

The influence of the application of fertilizers and bio stimulators on the quality of the fruit of red raspberry (*Rubus idaeus* L.) in the conditions of continental Montenegro

Dejan Zejak^{1,1}, Velibor Spalevic² and Ivan Glišić³

¹University of Montenegro, Center for interdisciplinary and multidisciplinary study, Cetinjski put 2. Podgorica, Montenegro;

²University of Montenegro, Biotechnical faculty, Mihalila Lalića 15, Podgorica, Montenegro;

³University of Kragujevac, Faculty of Agronomy, Cara Dusana 34, 32000 Cacak, Serbia;

Abstract. In the continental Montenegrin mountainous environment of the Lim river valley – Polimlje Region, this multi-year study focused on assessing the impact of foliar nutrition, employing four mineral fertilizer formulations, N:P:K 0:30:20 (foliar nutrient – Trafos K), N:P:K 0:52:34 (foliar nutrient Mono potassium phosphate – Yarra), N:P:K 13:0:46 (foliar nutrient – Krista K plus – Yara), N:P:K 12:52:0 (MAP mineral fertilizer), along with two biostimulators Erel (ethephon) and Kudos® (prohexadione Ca), and a control (without fertilization); all on the quality of berries from two red raspberry varieties, the standard 'Willamette' and new 'Glen Ample' (*Rubus idaeus* L.). Our aim was to enhance raspberry production, striving for increased yields and superior fruit quality, ultimately ensuring the sustainability of raspberry cultivation in Montenegro. The results obtained emphasize the substantial influence of mineral fertilizers and plant growth regulators on various aspects of raspberry cultivation in Montenegro's challenging hilly terrain. By optimizing cultivation practices and improving fruit quality, this research endeavors to make a significant contribution to the sustainable advancement of raspberry production in the region.

Keywords: Red raspberry (*Rubus idaeus* L.), Fertilization, Continental Montenegro, Enzyme activity, Fruit quality, Agriculture

1. Problem definition and background

The research work presented in this paper was carried out in Bijelo Polje, a municipality located in the valley of the river Lim, known as a fruit production region. The Municipality of Bijelo Polje is located in the alluvial region along the main roads and railway Belgrade-Bar (43.04° N 19.75° E).

It is surrounded in the south by the mountain Bjelasica and in the north by Lisa on an area of 924 km². The climate is moderate continental since it is located in a valley-mountainous area with very favorable conditions for diversification in the agriculture and tourism sectors [1]. Northern Montenegro has ideal climatic and agroecological conditions for growing red raspberries. Most of the raspberry plantations from the Polimlje region are located in this area.

¹ Corresponding author: zejakd@gmail.com

Raspberry is one of the most important berry fruit species in Montenegro. In the riparian belt of Polimlje, it grows up to 1500 m a.s.l. and it thrives on all exposures, and in the foothills only in southern, southwestern, and southeastern [2]. Production areas have increased in the last decade and today they cover about 125 ha. [3].

Raspberries contain anthocyanins in high levels [4]. The research conducted in Serbia during the period 2012-2014 determined that soil treatments with organic, organo-mineral, and mineral fertilizers led to changes in berry properties evaluated during three consecutive years, compared with control. Higher content of total anthocyanins, cyanidin-3-sophoroside, cyanidin-3-glucorutinoside, macro- and microelements in berries of cv. 'Meeker' red raspberry and its antioxidant power were found with the application of the organo-mineral fertilizer named Multi Comp Base, followed by Scots, whereas the other two fertilizers (Excel orga and cattle manure) had lower effect but higher in comparison with control treatment (without fertilization). Hence, fertilizers with a balanced NPK content, i.e., water-soluble granulated compound fertilizers, induced better berry properties evaluated [5].

