Bulgarian Journal of Agricultural Science, 31 (No 4) 2025, 702–708

Vegetative and reproductive potential of some highbush blueberry varieties grown in the Troyan region

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Abstract

Georgiev, D. & Georgieva, M. (2025). Vegetative and reproductive potential of some highbush blueberry varieties grown in the Troyan region. *Bulg. J. Agric. Sci., 31*(4), 702–708

The highbush blueberry is a fruit crop with specific requirements for agroclimatic conditions. Limiting factors for its distribution are its increased demands for atmospheric humidity and soil acidity. It thrives successfully in mountainous and semi-mountainous regions of the country, where there is a higher amount of precipitation, increased air humidity, and relatively favorable temperatures for realizing its biological potential.

The growth and development of five american varieties of highbush blueberries: Bluecrop, Bluegold, Patriot, Spartan, and Toro, were monitored in a demonstrative plantation at the RIMSA in Troyan, during the period 2020–2022. Under the agroclimatic conditions of the Pre-Balkans, fruit ripening of the studied highbush blueberry varieties begins from the second ten-day period of June, with no significant differences in timing between them. The quantity of plant pigments (chlorophyll a, chlorophyll b, and β-carotene) in leaf samples from the studied varieties was analyzed during the three-year experimental period. The highest levels of chlorophyll a and β-carotene in leaf samples were found in the second year of the experiment in the Patriot variety (1.31 mg/g and 0.83 mg/g, respectively).

The tallest average bush height was recorded in the Spartan varieties – 113.39 cm and Bluecrop – 110.11 cm during the experimental period.

The best results in terms of average yield were recorded in Toro (103.85 g/bush) and Bluecrop (99.94 g/bush).

The fruit weight had the highest average values in the Toro varieties – 1.69 g and Bluecrop – 1.45 g, while the fruits of the Spartan – 1.02 g and Patriot – 1.12 g varieties had the lowest weight.

Keywords: Vaccinium corymbosum L.; blueberry; chemical composition; yield; size; vegetable pigment

Introduction

Vaccinium corymbosum L. is a perennial fruit crop belonging to the Ericaceae family, valued for the antioxidant and pro-inflammatory properties of the fruits, used for the treatment of cardiac, malignant, and ophthalmic diseases in medicine (Lin et al., 2016; Golovinskaia and Wang, 2021).

In recent years, global blueberry production has increased (Retamales and Hancock, 2012), and for the establishment of plantations most often varieties created in the USA are used (Petridis et al., 2018).

According to FAO data, the largest producers of blueberries worldwide are the USA, Chile, Canada, Argentina, Poland, Germany etc., and in Europe – Poland and Ukraine (Leposavić et al., 2021; FAOSTAT).

Blueberry is a relatively poorly distributed fruit crop in Bulgaria, because of the lack of sufficient planting material and knowledge of its biological characteristics, as well as technology for its cultivation. Besides, it has a shallow root system and is very demanding on soil acidity and humidity, which is why it thrives best in the mountain and foot-hill regions of Bulgaria, where the annual precipitation amount is high above 900 mm, and the soil reaction is acidic. In recent years, climatic anomalies have become more frequent: extremely high temperatures, prolonged periods of drought or waterlogging, and mild winters with insufficient snow cover, which have an extremely negative effect on the productivity and quality of blueberry fruit production (Hancock et al., 1992; Petridis et al., 2018; Yang et al., 2019; Redpath et al., 2021; Georgieva et al., 2022).

Plant pigments are of key importance in determining the physiological state of plants, their quantity and quality are related to photosynthetic activity, and therefore have an important role on the growth and development of fruit orchard species (Zhao et al., 2016). Drought stress, which is increasingly observed worldwide, negatively affects the content of photosynthetic pigments (chlorophyll *a*, chlorophyll *b* and β-carotene) (Molnar et al., 2022). In a state of water stress, the plant tissue becomes dehydrated, which can increase oxidative stress, which is associated with a loss of chlorophyll (Cruz de Carvalho, 2008).

