**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**

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**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 Etrel (ethephon) and Kudos®

(prohexadione Ca), and a control (without fertilization); all on the quality

of berries from two red raspberry varieties, 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

endeavours 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**

Studied area belongs to the mountainous part of Montenegro and is characterised with the presence of deep valleys incised into limestone ranges. It is rather hilly and underlain by Palaeozoic rocks. The highest peaks of Montenegro are found in this region, including Komovi (2487 m a.s.l.) and Zla Kolata (the highest peak of Montenegro, 2535 m a.s.l.) in the Prokletije Mountains. The rivers in this region drain to the Black Sea, and some of them form deep canyons crossing limestone formations. Further downstream, the River Lim and Tara form broad valleys flowing through softer Palaeozoic material [1–5].

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The research work presented in this paper was carried out in Bijelo Polje, a municipality located in the valley of the river Lim, which is known as a region for fruit production. 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 has been framed on the south by the mountain Bjelasica and on the north by Lisa at the area of 924 km2. The climate is moderate continental, since it has been located at the valley-mountainous area with very favourable conditions for the development of many branches of agriculture and tourism [6].

Northern Montenegro has ideal climatic and agro ecological conditions for growing red raspberries. Most of the raspberry plantations from the Polimlje region are in this area. Raspberry is one of the most important types of berry fruits in Montenegro. In the parish belt of Polimlje, it grows up to 1500 m a.s.l. and it thrives on all exposures, and in the foothills only on the south, southwest and southeast [7]. Production areas have increased in the last decade and today there are about 125 ha. [8].

Growing raspberries in the north Montenegro has been increasing and is greatly contributing to the development of the region. The 'Willamette' variety dominates the production and, over the last decade, the 'Meeker' variety, as well as some new varieties, most notably, **‘**Tulameen**’**, **‘**Fertȍdi Zamatos**’** and ‘Glen Ample’ have broadly expanded [9]. Raspberries contain anthocyanins in high levels [10]. In the research conducted in Serbia during the period 2012-2014, it was determined that, soil treatments with organic, organo

mineral and mineral fertilizers led to changes in berry properties evaluated during three consecutive years when compared with control. e 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) induced lower impact but higher in comparison with control treatment (without fertilization). Hence, fertilizer with balanced NPK content, i.e. water-soluble granulated compound fertilizers, induced beer berry properties evaluated [11].

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

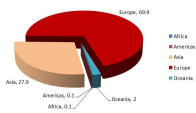
The existing raspberry (*Rubus idaeus* L.) plantations in Montenegro cover an area of about 159 ha in 2021 year [13], being mostlz in the valleys of the upper reaches of the Lim and Tara rivers of which more than 2/3 is in the municipality of Bijelo Polje. It has been long known that berries of red raspberry contain high levels of minerals which are dietary requirements in human nutrition and have various physiological impacts [12].

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 ploughing 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 sixties of the last century in Yugoslavia was 5-6000 kg [7].

**2. Research methodology and our progress**

The process of systematic research (*collection of data, documentation of information, analysis and interpretation of data in accordance with the appropriate methodologies*) of the cultivation of berry fruits in the mountainous area of Montenegro (*raspberries, strawberries, blueberries, blackberries, currants*) that have appropriate physical and geographical characteristics (*geological, soil and climatic*), with an established system of

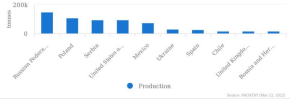
purchase and storage, and a long-standing tradition of growing of these crops (*over 33% of residents live in rural areas; the first raspberry plantations were established in the middle of the last century in Montenegro*) and an organized market (*possibility of selling on coastal area during the tourist 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*

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

Graph 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 [13].

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

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

Graph 2 shows the ten largest raspberry producers in the world, for the period 2010- 2020. years. The first 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. [13].

Many studies around the world have dealt with the in uence of diff erent factors on the content of primary and secondary metabolites in the fruits, including raspberry [11].Raspberry fruit has a complex nutritional composition (Table 1). Fruits contain a lot of water, 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 [14]. 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

[14,15]. 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 makes 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.1)*), and processing and fresh use of fruits with the use of new varieties *‘Glen Ample’ (Fig.2)*), 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 1 ‘Willamette’ Fig 2 ‘Glen Ample’**

**3. Future works and conclusion**

In the experimental raspberry plantations in 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);

− Etrel (ethephon);

− Kudos®(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 affects 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 analyzing 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.

In conclusion, this ongoing research in the raspberry plantations of the Lim river basin - Polimlje has the potential of 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.

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