 60 g N for

each plant (Virro et al., 2020). In order to obtain high quality yields for blueberry crops, the dose of fertilizer applied is important. In the precise fertilization of blueberry plants, the fertilizer must be well dosed in grams per plant (Lillerand et al., 2021). Organic fertilizers have proven to be of great importance for the implementation of sustainable agriculture techniques and for the prevention of environmental damage (Mufty et al., 2021). Research has shown that organic fertilizers have a beneficial effect on crop management, physical, chemical and biological properties of the soil, as well as being a source of macro and micro-nutrients needed for plant growth and development (Manea et al., 2019; Khan et al., 2020; Wajid et al., 2020). An increase in crop yield and quality has also been reported following the application of organic fertilizers (Habibzadeh et al., 2019). The content of micro-elements was significantly influenced by the application of mineral fertilizers (Medvecký et al., 2021). Excessive administration of chemical fertilizers can lead to a significant decrease in crop yield (Karlsons and Osvalde, 2019), can reduce soil structure and fertility as well as bacterial diversity and the activity of microorganisms (Dinesh et al., 2010). Many studies have shown a positive correlation between regular consumption of fresh fruits and vegetables and the prevention of many diseases. Blueberry fruits are increasingly appreciated by consumers due to their significant content of biologically active substances (Reque et al., 2014) but also as excellent sources of minerals (Medvecký et al., 2021). The present study aims to evaluate the effect of some organic or chemical fertilizers on the nutritional and productive parameters for blueberry highbush (*Vaccinium corymbosum* L.) in the conditions in Romania.

MATERIALS AND METHODS

Fertilizers program and plant material

The experiment took place on a farm in the Argeș meadow, in southern Romania (44° 54'n, 24° 52'e) during two consecutive seasons of vegetation in 2020 and 2021. The surface of the experimental plot was 1 ha and consisted of 20 rows. The distance between plants was 3 m between rows and 0.8 m between plants per row (4385 plants/ha). Four highbush blueberry varieties (*Vaccinium corymbosum* L.) were used as study material: 'Duke', 'Blueray', 'Hannah's Choice' and 'Elliott'. The analyzed vegetal organs were harvested as follows: the fruits at the technical stage of maturity and the leaves at the beginning of August.

The experimental design was bifactorial. Factor A, the highbidh blueberry (*Vaccinium corymbosum* L.) with 4 levels: four varieties of blueberry frequently cultivated in Romania. Factor B, foliar fertilizer with four treatments: V1 - control (untreated), V2 - Algacifo 3000 - seaweed extract *Macrocystis integrifolia* with betaine of vegetable origin (2% organic plant nitrogen, 10% organic carbon, 50% organic matter) - 2 L / ha, V3 - ERT 23 Plus seaweed extract (*Macrocystis integrifolia*), folic acid, betaine glycine (1.5% organic nitrogen, 11% organic carbon, 6.1% K_2O, 10% betaine) - 1 L/ha and V4 - a Poly-Feed 19-19-19 + ME chemical - 10 kg/ha, repeated four times every 10-14 days, from bud formation to early fruit ripening. The treatments were done in triplicate and there was a space of three plants between repetitions.

Soil Description

The plantation is located on a flat area with a brown-clay soil with a loam-clay texture in the first 60-70 cm, and in depth the texture becomes sandy. The soil was improved by adding acid peat along the rows of plants (30 t/ha).

The average nutrient content of the experimental plot in 2020 and 2021 is shown in Table 1. Soil samples were collected from the row of plants with an agrochemical probe, from a depth of 0-20 cm and 20-40 cm). To determine the concentration of macronutrients (N, P, K), $pH_{(H_2O)}$ and organic carbon content, soil samples were collected from the experimental plot, then air-dried and analyzed in the agrochemical laboratory of the Research-Development Institute for Pomiculture Pitesti - Maracineni. The pH value of the soil at fruit harvest was 5.67 in 2020, respectively 5.41 in 2021. To lower the pH of the soil, sulfur was administered at the start of vegetation.