The purpose of the present scientific experiment is to observe the content of plant pigments (chlorophyll *a*, chlorophyll *b,* and β-carotene), in fresh leaves of five varieties of highbush blueberry, their growth and reproductive potential, to assess the opportunity to cultivate them in the Troyan region.

Material and Methods

The experiment was conducted between 2020 and 2022, in a collection plantation of the Research Institute of Mountain Stockbreeding and Agriculture of Troyan. The objectives of the study were the introduced varieties of high bush blueberries: Bluecrop, Bluegold, Patriot, Spartan, and Toro, which develop well in the semi-mountain conditions of the Troyan region. Bluecrop variety was used as a control, which is characterized by high yields, medium-sized fruits with good taste, very good resistance to diseases, and is one of the most widespread varieties worldwide. The selection of the other varieties included in the study was based on fruit quality, harvest period, yield, disease resistance etc.

The studied varieties were planted in 2019, and grown under irrigated conditions with drip irrigation. The planting scheme of the plants is 3.00 m × 1.50 m. The inter-row spacings and intra-row areas are naturally grassed, with the application of the necessary mowing of the grass, and the area around the stems is maintained in black fallow by tillage. The collection plantation is located at an altitude of 460 m on a slope with eastern exposure. The soils are light gray forest with a pH of 4.6 to 5.6. The precipitation regime for the vegetation (from March to July) (2020–2022), is presented in Figure 1. The heaviest rainfall in the area fell during the vegetation in 2020 (346 l/m^2), whereas the lowest amount was registered in 2021 (232.1 l/m^2). In 2022, the vegetation amount of average monthly precipitation was 253.3 l/m^2. In the last two years of the experimental period, the lowest reported vegetation precipitation amount for the last five years was recorded (Atanasova, 2021).

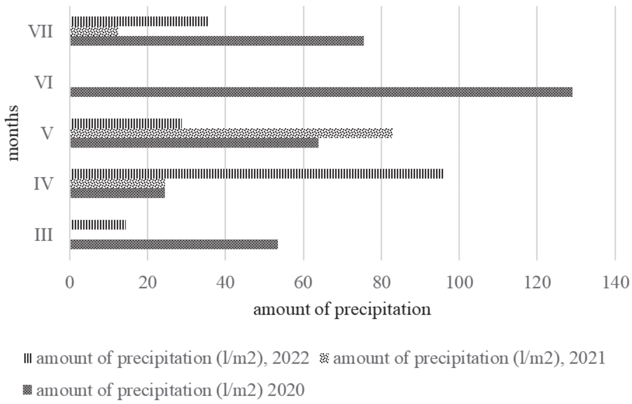

Fig. 1 Precipitation amount (l/m^2) during the vegetation period (2020–2022)

The average monthly temperature sum for the vegetation period (from March to July) does not differ significantly during the research period and was within the limits of 13.9°C (2020) to 14.3°C (2022) (Figure 2).

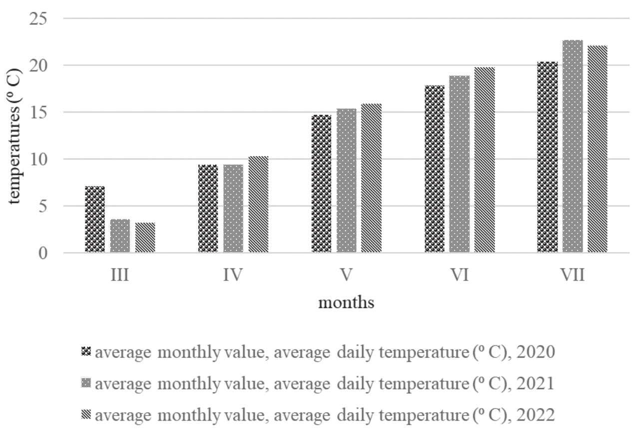

Fig. 2 Average daily temperatures (°C) for the period 2020–2022

The relative humidity for the vegetation period (from March to July) (2020–2022), is in the range of 69–81%, as the lowest was in 2022. The following vegetative and reproductive indicators were reported:

- height of bushes, cm;
- width of the bushes perpendicularly and in the direction of the row, measured at the end of the vegetation period, cm;
- average fruit weight, g;
- average yield, g.