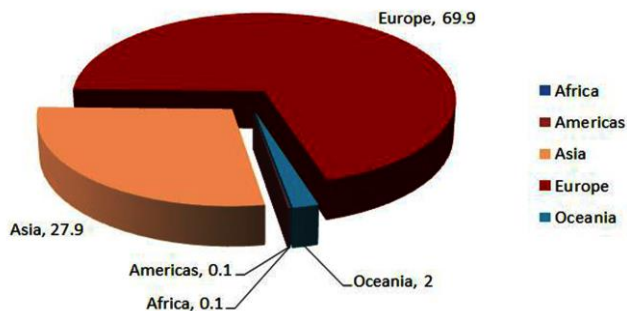
According to the available data for the period from 2015 to 2021, 500 to 600 tons of raspberry fruit are purchased annually in Montenegro.

The existing raspberry (*Rubus idaeus* L.) plantations in Montenegro covered an area of about 159 ha in 2021 year [6], mostly in the valleys of the upper reaches of the Lim and Tara rivers, of which more than 2/3 is in the municipality of Bijelo Polje. It has long been known that red raspberry berries contain high levels of minerals, which are dietary requirements in human nutrition and have various physiological impacts [7].

In Montenegro, with the dominant cultivation of the 'Willamette' cultivar (*fruit intended exclusively for freezing*), the trellis system of cultivation, with the application of mineral fertilizers before the growing season (*March, April*) by plowing along the roots of the plant, whose production is characterized by low fruit yields per unit of land area. The average yield of raspberries per hectare in the 1960s in Yugoslavia was 5-6000 kg [2].

2. Research methodology and our progress

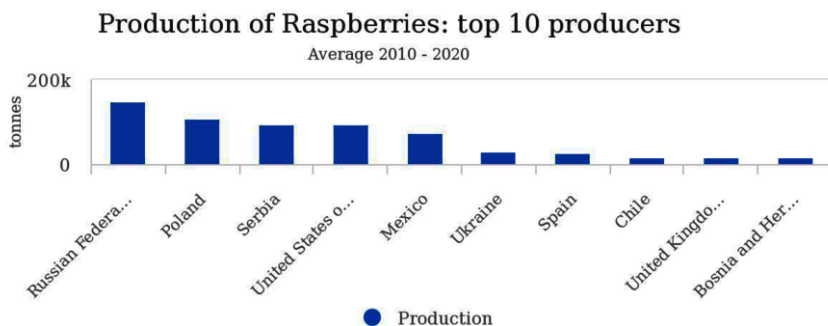
The process of systematic research (*data collection, documentation of information, analysis, and data interpretation in accordance with the appropriate methodologies*) of the cultivation of berry fruits in the mountainous area of Montenegro (*raspberries, strawberries, blueberries, blackberries, currants*) with appropriate physical and geographical characteristics (*geological, soil and climatic*), with an established system of purchase and storage, and a long-standing tradition of growing these crops (*over 33% of residents live in rural areas; the first raspberry plantations were established in the middle of the last century in Montenegro*) and an organized market (*possibility of selling in the coastal area during the tourist season, the possibility of exporting frozen fruits to EU countries and globally*), without recording significant results expressed in the needs of the local market and the quantities projected for export.



Source :<https://www.fao.org/faostat/en/#data/QCL/visualize>

Figure 1. Share of raspberry production by world region for the period 2010-2020.

Figure 1. shows the share of raspberry fruit production regions for the observed period from 2010 to 2020. Europe leads the way in raspberry production with a share of 69.9% of world production. Average production in this period in Europe was 496,721.45 tons, followed by America with 27.9% or 198,397.93 tons, Asia with 2% or 14,215.91 tons, Africa with 0.1% or 319, 18 tons and Oceania with 0.1% or 753.64 tons [6].



Source: FAOSTAT (Mar 12, 2022)

Source :<https://www.fao.org/faostat/en/#data/QCL/visualize>

Figure 2. The world's ten largest raspberry producers for the period 2010-2020.