Table 1. Macronutrient and organic carbon content of the soil in the years 2020 and 2021, at fruit harvest

Year	Depth (cm)	pH	N%	$P-P_2O_5$ (ppm)	$K-K_2O$ (ppm)	C%	H%
2020	0-20	5.67	0.11	80.00	80.59	2.67	4.60
	20-40	5.97	0.09	52.14	52.35	0.77	1.33
2021	0-20	5.41	0.14	73.14	69.42	2.64	4.56
	20-40	5.80	0.09	50.43	30.72	0.80	1.38

Weather conditions

Romania is located in southeastern Central Europe in a temperate-continental climate zone with four seasons. The Argeș area is characterized by an average annual temperature of 9.9°C, with an accumulation of average annual rainfall between 450-700 mm. Precipitation is continental with a maximum in June. Irrigation of the plantation was administered from mid-May to the end of September. The plants were irrigated using two lines of polyethylene drip tubes located along the row near the base of the plants. Groundwater was about 1.5 m.

Yield and Nutritional Parameters

The production of fruit on the bush was determined by the gravimetric method, by the repeated weighing of the fruit at the time of harvest. It is known that blueberry fruits ripen in stages. In the studied varieties, the fruits were harvested in four tranches per year.

The macronutrient content was determined from previously dried and ground samples of plant material (leaves and fruits).

The total nitrogen concentration was determined by the Kjeldahl method. The principle of the method is mineralization with concentrated sulfuric acid, followed by distillation and then titration with sulfuric acid (Bataglia et al., 1983). The results were expressed as a percentage.

The available phosphorus content (P), expressed as a percentage, was estimated spectrophotocolorimetric using a PG Instruments T70 spectrometer, Uv-Vis. The principle of this method is based on the colorimetry of the yellow $[(NH_4)_3 P(V_3O_{10})_4]$ complex formed between the vanadate anion and phosphorus in the presence of concentrated mineral acids at 420-470 nm.

The available concentrations of K in the tissues of blueberry plant material were estimated by the flammphotometric method using a Flame Photometer (Sherwood, 360, Cambridge, UK). The results were expressed as a percentage.

RESULTS AND DISCUSSIONS

The impact of foliar fertilization on the production and nutritional traits of blueberry plants (*Vaccinium corymbosum* L.) during the two years of study was significant. In terms of fertility, the soil is characterized by a poor supply of nitrogen, phosphorus and potassium as shown in Table 1. It is known that in an acidic soil reaction the mobilization of nutrients in the soil is diminished. At an acidic pH of the soil, phosphorus in the soil is found "retrograde" (inaccessible to plants) in compounds chelated with aluminum and iron. For the maintenance of vegetative growth, production and for the development of the flower buds of the next year's crop, nitrogen is the key element in blueberry nutrition (Karlsons and Osvalde, 2019). Nitrogen concentration in leaves is higher in early spring than in late autumn (Retamales & Hanson, 1990). In flowers and fruits, the concentration of nitrogen decreases from the beginning of flowering to the harvest of fruit (Banados et al., 2012).

Numerous studies have aimed to establish the optimal level of nutrients for the success of the culture of this species (Banados et al., 2012; Bryla et al., 2012; Larco et al., 2013; Ehret et al., 2014). Although the absorption of most nutrients increases throughout the growing season, it is recommended that the application of most fertilizers be administered in spring in some cases and in mid-summer (Bryla et al., 2012).

Chemical composition of blueberry leaves and fruits of the 'Duke' variety

The nitrogen content of the leaf samples taken in early August increased with the application of nitrogen fertilizers (Table 2). However, on average, after two years of study, the concentrations of nitrogen in the leaves of the 'Duke' variety were higher (in variants V2 - fertilized with Algacifo 3000 and V4 - fertilized with Polyfeed) than what is considered normal according to Hans et al., (2006) (1.76% to

2.00%) for highbush blueberry. In the control variant, where no fertilizers were applied, the nitrogen concentration in the leaves after the two years of study was 1.61%.