The content of chlorophyll *a*, chlorophyll *b,* and β-carotene in blueberry leaf samples was determined spectrometrically.

The methodology for studying plant resources in fruit plants was used to report the vegetative and reproductive indicators (Nedev et al., 1979).

The data were statistically processed using the software product MS Excel – 2010.

Results and Discussion

The composition of pigments is of fundamental significance for the intensity of photosynthesis of fruit plants, which are distinguished from other organisms with an autotrophic nutrition type. Photosynthesis varies widely depending on light intensity and temperature, which have a significant impact on blueberry fruit yield (Petridis et al., 2018).

Tables 1, 2, and 3 present the results for the content of plastid pigments in leaf samples of five highbush blueberry varieties. Comparing the results of the three-year study period, it was found that chlorophyll values were lowest in the first year (0.44 mg/g to 1.00 mg/g) and highest in the following year in Patriot variety (1.31). Bluegold variety was distinguished by the lowest values for the second and third years of the study period (respectively: 0.94 mg/g and 0.90 mg/g). Average values for varieties range widely, from 0.64 mg/g (2020), to 1.05 mg/g (2021). The statistical analysis shows that the coefficient of variation is very high in the first year (37.50), with average values in the second year (14.34), and low values in the third year (10.37).

The results show that the leaf samples of Spartan variety (2020 and 2021) have lower chlorophyll *b* values, whereas those of Patriot (2021 and 2022), have the highest (respectively, 0.81 mg/g and 0.48 mg/g) for the study period. The average values for that indicator for the three years are in the range from 0.38 mg/l (2020) to 0.67 mg/l (2021). The statistical analyses performed show that the results for the

Table 1. Chlorophyll *a* content (mg/g) in leaves of blueberry varieties for the period 2020–2022

Plant pigments / Varieties	Chlorophyll *a*, mg/g 2020	Chlorophyll *a*, mg/g 2021	Chlorophyll *a*, mg/g 2022
Bluecrop	0.76	0.95	0.99
Bluegold	0.53	0.94	0.90
Patriot	0.44	1.31	0.97
Spartan	0.45	1.03	1.17
Toro	1.00	1.04	1.10
Mean	0.64	1.05	1.03
St error	0.11	0.07	0.05
St Dev	0.24	0.15	0.11
CV %	37.50	14.34	10.37
Minimum	0.44	0.94	0.90
Maximum	1.00	1.31	1.17

Table 2. Chlorophyll *b* content (mg/g) in leaves of blueberry varieties for the period 2020–2022

Plant pigments / Varieties	Chlorophyll *b*, mg/g 2020	Chlorophyll *b*, mg/g 2021	Chlorophyll *b*, mg/g 2022
Bluecrop	0.46	0.70	0.43
Bluegold	0.31	0.69	0.39
Patriot	0.28	0.81	0.48
Spartan	0.27	0.53	0.43
Toro	0.56	0.60	0.46
Mean	0.38	0.67	0.44
St error	0.06	0.05	0.02
St Dev	0.13	0.11	0.03
CV %	34.20	15.79	7.87
Minimum	0.27	0.53	0.39
Maximum	0.56	0.81	0.48

Table 3. β-carotene content (mg/g) in leaves of blueberry varieties for the period 2020–2022

Plant pigments / Varieties	β-carotene, mg/g 2020	β-carotene, mg/g 2021	β-carotene, mg/g 2022
Bluecrop	0.47	0.61	0.74
Bluegold	0.33	0.59	0.54
Patriot	0.29	0.83	0.55
Spartan	0.30	0.62	0.66
Toro	0.61	0.60	0.62
Mean	0.40	0.65	0.62
St error	0.06	0.04	0.04
St Dev	0.14	0.10	0.08
CV %	33.82	15.45	12.87
Minimum	0.29	0.59	0.54
Maximum	0.61	0.83	0.74

coefficient of variation are equivalent, similar to the previous indicator chlorophyll *a*.

