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Effects of the growing systems on growth and yield of high-bush blueberries (*V. corymbosum* L.)

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Abstract

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The purpose of this study is to present the impact of growing system of high-bush blueberries (*Vaccinium corymbosum* L.) on growth and yield. In recent years, new approaches to intensive blueberry production have become necessary, especially in terms of planting systems. These systems are designed to avoid various difficulties related to the specific requirements that blueberries have regarding soil pH. Considering the grower’s interest in potting and raised beds planting methods, our study focused on four blueberry cultivars at five years of age, ‘Duke’, ‘Huron’, ‘Blue Ribbon’ and ‘Draper’ planted in pots and raised beds. Plant growth on pots was significantly lower for ‘Duke’ (147.5 dm^3) compared to that on the raised bed (235 dm^3) and ‘Blue Ribbon’ (150.1 dm^3) compared to that on the raised bed (176.2 dm^3). While the other two cultivars ‘Huron’ and ‘Draper’ were the opposite. The yield of ‘Duke’ was higher in pots (3370 g/plant) compared to that on the raised bed (3132 g/plant) but in ‘Blue Ribbon’ the yield was higher in the raised bed (3086 g/plant) compared to planting in pots (2969 g/plant). Moreover, even in ‘Draper’ the yield was higher (3895 g/plant) in the pot compared to the raised bed (3010 g/plant), while in ‘Huron’ the yield was also higher in the pot (2729 g/plant) compared to the raised bed (2451 g/plant). These data indicate that potting can be a useful method for blueberry cultivation.

Keywords: blueberry; substrate; plant volume; yield; pots; raised bed

Introduction

Successful cultivation of high-bush blueberry (*Vaccinium corymbosum* L.) requires a substrate with low pH (4.5–5.5), high organic matter (7–10%) and good aeration of the substrate (Li & Bi, 2019; Kingston et al., 2017). These plants can grow in soil rich in organic matter, e.g. peat, sawdust and bark of confers and deciduous trees or a mixture of these substrate (Strik, 2017).

Meeting and maintaining these parameters at optimal levels can be challenging for most growers, because a significant number of land plots do not meet these requirements (Fang et al., 2020). Consequently, in recent years, growers have shown increased interest in alternative planting methods using custom substrates.

Cultivation of high-bush blueberry in raised beds (soil ridges) and pots where even the smallest amount of substrate is required is being done due to the adaptation of the pH of the substrate required by the blueberry, organic matter in the substrate as well as easier maintenance of aeration. Having shallow roots (Eck & Childers, 1966), a highly branched and extremely fine root system (Valenzuela-Estrada et al., 2009), and fine roots of less than 50 μm in diameter highbush blueberries are susceptible to drought injury (Bryla & Strik, 2006) and requires a well-drained soil and sufficient irrigation to achieve acceptable yields. Planting on raised beds improves drainage and help protect plants from standing water (Scherm & Krewer, 2008). Raised beds do not mitigate high soil temperatures during the summer (White, 2006), but improve soil conditions by lowering compaction and providing greater internal drainage (Magdoff & Van Es, 2000). Raised beds thus help prevent saturated soils and pest problems like phytophthora root rot (Bryla & Linderman, 2007). Cultivation in pots can be carried out in areas with unsuitable soil properties such as poor saline soils. A disadvantage of growing blueberry in pots is limited root growth and therefore a reduced surface area for water and nutrient absorption with potential effects on long-term production due to shorter plant life. Small volume pots can suffer from the wind and can lead to the overturning of the plant (Li & Bi, 2019). Potting also represents an additional cost for intensive blueberry cultivation but allows also the possibility of manipulating the fruit harvesting period (Heiberg & Lunde, 2006).

Different species and cultivars of *Vaccinium* have different abilities to adapt to different pH values. (Poorter et al., 2012 ; Owen & Altand, 2008; Austin & Bondari, 1992). In the case of high-bush blueberries, a very high pH can lead to limited plant growth and yield, and limited uptake of individual nutrients, such as iron, manganese and copper (Vargas & Bryla, 2015). Various researchers have argued that elevated rhizosphere pH in blueberry will lead to nutritional imbalance, chlorosis as a result of iron deficiency in leaves and a decrease in photosynthesis, thus inhibiting plant growth and reducing yield (Owen & Altand, 2008 ; Jiang et al., 2017). For example, fertilizing cv. 'Bluecrop' with ammonium sulphate gave a 17% higher yield than plants fertilized with urea. Yields were higher when plants were fertigated than when other methods were used (Vargas & Bryla, 2015). Manganese is also required by the blueberry plant, but is usually available in abundance in acidic soil conditions (Whidden, 2008).