Table 2. The effect of foliar fertilizers on the concentration of macronutrients in the leaves and fruits of highbush blueberries, 'Duke' variety in the years 2020-2021

Foliar treatment	**Macronutrients (%) of leaves**			**Macronutrients (%) of fruits**		
	N	**P**	**K**	**N**	**P**	**K**
2020						
Control	$1,32 \pm 0,04^{d}$	$0,20 \pm 0,003^{c}$	$0,43 \pm 0,003^{b}$	$1,28 \pm 0,02^{b}$	$0,16 \pm 0,001^{c}$	$0,47\ \ 0,003^{c}$
Algacifo 3000	$2,27 \pm 0,12^{a}$	$0,21 \pm 0,003^{b}$	$0,46 \pm 0,02^{ab}$	$1,29 \pm 0,01^{b}$	$0,17 \pm 0,001^{b}$	$0,50 \pm 0,01^{b}$
Ert23Plus	$1,82 \pm 0,09^{c}$	$0,22 \pm 0,003^{a}$	$0,48 \pm 0,06^{a}$	$1,37 \pm 0,02^{a}$	$0,19 \pm 0,003^{a}$	$0,52 \pm 0,003^{a}$
PolyFeed	$1,91 \pm 0,13^{b}$	$0,21 \pm 0,003^{b}$	$0,49 \pm 0,04^{a}$	$1,09 \pm 0,02^{c}$	$0,21 \pm 0,002^{a}$	$0,50 \pm 0,01^{b}$
2021						
Control	$1,90 \pm 0,01^{d}$	$0,20 \pm 0,02^{b}$	$0,40 \pm 0,04^{c}$	$1,02 \pm 0,03^{c}$	$0,17 \pm 0,01^{c}$	$0,52 \pm 0,003^{c}$
Algacifo 3000	$1,94 \pm 0,12^{b}$	$0,21 \pm 0,01^{ab}$	$0,44 \pm 0,04^{b}$	$1,09 \pm 0,01^{b}$	$0,21 \pm 0,02^{a}$	$0,55 \pm 0,004^{b}$
Ert23Plus	$1,93 \pm 0,08^{c}$	$0,21 \pm 0,01^{ab}$	$0,46 \pm 0,04^{b}$	$1,00 \pm 0,02^{d}$	$0,19 \pm 0,01^{b}$	$0,57 \pm 0,003^{a}$
PolyFeed	$2.22 \pm 0,03^{a}$	$0,22 \pm 0,01^{a}$	$0,51 \pm 0,04^{a}$	$1,20 \pm 0,01^{a}$	$0,22 \pm 0,01^{a}$	$0,55 \pm 0,003^{b}$
2020-2021						
Control	$1,61 \pm 0,29^{d}$	$0,20 \pm 0,14^{b}$	$0,42 \pm 0,03^{c}$	$1,15 \pm 0,13^{a}$	$0,17 \pm 0,01^{c}$	$0,50 \pm 0,03^{c}$
Algacifo 3000	$2.11 \pm 0,17^{a}$	$0,21 \pm 0,01^{a}$	$0,45 \pm 0,03^{b}$	$1,19 \pm 0,10^{a}$	$0,19 \pm 0,02^{b}$	$0,53 \pm 0,03^{b}$
Ert23Plus	$1,88 \pm 0,05^{c}$	$0,22 \pm 0,14^{a}$	$0,47 \pm 0,05^{b}$	$1,18 \pm 0,19^{a}$	$0,19 \pm 0,01^{b}$	$0,55 \pm 0,02^{a}$
PolyFeed	$2.06 \pm 0,16^{b}$	$0,22 \pm 0,01^{a}$	$0,50 \pm 0,04^{a}$	$1,14 \pm 0,06^{a}$	$0,21 \pm 0,02^{a}$	$0,53 \pm 0,03^{b}$

From the data of the analysis test of the Anova variant, it appears that the fertilization variants had a very significant effect on the nitrogen content of the leaves in the 'Duke' variety, p = 0.000 (partially and squared = 99.6%). Also, the study year had a very significant influence (p = 0.000) of the nitrogen content of the leaves in the 'Duke' variety by 97.7%. The combined effect of the two factors (fertilization variant and year) on the nitrogen content was very significant, of 99.4%.

The concentration of other macronutrients in the leaves (phosphorus and potassium) increased significantly with the application of foliar fertilizers in the first year of fertilization. Regarding the phosphorus content in the leaves, in the 'Duke' variety, the appearance of two series of homogeneous values (a, b) is observed after the two experimental years. All foliar treatments had the effect of increasing the total phosphorus content compared to the unfertilized control. There were no statistically assured differences between fertilization variants with organic or conventional fertilizers regarding the accumulation of phosphorus in the leaves of this variety.