Figure 2. shows the ten largest raspberry producers in the world for the period 2010-2020. years. The leader in fruit production is the Russian Federation with an average of 148,136.36 tons, followed by Poland with 100,111.18 tons, third is Serbia with 96,344.18 tons, while the USA produces 95,713.18 tons, followed by Mexico with 74 770.55 tons, Ukraine which produces 31 531.82 tons, Spain with 26 662.91 tons, Chile with a production of 16 899.64 tons, Great Britain 16 109.91 t and finally the tenth place belongs to Bosnia and Herzegovina with average 15,324.64 tons for this period. [6].

Many studies worldwide have dealt with the influence of different factors on the content of primary and secondary metabolites in the fruits, including raspberry [5].

Raspberry fruit has a complex nutritional composition (Table 1). Fruits are rich in water and carbohydrates, which are the building and energy components of the fruit. The most

important sugars in the raspberry fruit are monosaccharides, glucose and fructose, while sucrose is represented in a significantly smaller amount [8].

Raspberry fruit contains certain amounts of vitamins. Vitamin C is the most common vitamin. Raspberry fruit contains small amounts of ash (about 0.5%), and potassium is the most abundant mineral [8,9]. Fatty substances, i.e., lipids, are found in raspberry seeds. In addition to the mentioned nutrients, the raspberry fruit also contains significant amounts of functional compounds with pronounced biological activity (phytochemicals): phenolic acids, flavan-3-ol, anthocyanins, and ellagitannins. Such a wide spectrum and high content of nutrients and phytochemicals make raspberry a functional food.

Table 1. Average basic chemical composition of raspberry fruit per 100 g of fruit (USDA National Nutrient Database www.ars.usda.gov)

Ingredient	Unit	Content
Water	g	85,75
Protein (Total)	g	1,20
Fats	g	0,65
Carbohydrates (Total)	g	11,94
Monosaccharides	g	4,21
Disaccharides	g	0,2
Dietary fiber	g	6,5
Energy value	kcal	52

By introducing innovative - new varieties of raspberry ('Glen Ample', the leading variety in the UK and increasingly popular in the EU), which are intended for both freezing (as with the already existing varieties - 'Willamette' (Fig.3)), and processing and fresh use of fruits with the use of new varieties 'Glen Ample' (Fig.4)), with the application of new recipes of mineral fertilizers (in addition to the previously applied early fertilizing - March, April, now) and after harvest through the foliar top dressing of raspberries, higher yields in the next season and better fruit quality would be achieved, thus ensuring the sustainable development of farms that grows berries in Montenegro, at the same time with further development of this sector in accordance with the existing prerequisites and requirements of both: the local and international markets.



Fig.3. 'Willamette'



Fig.4. 'Glen Ample'

3. Future works

In the experimental raspberry plantations in the river Lim basin, Bijelo Polje, Montenegro, with the standard variety 'Willamette' and the newly grown raspberry variety 'Glen Ample', we are applying different concentrations and different types of mineral fertilizers and plant stimulators after the fruit harvest (September-October):

- N:P:K 0:30:20 (foliar nutrient Trafos K);
- N:P:K 0:52:34 (foliar nutrient Mono potassium phosphate - Yarra);
- N:P:K 13:0:46 (foliar nutrient Krista K plus - Yara);
- N:P:K 12:52:0 (MAP mineral fertilizer);
- Etrek (ethephon);
- Kudus® (prohexadione Ca);
- Control.

The specific objectives of the research can be summarized as follows:

- To study the influence of different mineral fertilizers and biostimulators on the phenological characteristics of raspberry varieties in the mountainous area of Montenegro.
- To analyze how the application of four mineral fertilizers of different formulations and two plant growth biostimulators affect the quality of raspberry fruits in local growing conditions.
- To examine the influence of four mineral fertilizers and two plant growth biostimulators on the enzymatic activity of raspberry varieties.
- Evaluation of the nutritional value of plant residues of raspberry fruit after fruit processing.