Considering that in soils with high pH the cost of soil acidification is quite high and may not be long-term (Poorter et al., 2012), breeding blueberries for tolerance to high pH is the right approach to avoid this problem. New blueberry cultivars with increased tolerance to high pH soils is an important objective of breeding programs. However, new blueberry germplasm is created by crossing, a method that takes several years to flower and bear fruit. Since fruit yield is the target of blueberry production, the time required to evaluate this character takes too long to be used in breeding for tolerance to high soil pH.

Substrates are mixtures of organic matter such as peat with a low pH, sawdust or sawdust from conifers. Pine bark, which generally has a pH of 4.0 and 4.2, while the EC is below 0.5 dS/m, is the suitable substrate for growing blueberry in pots. Unlike most crops, blueberry mainly absorbs ammonia nitrogen (NH_4) rather than nitrate (NO_3), due to the low activity of nitrate reductase in roots and leaves (Merhaut & Darnell, 1995). Other substances used for blueberry nutrition include P, K, Ca, Mg, elemental sulphur which is used to lower soil pH, iron, boron, copper and zinc (Korcak, 1998). Composting pine bark in the absence of oxygen (anaerobic respiration) results in a pH as low as 2.0. This can happen on pine bark when the fungus (mycelium) develops at 60 to 75 cm below the surface of the pile. This creates a cap that seals out the oxygen. Acetic acid, phenolic compounds and toxic alkaloids for the plant are produced in that part where oxygen is missing (Strik, 2017).

Mixing pine bark with sand is more common for large containers. Ratios of 6:1 or 8:1 pine bark:sand are popular. Sand in the potting mix adds weight and provides anchorage to reduce buffeting by wind gusts. Since the substrate in smaller pots dries out faster, 60-L pots have been shown to be more efficient in meeting the water requirements of plants. When plants are supplied with low levels of nitrogen (N), growth is poor and leaves turn pale green or chlorotic yellow and often develop a reddish tinge. In the case of phosphorus (P), deficiency symptoms are not usually seen and field plants rarely respond to P application (Retamales & Hancock, 1996). Potassium (K) deficiency can be due to a number of factors: reduced root function, flooding, poor drainage, high levels of nitrogen (N), drought and highly acidic soils (Retamales & Hancock, 2018). Fertigation has been shown to provide superior results compared to surface applications of nitrogen, possibly due to the easy availability of nitrogen located in the root zone (Finn & Warmund, 1997).

The objective of this study was to identify the most efficient growing system for highbush blueberries for various cultivars.

Materials and Methods

The experiment was carried out in 2021 on 5-year-old blueberry plants with cultivars 'Duke', 'Draper', 'Blue Ribbon' and 'Huron'. The place where the orchard is located, Vitomiricë village, Pejë municipality, lies between the northern latitude 42° 39′ 47″ N and the eastern longitude 20° 58′ 30″ E. Peja lies in the valley of Lumbardhi surrounded by the Albanian Alps. Peja, together with the entire Dukagjin Plain, is located on the Neogene alluvial terrace at an altitude of 505-520 m above sea level. The characteristic of the position of this area is that it lies on the north-western edge of the Dukagjin plain. Average annual temperature 10.6 C°, while during the vegetation 16.9°C, in the hottest months August with 21.7 C°

and July 21.6°C and 0.5°C in the coldest month January. Annual precipitation reaches 822 mm while during the period of vegetation 366.8 mm.

Uniform plants at five years of age of four blueberry cultivars, namely ‘Duke’, ‘Huron’, ‘Blue Ribbon’ and ‘Draper’ were included in the experiment. The experimental design used was Randomized Block Design (RBD) with four repetitions. Cultivars were selected and planted in 60-L black pots and on the benches. Pots were filled with substrate are inserted into the soil in order to avoid temperature fluctuations and wind blows. Planting distances were 0.8 m in the row direction and 2.7 m between rows. The substrate was a mixture of soil, peat and pine sawdust (in a ratio of 1:1:1).