In the experiment, the concentration of potassium in the leaves of the variety 'Duke' recorded the highest value in variant V4 - fertilized with the chemical fertilizer Polyfeed (0.51%), the year 2021 and (0.50%) on average after the two years fertilization (Table 2).

In the processes of absorption of mineral components by the cells of the leaf epidermis, climatic conditions as well as various factors such as temperature and relative humidity play a significant role (Wach and Błażewicz-Woźniak, 2012).

The average values of the fertilization variants show statistically assured differences between the conventional fertilization variant V4 and the organic variants V2 and V3 on the nitrogen, phosphorus and potassium content of fruits in the 'Duke' variety. The exception was the nitrogen concentration in the fruit after the two years of study where the appearance of a single series of homogeneous values (a) between all fertilization variants is observed. Regarding the phosphorus content of fruit, 68.1% of the variation in the concentration of this nutrient in fruit could be explained by the effect of the fertilization variant.

Chemical composition of blueberry leaves and fruits of the 'Elliott' variety

The levels of mineral nutrients in blueberry leaves in the 'Elliott' variety during the years 2020-2021 are shown in Table 3.

Table 3. The effect of foliar fertilizers on the concentration of macronutrients in the leaves and fruits of highbush blueberries, variety 'Elliott' in the years 2020-2021

Foliar treatment	Macronutrients (%) of leaves			Macronutrients (%) of fruits		
	N	P	K	N	P	K
2020						
Control	2,06 ± 0,001a	0,19 ± 0,002b	0,59 ± 0,004d	1,26 ± 0,01d	0,15 ± 0,01d	0,56 ± 0,01a
Algacifo 3000	1,86 ± 0,005c	0,21 ± 0,008a	0,63 ± 0,005c	1,43 ± 0,01b	0,18 ± 0,002b	0,51 ± 0,01a
Ert23Plus	1,61 ± 0,001d	0,19 ± 0,004b	0,65 ± 0,001b	1,29 ± 0,02c	0,16 ± 0,001c	0,52 ± 0,15a
PolyFeed	1,89 ± 0,004b	0,19 ± 0,004b	0,79 ± 0,004a	1,54 ± 0,00a	0,19 ± 0,001a	0,54 ± 0,01a
2021						
Control	1,84 ± 0,15b	0,16 ± 0,01a	0,59 ± 0,07c	0,75 ± 0,01c	0,15 ± 0,02c	0,55 ± 0,002b
Algacifo 3000	1,85 ± 0,01b	0,16 ± 0,01a	0,72 ± 0,04b	1,20 ± 0,01a	0,24 ± 0,01b	0,55 ± 0,003b
Ert23Plus	1,74 ± 0,04c	0,17 ± 0,02a	0,73 ± 0,07ab	1,05 ± 0,10b	0,16 ± 0,01c	0,52 ± 0,003c
PolyFeed	1,99 ± 0,01a	0,17 ± 0,02a	0,79 ± 0,06a	1,20 ± 0,01a	0,26 ± 0,01a	0,59 ± 0,002a
2020-2021						
Control	1,95 ± 0,12a	0,18 ± 0,02b	0,59 ± 0,03c	1,01 ± 0,26c	0,15 ± 0,01b	0,53 ± 0,02ab
Algacifo 3000	1.86 ± 0,01c	0,19 ± 0,03a	0,67 ± 0,05b	1,31 ± 0,12a	0,21 ± 0,03a	0,53 ± 0,02ab
Ert23Plus	1,67 ± 0,07d	0,18 ± 0,02ab	0,69 ± 0,06b	1,17 ± 0,13b	0,16 ± 0,01b	0,52 ± 0,10b
PolyFeed	1.94 ± 0,05b	0,22 ± 0,18ab	0,79 ± 0,18a	1,37 ± 0,18a	0,22 ± 0,04a	0,57 ± 0,03a

Surprisingly, in 2020, the highest nitrogen content was recorded in unpowdered blueberry leaves, and in the second year for those treated with PolyFeed. The lowest rate of leaf nitrogen accumulation in the 'Elliott' variety was observed with the administration of the biostimulant Ert 23 plus. According to the analysis of the Anova variant, the total nitrogen content of the leaves in the 'Elliott' variety was very significant (p = 0.000) influenced by the fertilization variant (partial and squared = 98.5%). The effect of the year on the nitrogen content of the leaves in this variety was insignificant.