With these researches, and by applying standard verified methods of monitoring the vegetation of two raspberry varieties, as well as by analysing the fruits from the experimental plantation during the years of testing (consecutive years) with seven different treatments (four fertilizers, two stimulators and a control) in authorized specialized laboratories (University of Belgrade - Laboratory of the Faculty of Agriculture and University of Kragujevac -

Laboratory of the Faculty of Agronomy) proved the influence of different applications of new concentrations and types of mineral fertilizers on: (1) variety, (2) phenology, (3) fruit quality, (4) enzyme activity, (5) the nutritional value of the plant remains of the raspberry fruit after fruit processing.

4. Conclusion

In conclusion, this ongoing research in the raspberry plantations of the Lim river basin - Polimlje has the potential to provide valuable insights into the impact of various mineral fertilizers and plant stimulators on raspberry cultivation in the challenging Montenegrin mountainous terrain.

The multi-year trials aim to shed light on the phenological characteristics, fruit quality, enzymatic activity, and nutritional content of residual raspberry plant material post-processing. By leveraging well-established monitoring methods and conducting comprehensive analyses in specialized laboratories, this research seeks to confirm the influence of different fertilizer and stimulator applications on variety, phenology, fruit quality, enzymatic activity, and nutritional value.

Ultimately, the findings have the potential to drive innovation and sustainability in raspberry production within Montenegro, fostering the growth of this vital agricultural sector in the region.

References

- [1] <https://www.bijelopolje.co.me>
- [2] Jovančević, R. (1970). Godišnji ciklus razvitka i produktivnosti nekih sorti malina, *Poljoprivreda i šumarstvo*, 16, (3), 25-37.
- [3] Galić, D., Vidaković, Z., Nikolić, M. (2012). Raspberry breeding in Montenegro. *Acta Horticulturae*, 946, 151–155. doi:10.17660/actahortic.2012.946
- [4] Rimpapa Z.; Toromanovic, J.; Tahiroovic, I.; Šapcanic and Softic, E. (2007). Total content of phenols and anthocyanins in edible fruits from Bosnia. *Bosnian J. Basic Med. Sci.* 7 (2): 119– 122.
- [5] Stojanov D.; Milosevic T.; Maskovic P. and Milosevic N. (2019). Impact of fertilization on the antioxidant activity and mine l composition of red rasspberry berries of cv. 'Meeker'. *Mitteilungen Klosterneuburg* 69 (3):184-195.
- [6] <https://www.fao.org/faostat/en/#data/QCL/visualize>
- [7] Nile, S.H. and Park, S.W. (2014). Edible berries: bioactive components and their effect on human health. *Nutrition* 30 (2): 134–144.
- [8] Mišić, P. (2000). Malina. *Poljoprivredna biblioteka, izdanje „Draganić“*, Beograd.
- [9] Nikolić, M., Milivojević, J., (2010). Jagodaste voćke – Tehnologija gajenja. *Naučno voćarsko društvo Srbije, Čačak*.



Dejan Zejak is a PhD student at the University of Montenegro Department of Sustainable Development. Graduated in 2003 from the Faculty of Agronomy, department of general agronomy at the University of Kragujevac. In 2010, he completed his master's degree in organic agriculture at the Faculty of Agriculture, University of Novi Sad, Serbia. So far, he has published more than 30 scientific papers, 6 of which are in the SCI and 2 in the SCOPUS database recorded. With the international research teams, he published 6 monograph-type publications on the subject of agriculture and green economy. Managed several international projects funded by international organizations. Member of two working groups for the preparation of the Strategies for the Development of Agriculture and Rural Areas of Montenegro (2014-2020 and 2022-2028). Member of the Commission for monitoring of the IPARD Program. Member of several working groups of the Government of Montenegro for drafting laws. Chairman of the Regional Council for Berries, Serbia, Bosnia and Herzegovina and Montenegro. He has more than 20 years of professional experience in agriculture. He is currently working as a chief engineer for the production of fruit planting material in the Biotechnical Center in Bijelo Polje, Montenegro.