From the comparative analysis of the results for the content of β-carotene in the leaf samples, it follows that the lowest values were registered in Spartan (0.27 mg/g) and Patriot (0.28 mg/g) in the first experimental year, whereas the highest was found in Patriot (0.83 mg/g) in the second experimental year. The coefficient of variation is very high in 2020 (33.82), and in 2021 and 2022, there are average values (respectively: 15.45 and 12.87).

The performance of the biological potential of fruit orchard crops is directly dependent on the varietal characteristics, the soil and climate conditions in the area of their cultivation, and the agrotechnical events applied during the vegetation period.

The data from the average values of the vegetative indicators for the studied varieties are presented in Table 4. Comparing the obtained results, it is noticeable that Spartan (113.39 cm) and Bluecrop (110.11 cm) are distinguished with the highest average height of the bushes, whereas the smallest height is measured in Toro (83.44 cm) and Bluegold (86.50 cm).

Table 4. Vegetative indicators of the tested blueberry varieties on average for the period 2020–2022

Indicators / Varieties	Average height of bushes, cm	Average diameter of bushes in the row, cm	Average diameter perpendicular to row, cm
Bluecrop	110.11	47.19	55.39
Bluegold	86.50	47.58	50.92
Patriot	92.83	43.39	45.11
Spartan	113.39	66.86	39.44
Toro	83.44	42.97	46.44
Proof of Differences ($P < 0.05$)	n.s	n.s	n.s

In agreement with the present results, Wach (2008) compared the vegetative growth of six fruiting highbush blueberry cultivars (Bluecrop, Blueray, Darrow, Ivanhoa, Northland, and Spartan) and reported the strongest vegetative growth for Northland and the weakest for Darrow and Spartan.

The highest value of the average diameter of the bushes in the row is measured for Spartan variety with 66.86 cm. For the other varieties, there are no significant differences and the values are in the range from 42.97 cm (Toro) to 47.58 cm (Bluegold).

Bluecrop and Bluegold varieties have the largest average diameter perpendicular to the row, respectively: 55.39 cm and 50.92 cm, whereas the smallest is measured in the bushes of Spartan with 39.44 cm. There are no statistically proven differences between varieties in terms of vegetative parameters ($P > 0.05$).

Table 5 presents the obtained values for the yield of the blueberry varieties included in the study. The best results as average values for this indicator was registered for Toro (103.85 g/bush) and Bluecrop (99.94 g/bush), as the other three varieties occupy an intermediate position. Leposavic (2014), like us, studied the reproductive characteristics of some highbush blueberry varieties and reported the highest yield per bush for Reka variety (2626.53 g), whereas the lowest for Nui (1318.18 g). The highest coefficient of variation was reported for Bluecrop (114.26%), whereas the lowest was for Bluegold (61.83%). For the other varieties, the indicator is in very high values. The mathematical analysis shows that there is no statistical proof among the varieties, but there is a very good proof between the individual years ($P < 0.001$) (Table 6).