The phosphorus content of blueberry leaves did not vary significantly between study years. The highest levels of phosphorus were found in blueberry leaves in 2020 and the lowest in the following year. Statistical analysis showed a significant effect of foliar fertilization with Algacifo 3000 on the concentration of that element in the leaves compared to the control treatment and no significant difference compared to the variant sprayed with chemical fertilizer. From the data of the analysis test of the Anova variant, it appears that the fertilization variants had an effect on the phosphorus content of the leaves in the 'Elliott' variety of only 11.7% (p = 0.046). The combined effect of the two factors (fertilization variant and year) on the phosphorus content of the leaves in the 'Elliott' variety was significant, of 22.1% (p = 0.001).

The potassium content of blueberry leaves, the 'Elliott' variety in the years 2020-2021 is shown in Table 3. The lowest concentration of potassium was recorded in both years in the non-fertilized variant (0.59%) and the highest in both years in Polyfeed-fertilized variant study.

In fruit, the content of macronutrients (nitrogen, phosphorus and potassium) in blueberry fruit ('Elliott' variety) is shown in Table 3. Statistically assured differences were observed between fertilization variants regarding the content of macronutrients analyzed in fruit. Polyfeed-fertilized blueberry fruits and those fertilized with Algacifo 3000 organic fertilizer had a significantly higher nitrogen concentration than the control treatment (1.37% and 1.31%, respectively, after two years of fertilization). Significant differences in nitrogen accumulation in fruit were observed between the two years of fertilization. From the data of the analysis test of the Anova variant, it appears that the fertilization variants had a very significant effect on the nitrogen content of the fruit in the 'Elliott' variety, p = 0.000 (partially and squared = 99.5%). Also, the study year very significantly influenced (p = 0.000) the nitrogen content of the leaves in the 'Elliott' variety by 99.7%. The combined effect of the two factors (fertilization variant and year) on the nitrogen content was very significant, 93%. In 2020, a higher amount of nitrogen in fruits of this variety has accumulated.

Regarding the phosphorus content in the fruit, it is observed that the highest level was recorded in the fruit spraying blueberries with the chemical fertilizer PolyFeed both in 2020 and in

2021. The fertilization variant had a very significant influence on the accumulation of this nutrient in fruits of 92.3%.

The accumulation of potassium in fruits (Table 3) was also influenced by the study year (p = 0.000) according to the analysis data of the Anova variance (partially eta squared = 77.7%). In Table 3, analyzing the average values, can shows an insignificant level of potassium in the blueberry fruits ('Elliott' variety) influenced by the fertilization variants in the first year of fertilization, observing the existence of a single series of homogeneous values (a).

Chemical composition of 'Hannah's Choice' leaves and blueberries

Regardless of the year of study and the fertilizer administered, a statistically assured variation in the nitrogen concentration of blueberry leaves in 'Hannah's Choice' variety was obtained compared to the control treatment (Table 4). Moreover, a significant difference was observed between the chemical fertilizer and the other fertilizers used after the two consecutive years on the nitrogen concentration in the leaves.

From the data of the analysis test of the Anova variant, it appears that the fertilization variants had a very significant effect on the nitrogen content of the leaves in the 'Hannah's Choice' variety, p = 0.000 (partial and squared = 95.2%). Also, the study year significantly influenced (p = 0.000) the nitrogen content of the leaves in the 'Hannah's Choice' variety by 99.0%. The combined effect of the two factors (fertilization variant and year) on the nitrogen content was very significant, of 96.1%. The phosphorus content of leaves in the 'Hannah's Choice' blueberry variety (Table 4) recorded the highest average value (0.23%) for the chemical fertilizer sprayed in 2021. On average, after two years of experiment, the content of phosphorus accumulated in the leaves had the highest values in the plants sprayed with organic fertilizer Algacifo 3000, and the lowest in the non-fertilized version.