The surface along the raised beds and pots is covered with polypropylene (polypropylene foil), which prevents the growth of weeds and affects the heating of the substrate, while the pipes of the drip irrigation system are placed under it. Through the irrigation system, the trees were fertigated with crystalline fertilizers eight times during the vegetative growth season, starting from the end of March until the middle of June. Ammonium sulphate, magnesium sulphate, ammonium phosphate, potassium sulphate, and microelements Fe, Zn, Mn, Cu, Borax and Sodium molybdate were used as fertilizers.

The water used for irrigation has a pH of 5.0, while EC = 1.8, 1.6 and 1.1 on hot days, whereas higher EC inhibits nutrient uptake by increasing the osmotic pressure of the nutrient solution, and increases nutrient discharge to the environment.

Iron is given in the form of chelates, such as diethylene triamene penta acetate (DTPA 6%), to increase its availability in the soil solution and to prevent its deposition by carbonates or bicarbonates which bind iron and make it unavailable to the plant. Plants usually use iron as $(Fe)^{2+}$.

The substrate which was used during the planting of seedlings in the raised beds and pots (soil, peat and pine sawdust) was subjected to laboratory analysis where the soil was found to have a pH = 5.2; peat pH (H_2O) = 4.5 – 5.5 while pH ($CaCl_2$) = 4.0 – 5.0 and sawdust from pine pH = 4.36.

The fruits were harvested five times for each cultivar starting from July 1, 2021. While the measurement of the volume of the canopy (in dm^3) was carried out by measur-

Fig. 1. Presentation of cultivars according to planting methods

ing the height of the crown as well as two diameters; the diameter of the canopy in the direction of the row and the diameter in the direction from the other row.

Statistical analysis was applied using two-way ANOVA at a level of confidence α = 0.05 according to Vukadinović, where the F values were significant.

Results and Discussion

The results showed that the planting methods had a significant effect on plant growth and yield. In general, when analysing the yield in the cultivars 'Draper', 'Duke' and 'Huron', a trend was observed for higher yields when planted in pots with the exception of the cultivar 'Blue Ribbon' which gives a slightly lower yield in pots compared to growing in raised bed.

Differences were also observed in plant growth as a result of growing system, where higher values were observed when planting in raised bed for the 'Duke' and 'Blue Ribbon' cultivars, in contrast to the 'Huron' and 'Draper' cultivars, which recorded higher plant volume values to the method of planting in pots compared to planting on the raised beds.

The data from (Table. 3) show that there are significant differences (at the α = 0.05 confidence level) in terms of

Table 1. Average yield data according to growing system, g/plant

Factor: A	Factor: B	R_1	R_2	R_3	R_4	Average
Cultivar	Planting Method					
Duke	Pots	3100	3470	3290	3300	3370
	Raised bed	2800	3185	2932	2972	3132
Huron	Pots	2541	2700	2750	2700	2729
	Raised bed	2176	2315	2351	2374	2451
Blue Ribbon	Pots	2731	2969	3226	2950	2969
	Raised bed	3134	2936	3085	3150	3086
Draper	Pots	3590	3885	3995	3860	3895
	Raised bed	2920	2940	2990	3185	3010

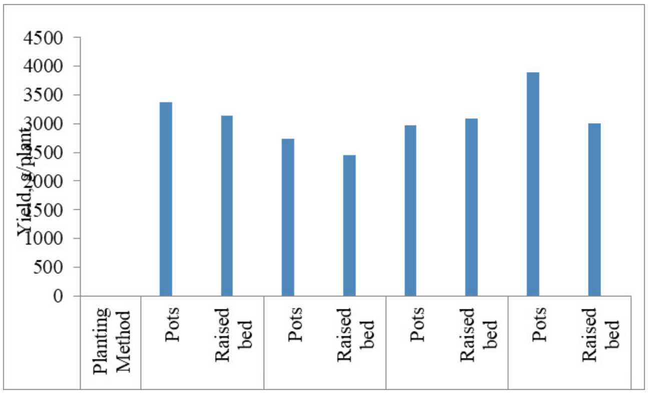

Fig. 2. Yield (g/plant) according to planting methods

Table 2. Test of the interaction between the tested factors yield, g/plant

Source	Sum of Squares	*df*	Mean Square	F
Blocks	1729472.0000	3	576490.6875	3.432*
Factor A	99680.0000	1	99680.0000	0.593
Factor B	177408.0000	3	59136.0000	0.352
Interaction A*B	21216.0000	3	7072.0000	0.042
Error	220192.0000	21	12232.8887	
Total	5555328.0000	31		

Average of trials 3077.3125

Table 3. The effect of planting methods on the average yield according to cultivars, g/plant