Table 5. Average yield per bush for blueberry varieties (g) for the period 2020–2022

Varieties / Quantities, g	Bluecrop	Bluegold	Patriot	Spartan	Toro
	2020				
	35.63	76.40	35.96	34.27	51.6
	2021				
	32.41	38.28	41.87	47.16	41.11
	2022				
	231.78	143.31	173.34	167.1	218.83

Comparing vegetative growth and reproductive characteristics of eight northern highbush blueberry varieties (Brigitta, Bluecrop, Bluejay, Earliblue, Duke, Nelson, Patriot, and Spartan) at different altitudes (690 m, 440 m, 175 m, and 140 m) Celik (2009), found that Bluecrop and Patriot were characterized by the greatest bush height of all locations. In addition to the highest altitudes (690 m), the best average yields were reported for Brigitta (395 kg/da), Bluecrop (240 kg/da), and Patriot (113 kg/da). Besides, the largest fruit was obtained at the highest altitude (690 m) from Spartan genotype (3.78 g).

The largest fruit weight was registered for Toro with 2.4 g (2020), 1.54 g (2021), and 1.14 g (2022), respectively, concerning the average values (Table 7, Figure 3). A probable reason for the reported smaller fruits in the last two years is the smaller amounts of precipitation for the area, which were at their lowest values over five years. In line with the present results, the negative impact of water deficit combined with

Table 6. Mathematical analysis of the yield of blueberry varieties on average for the period 2020–2022

Indicators \ Varieties	Bluecrop	Bluegold	Patriot	Spartan	Toro
Mean	99.94	86.00	83.72	82.84	103.85
Standard Error	65.93	30.70	44.84	42.29	57.57
Standard Deviation	114.19	53.17	77.67	73.25	99.72
CV	114.26	61.83	92.77	88.42	96.02
Minimum	32.41	38.28	35.96	34.27	41.11
Maximum	231.78	143.31	173.34	167.1	218.83
Level of significance (P) among varieties	n.s				
Level of significance (P) among years	P < 0.001				

Table 7. Average fruit weight of blueberry varieties (g) for the period 2020–2022

Weight, g \ Variety	Bluecrop	Bluegold	Patriot	Spartan	Toro
	2020				
	2.17	1.83	1.37	0.97	2.4
	2021				
	1.49	1.17	1.20	1.17	1.54
	2022				
	0.68	0.94	0.79	0.91	1.14

Fig. 3. Fruit size of the studied highbush blueberry varieties

Table 8. Mathematical analyzes of the average fruit weight of blueberry varieties on average for the period 2020–2022

Indicators \ Varieties	Bluecrop	Bluegold	Patriot	Spartan	Toro
Mean	1.45	1.31	1.12	1.02	1.69
St error	0.43	0.27	0.17	0.08	0.37
St Dev	0.75	0.46	0.30	0.14	0.64
CV %	51.56	35.18	26.62	13.39	38.02
Minimum	0.68	0.94	0.79	0.91	1.14
Maximum	2.17	1.83	1.37	1.17	2.4
Level of significance among varieties	n.s				
Level of significance among years	$P < 0.01$				

high temperatures and drought on blueberry fruit volume has also been reported by other authors (Mingeau et al., 2001; Almutairi et al., 2017; Fan-Hsuan et al., 2020).

In the first two years, Bluecrop (control) was remarkable with its large fruits, respectively, 2.17 g (2020) and 1.49 g (2021). On average for the period, the highest values for this indicator were obtained in Toro with 1.69 g and Bluecrop with 1.45 g, which is in accordance with the data of Leposavic (2014), who reported a significantly higher average fruit weight in Nui (1.99 g) and Duke (1.76 g) than the control (Bluecrop) 1.58 g. The minimum weight is registered for fruits of Spartan with 1.02 g and Patriot with 1.12 g. The coefficient of variation is average for Spartan (13.39%) and very high for the other varieties, reaching 51.56% for Bluecrop. Mathematically, the differences between the varieties were not proven, but they were well-proven for the different years ($P < 0.01$) (Table 8).

Like us, Strik et al., (2017) investigated the reproductive potential of ten cultivated blueberry varieties, such as Duke, Bluecrop, Reka, Bluejay, Bluegold, Draper, Legacy, Liberty, Ozarkblue, and Aurora in the US region, and found that Ozarkblue had the largest fruits were on.