Table 4. The effect of foliar fertilizers on the concentration of macronutrients in the leaves and fruits of highbush blueberries, the variety 'Hannah's Choice' in the years 2020-2021

Foliar treatment	Macronutrients (%) of leaves			Macronutrients (%) of fruits		
	N	P	K	N	P	K
2020						
Control	1,85 ± 0,14[d]	0,19 ± 0,00[b]	0,37 ± 0,01[d]	1,15 ± 0,001[c]	0,14 ± 0,001[c]	0,56 ± 0,01[b]
Algacifo 3000	2,00 ± 0,004[c]	0,21 ± 0,01[a]	0,48 ± 0,001[c]	1,29 ± 0,001[b]	0,15 ± 0,001[b]	0,54 ± 0,01[c]
Ert23Plus	2,05 ± 0,002[a]	0,19 ± 0,01[b]	0,52 ± 0,003[b]	1,13 ± 0,002[a]	0,16 ± 0,001[a]	0,58 ± 0,00[a]
PolyFeed	2,04 ± 0,000[b]	0,19 ± 0,01[b]	0,55 ± 0,001[a]	1,29 ± 0,001[b]	0,16 ± 0,001[a]	0,58 ± 0,004[a]
2021						
Control	1,74 ± 0,12[c]	0,22 ± 0,01[a]	0,49 ± 0,07[b]	0,74 ± 0,001[d]	0,11 ± 0,02[c]	0,61 ± 0,004[b]
Algacifo 3000	1,78 ± 0,02[b]	0,22 ± 0,01[a]	0,49 ± 0,05[b]	0,82 ± 0,13[c]	0,13 ± 0,02[b]	0,59 ± 0,003[c]
Ert23Plus	1,74 ± 0,02[c]	0,22 ± 0,01[a]	0,49 ± 0,05[b]	0,90 ± 0,02[b]	0,12 ± 0,01[c]	0,63 ± 0,002[a]
PolyFeed	1,81 ± 0,01[a]	0,23 ± 0,01[a]	0,64 ± 0,04[a]	0,93 ± 0,02[a]	0,15 ± 0,01[a]	0,63 ± 0,002[a]
2020-2021						
Control	1,80 ± 0,06[c]	0,20 ± 0,02[b]	0,43 ± 0,08[c]	0,94 ± 0,04[b]	0,13 ± 0,02[c]	0,58 ± 0,03[b]
Algacifo 3000	1.89 ± 0,12[b]	0,22 ± 0,01[a]	0,48 ± 0,03[b]	1,05 ± 0,10[ab]	0,14 ± 0,02[b]	0,57 ± 0,03[c]
Ert23Plus	1,90 ± 0,16[b]	0,21 ± 0,02[b]	0,50 ± 0,04[b]	1,11 ± 0,04[a]	0,13 ± 0,02[bc]	0,61 ± 0,03[a]
PolyFeed	1.93 ± 0,12[a]	0,21 ± 0,02[b]	0,59 ± 0,05[a]	1,11 ± 0,06[a]	0,15 ± 0,01[a]	0,61 ± 0,03[a]

The potassium content of blueberry leaves increased significantly during the experiment. The leaves of the bushes sprayed with PolyFeed leaves had a significantly higher potassium content than the plants fertilized with organic fertilizers. Regardless of the year, the lowest level of calcium was recorded in the blueberry leaves from the control plants. Statistical analysis showed significant differences between fertilization options (72.4%; p = 0.000) and study years (26.7%; p = 0.000), and the interaction between years and fertilizer variant (38.2%; p = 0.000).

The accumulation of nutrients in the fruits of the highbush blueberry, the variety 'Hannah's Choice' according to the fertilization options and the years of study is presented in Table 4. In most cases, the nutrient content of the fruit had the highest values in the sprayed version with chemical fertilizer. Organic fertilizers have also had a beneficial effect on plant nutrition. However, there were a few exceptions. The potassium content of the fruit was higher in the non-fertilized version compared to the sprayed version with Algacifo 3000, which was observed in both years of testing. This can also be seen in the leaves in 2020. The average values of the other nutrients in the fruit were lower in non-fertilized plants as in the other varieties.

Chemical composition of blueberry leaves and fruits of the 'Blueray' variety

In the 'Blueray' variety, the content of macronutrients (N, P and K) in plant tissue and blueberry fruit was significantly affected by the foliar application of fertilizers. The total nitrogen content of the leaves in the 'Blueray' variety, according to the analysis of the Anova variant, was very significant ($p = 0.000$) influenced by the fertilization variant (partial and squared = 38.7%). The effect of the year on the nitrogen content of the leaves in this variety was also very significant (partially and squared = 63.7%). The combined effect of the two experimental factors (fertilization variant and year of study) was 52.0%.