Factor (A) Cultivar	Factor (B) Planting Method		Average (A)
	Pots	Raised bed	
Duke	3370 NS	3122 NS	3246 NS
Huron	2729 NS	2451*	2590*
Blue Ribbon	2969 NS	3086 NS	3027.5 NS
Draper	3895 NS	3010*	3452.5 *
Average (B)	3240 *	2917.5*	3077.321*

Differences were demonstrated at significance level LSD 0.05%
Legend: Ns = not significant, * = significant, ** = highly significant

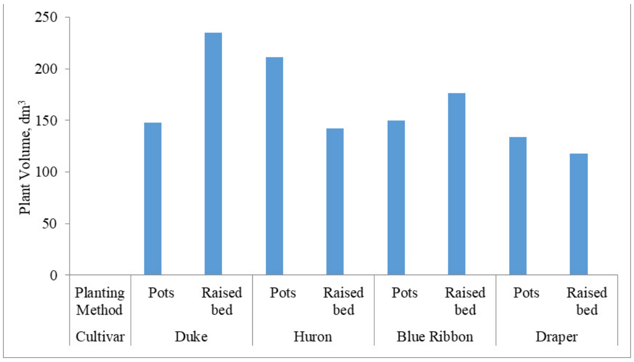

Fig. 3. Volume of plants according to planting methods

Table 4. Average data according to planting methods for plant volume by cultivar, dm^3

Factor A: Cultivar	Factor B: Planting Method	R_1	R_2	R_3	R_4	Average
Duke	Pots	143	147	155	145	147.5
	Raised bed	230	220	235	255	235
Huron	Pots	235	210	195	205	211
	Raised bed	152	141	135	140	142
Blue Ribbon	Pots	164	150	130	156	150
	Raised bed	193	176	156	180	176.2
Draper	Pots	150	134	128	123	133.7
	Raised bed	125	115	112	118	117.5

Table 5. Test of the interaction between the tested factors plant volume

Source	Sum of Squares	df	Mean Square	F
Blocks	12245.3750	3	4081.7917	3.062*
Factor A	5050.1250	1	5050.1250	3,789
Factor B	1281.6250	3	427.2083	0.321
Interaction A*B	354.1250	3	118.0417	0.089
Error	1551.2500	21	86.1806	
Total	20482.5	31		

Average of trials 163.6875

Table 6. Effect of planting method on plant volume according to cultivars, dm^3

Factor (A) Cultivar	Factor (B) Planting method		Average (A)
	Pots	Raised bed	
Duke	147.5 *	235.0*	191.00 *
Huron	211.0*	142.0 *	176.50 NS
Blue Ribbon	150.1 NS	176.2 NS	163.15 NS
Draper	133.7 NS	117.5 NS	125.60 *
Average (B)	160.45 NS	167.6 NS	163.6875 NS

Differences were demonstrated at significance level LSD 0.05%
Legend: NS = not significant, * = significant, ** = highly significant

yield based on the planting method (pot, raised bed) in the cv. 'Draper', where in pots reaches values (3895 g/plant) while in the raised bed (3010 g/plant). Also, significant differences between growing systems were found in cv. 'Huron' with highest yields achieved in pots (2729 g/plant) compared to the raise bed (2451 g/plant). No significant differences related to growing systems were observed within cvs. 'Duke' and 'Blue Ribbon' but we found differences between the cultivars (Table 4).

Significant differences in plant growth were found between the growing system (Table 6). Higher values of plant volume were observed in the cultivar 'Duke' planted in raised beds (235 dm^3) compared to planting in pots (147.5 dm^3). On the contrary, 'Huron' reaches a higher canopy volume (211 dm^3) in pots compared to raised beds (142 dm^3). No significant differences were found within the two growing systems for cvs. 'Blue Ribbon' and 'Draper' but only between cultivars.

Conclusions

This research provides results regarding the effect of growing system on plant growth and yield of high-bush blueberries, in pots and raised beds. Based on the results, it was observed that planting blueberry plants in pots represents a suitable production method for cultivars 'Draper', 'Duke' and 'Huron' in terms of yield and for 'Huron' and 'Draper' in terms of plant growth. Based on the data of the current study, we can conclude that the blueberry cultivars 'Draper', 'Duke' and 'Huron' are suitable for cultivation in pots, while 'Blue Ribbon' is not recommended for planting in pots. Regardless of these encouraging results, further research is needed in the following years for these three cultivars, considering that the orchard is at a young age.

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