In addition to our results for fruit weight comparing different cultivation technologies (high tunnel and black anti-hail net) in highbush blueberry, Smrke et al. (2021) reported fruit weight in the range 1.04 g – 1.17 g (Duke), 1.07 g – 1.63 g (Aurora), and 1.11 g – 1.47 g (Brigita).

Conclusion

The present research is a comprehensive study that evaluates the opportunities of growing five varieties of introduced highbush blueberries (Bluecrop, Bluegold, Patriot, Spartan, and Toro) under semi-mountain conditions in the area of Troyan, based on their vegetative and reproductive characteristics.

From the analysis of the results for the amount of plant pigments (chlorophyll *a* and chlorophyll *b*) in the leaf samples, a tendency to increase the values in the second year can be noticed, as distinctly higher values were registered for Patriot variety.

Comparing the average values of the five high-bush blueberry varieties tested in terms of yield, the best results were found for Toro (103.85 g/bush) and the control – Bluecrop (99.94 g/bush), with very good statistical proof for the different years. The highest average values for fruit size were recorded in the same varieties Toro (1.69 g) and Bluecrop (1.45 g), whereas the smallest were the fruits of Spartan (1.02 g) and Patriot (1.12 g), for the three-year experimental period under the conditions of the Troyan region. From the statistical analyses, it follows that there are no proven differences among the varieties, but there is good proof for the different years ($P < 0.01$). The evaluation of the vegetative and reproductive characteristics of the studied highbush blueberry varieties shows that they can grow successfully in the semi-mountain regions of Bulgaria, and the valuable properties of its fruits could be used as components of food ingredients and healthy foods.

References

Almutairi, K. F., Bryla, D. R., & Strik, B. C. (2017). Potential of deficit irrigation, irrigation cutoffs, and crop thinning to maintain yield and fruit quality with less water in northern highbush blueberry. *Hort Science Horts*, *52*, 625.

Atanasova, S. (2021). Behavior of *in vitro* raspberry plants grown *in vivo* condition. PhD Thesis, Stara Zagora, Trakia University, 48 – 56 (Bg).

Strik, B. C., Vance, A. J. & Finn, C. E. (2017). Northern highbush blueberry cultivars differed in yield and fruit quality in two organic production systems from planting to maturity. *HortScience horts*, *52*(6), 844 – 851.

Celik, H. (2009). Yield and berry characteristics of some northern highbush blueberries grown at different altitudes in Turkey. Proceedings of the Workshop on Berry Production in Changing Climate Conditions and Cultivation Systems in the context of COST – Action 863, Geinsenheim (Germany). *Acta Horticulturae*, 838, 63 – 66.

Cruz de Carvalho, M. H. (2008). Drought stress and reactive oxygen species: Production, scavenging and signaling. *Plant Signal. Behav*., 3, 156 – 165.

Fan-Hsuan, Y., David, R. B., Scott, T. O., Bernadine, C. S. & Yanyun, Z. (2020). Thermal cooling with sprinklers or microsprinklers reduces heat damage and improves fruit quality in northern highbush blueberry. *Hort Sci. Horts*, *55*, 1365 – 1371.

FAOSTAT. Available online: https://www.fao.org/faostat/en/#data/QCL (accessed on 14 September 2022).

Georgieva, V, Kazandjiev, V., Bozhanova, V., Mihova, G., Ivanova, D., Todorovska, E., Uhr, Z, Ilchovska M., Sotirov, D. & Malasheva, P. (2022). Climatic changes – a challenge for the Bulgarian farmers. *Agriculture*, *12*(12), 2090.

Golovinskaia, O. & Wang, C. K. (2021). Review of functional and pharmacological activities of berries. *Molecules*, *26*, 3904.

Hancock, J., Haghighi, K., Krebs, S., Flore, J. & Draper, A. (1992). Photosynthetic heat stability in highbush blueberries and the possibility of genetic improvement. *Hort Science*, 27, 1111 – 1112.