In the 'Blueray' variety, the level of macron-trients in the leaves (Table 5) recorded the highest average values in the plants sprayed with PolyFeed fertilizer. However, after two years of experimentation, the phosphorus content in the leaves was higher in the fertilized version with organic fertilizer Algacifo 3000. As in the other varieties, the accumulation of phosphorus in the leaves was more efficient after fertilization with Algacifo 3000. In fruits, nutrition was better in chemically fertilized plants.

Table 5. The effect of foliar fertilizers on the concentration of macronutrients in the leaves and fruits of highbush blueberries, the variety 'Blueray' in the years 2020-2021

Foliar treatment	Macronutrients (%) of leaves			Macronutrients (%) of fruits		
	N	P	K	N	P	K
2020						
Control	$2,20 \pm 0,003^{a}$	$0,16 \pm 0,01^{b}$	$0,45 \pm 0,05^{c}$	$0,99 \pm 0,003^{c}$	$0,15 \pm 0,001^{a}$	$0,51 \pm 0,02^{c}$
Algacifo 3000	$2,09 \pm 0,005^{c}$	$0,17 \pm 0,01^{b}$	$0,49 \pm 0,01^{b}$	$1,05 \pm 0,001^{b}$	$0,15 \pm 0,000^{a}$	$0,54 \pm 0,00^{a}$
Ert23Plus	$2,13 \pm 0,004^{b}$	$0,17 \pm 0,01^{b}$	$0,49 \pm 0,05^{b}$	$0,99 \pm 0,002^{c}$	$0,14 \pm 0,001^{b}$	$0,52 \pm 0,01^{b}$
PolyFeed	$2,11 \pm 0,01^{b}$	$0,18 \pm 0,01^{a}$	$0,55 \pm 0,01^{a}$	$1,13 \pm 0,001^{a}$	$0,15 \pm 0,001^{a}$	$0,55 \pm 0,01^{a}$
2021						
Control	$1,97 \pm 0,10^{b}$	$0,19 \pm 0,01^{c}$	$0,79 \pm 0,08^{c}$	$0,92 \pm 0,001^{b}$	$0,16 \pm 0,01^{a}$	$0,55 \pm 0,004^{c}$
Algacifo 3000	$1,97 \pm 0,01^{b}$	$0,21 \pm 0,01^{b}$	$0,86 \pm 0,06^{b}$	$0,95 \pm 0,13^{ab}$	$0,15 \pm 0,04^{a}$	$0,63 \pm 0,004^{a}$
Ert23Plus	$2,08 \pm 0,01^{a}$	$0,22 \pm 0,01^{ab}$	$0,87 \pm 0,07^{b}$	$0,92 \pm 0,002^{b}$	$0,16 \pm 0,02^{a}$	$0,62 \pm 0,003^{b}$
PolyFeed	$2,10 \pm 0,01^{a}$	$0,23 \pm 0,01^{a}$	$0,97 \pm 0,10^{a}$	$1,01 \pm 0,02^{a}$	$0,15 \pm 0,04^{a}$	$0,63 \pm 0,003^{a}$
2020-2021						
Control	$2,09 \pm 0,14^{a}$	$0,17 \pm 0,02^{c}$	$0,64 \pm 0,17^{c}$	$0,95 \pm 0,03^{c}$	$0,15 \pm 0,01^{a}$	$0,53 \pm 0,02^{b}$
Algacifo 3000	$2.03 \pm 0,07^{b}$	$0,19 \pm 0,03^{b}$	$0,66 \pm 0,22^{bc}$	$1,00 \pm 0,10^{b}$	$0,15 \pm 0,02^{a}$	$0,59 \pm 0,05^{a}$
Ert23Plus	$2,11 \pm 0,03^{a}$	$0,19 \pm 0,03^{b}$	$0,68 \pm 0,20^{b}$	$0,95 \pm 0,04^{c}$	$0,15 \pm 0,02^{a}$	$0,57 \pm 0,05^{a}$
PolyFeed	$2.11 \pm 0,01^{a}$	$0,20 \pm 0,02^{a}$	$0,76 \pm 0,23^{a}$	$1,07 \pm 0,06^{a}$	$0,15 \pm 0,02^{a}$	$0,59 \pm 0,04^{a}$