Leposavic, A. (2014). Pomological properties of newly introduced highbush blueberry (*Vaccinium corymbosum* L.) cultivars. PhD Thesis, Novi Sad, University of Novi Sad, 91 – 98 (Sr).

Leposavić, A., Jevremović, D., Vasić, T., Paunović, S. M. & Tomić, J. (2021). Berries in Serbia-current state and prospects. *Journal of Mountain Agriculture on the Balkans, 24*(4), 306 – 323.

Lin, D., Xiao, M., Zhao, J., Li, Z., Xing, B., Li, X., Kong, M., Li, L., Zhang, Q., Liu, Y. & Chen, H. (2016). An overview of plant phenolic compounds and their importance in human nutrition and management of type 2 diabetes. *Molecules*, *21*(10), 1374.

Mingeau, M., Perrier, C. & Améglio, T. (2001). Evidence of drought-sensitive periods from flowering to maturity on highbush blueberry. *Sci. Hortic., 89*, 23 – 40.

Molnar, S., Clapa, D. & Mitre, V. (2022). Response of the five highbush blueberry cultivars to *in vitro* induced drought stress by polyethylene glycol. *Agronomy*, 12, 732.

Nedev, N., Grigorov, Y., Baev, Hr., Serafimov, S., Strandzhev, Al., Kavardzhikov, L., Lazarov, Kr., Nikolov, N., Dzhuvinov, V., Popova, L., Slavov, N., Iliev, P., Stoyanov, D., Kanev, Il., Krinkov, H., Vishanska, Yu., Topchiyska, M. & Petrova, L. (1979). Methods for Studying of Planting Resources of Fruit Crops. Plovdiv, Research Institute of Fruit Growing, 111 – 116 (Bg).

Petridis, A., Kaay, J. V. D., Chrysanthou, E., McCallum, S., Graham J. & Hancock, R. D. (2018). Photosynthetic limitation as a factor influencing yield in highbush blueberries (*Vaccinium corymbosum*) grown in a northern European environment. *Journal of Experimental Botany*, *69*(12), 3069 – 3080.

Redpath, L. E., Gumpertz, M., Ballington, J. R., Bassil, N. & Ashrafi, H. (2021). Genotype, environment, year, and harvest effects on fruit quality traits of five blueberry (*Vaccinium corymbosum* L.) cultivars. *Agronomy*, 11, 1788.

Retamales, J. B. & Hancock, J. F. (2012). Blueberries. Wallingford: *CABI*, 75 – 102.

Smrke, T., Veberic, R., Hudina, M., Zitko, V., Ferlan, M. & Jakopic, J. (2021). Fruit quality and yield of three highbush blueberry (*Vaccinium corymbosum* L.) cultivars grown in two planting systems under different protected environments. *Horticulturae*, 7, 591.

Strik, B. C. & Vance, A. J. (2017). Northern highbush blueberry cultivars differed in yield and fruit quality in two organic production systems from planting to maturity. *Hortscience, 52*(6), 844 – 851.

Wach, D. (2008). Estimation of growth and yielding of highbush blueberry (*Vaccinium corymbosum* L.) cultivated on soil developed from weakly loamy sand. *Folia Horticulturae, 20*(2), 47 – 55.

Yang, F. H., Bryla, D. R. & Strik, B. C. (2019). Critical temperatures and heating times for fruit damage in northern highbush blueberry. *HortScience*, 54, 2231–2239.

Zhao, L. S., Su, H. N., Li, K., Xie, B. B., Liu, L. N., Zhang, X. Y., Chen, X. L., Huang, F., Zhou, B. C. & Zhang, Y. Z. (2016). Supramolecular architecture of photosynthetic membrane in red algae in response to nitrogen starvation. *BBAbioenergetics, 1857*(11), 1751 – 1758.

Received: **February, 01, 2024**; *Approved*: **April, 27, 2024;** *Published:* **August, 2025**