Throughout the experiment, the results of the analysis test of the Anova variance suggest that the accumulation of nitrogen in the leaves was very significantly influenced by the variety (partially and squared = 94.2%), the fertilization variant (88.3%), the year of study with (43.9%) ($p = 0.000$). The cumulative effect of the three experimental factors was 93.6%. Phosphorus accumulation in plant tissue was very significantly influenced ($p = 0.000$) by variety (63.2%), fertilization variant (20.0) and year of study (19.7%). It was found that the level of potassium in the leaves of blueberry highbush was significantly influenced by variety (85.5%), fertilization options (59.2%) and the study year by 63.7% ($p = 0.000$).

The analysis of fruit macronutrients in all the varieties selected for analysis showed a very significant influence on the nitrogen concentration, due to the variety (91.8%), the applied fertilizers (84.2%) and the study year (95.9%). The cumulative effect of the three experimental factors was 77.2%. Regarding the phosphorus content in fruits, it was found that a very significant influence had the variety with 74.3%, the fertilization variant with 50.4% and the experimental year with only 9.1%. On the accumulation of potassium in fruits, the influence of experimental factors was lower: the variety by 51%, the foliar fertilizers applied by only 21.1% and the study year by 49.9% ($p = 0.000$).

In our study, for all treatments applied, the levels of nitrogen (N), phosphorus (P) and potassium (K) in the leaves and fruits of the highbush blueberry analyzed were relatively sufficient. It is clear that agricultural practices influence the accumulation of macronutrients in the fruits and leaves of highbush blueberry (*Vaccinium corymbosum* L.).

Crop yield

The purpose of the experiment was to examine the production of blueberries. In general, fruit yield was significantly influenced by the application of foliar fertilizers ($p \leq 0.05$). The most productive variety was 'Elliot', followed by 'Duke'. The variety with the lowest production per plant was 'Hannah's Choice'. The highest yield was obtained in plants fertilized with chemical fertilizers (V4). However, there were no significant differences in blueberry production between plants fertilized with organic fertilizers and those fertilized with chemical fertilizers after two years of study.

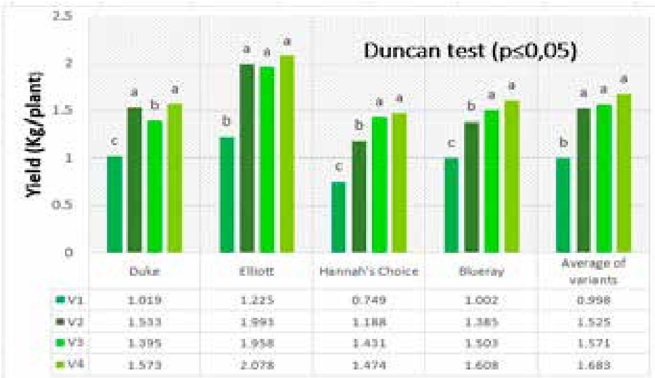

Figure 1. The influence of foliar fertilizers on plant yield by variety in the years 2020-2021

Our results are consistent with those in the literature. Starast et al. (2002), Karlsons and Osvalde (2019) reported higher yields for blueberry fertilized with foliar fertilizers. From the data of the analysis test of the Anova variance, it appears that the fruit yield was very significantly influenced by the variety (partially and squared = 45.6%) (p = 0.001). The fertilizer variant also had a very significant influence on plant yield (33.8%). The effect of the year on the production yield was 57.5% (p = 0.000).

CONCLUSIONS

The data presented suggest that different fertilization systems can significantly affect the nutrient content of plant tissue and blueberry fruit.

There are significant differences between the two cultivation practices (organic and conventional). Blueberries produced from conventional crops generally contain significantly higher amounts of macronutrients (N, P and K) than those produced in organic crops.

Foliar fertilization can become an effective method for increasing the production of blueberry crops.

Given the positive effect of organic fertilizers on plant nutrition and crop yields, partial replacement of mineral fertilizers with organic fertilizers may be recommended.

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