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ORGANIC AGRICULTURE AT HIGH ALTITUDES: EXPERIMENTAL ORGANIC GARDEN IN ILOVICE, BOSNIA AND HERZEGOVINA

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ABSTRACT

Agriculture at high altitudes is a challenge, especially in terms of organic vegetable production. In mountainous regions, most of the arable land is at high altitude, which significantly affects agricultural production, limiting the number of crops. This research was carried out in order to verify the possibility of growing a wide range of vegetables and herbs in these regions. The experimental plot (4500 m^2) was formed in the village Ilovice (municipality Trnovo, Bosnia and Herzegovina), at 950 m above sea level. After the analysis of the soil fertility, the organic production of vegetables, some spices and medicinal herbs was designed in the open field, without additional fertilization. Some typical Mediterranean species, such as artichoke and kale, were also planted. Some of the most important principles of organic agriculture - beneficial organisms, companion crops and intercropping - were fully met in the garden. Finally, although the production on the experimental plot took place at high altitudes, the health of plants, the appearance of fruits and the yield, confirmed the possibility of successful organic vegetable production in such regions. In addition, the experimental organic garden in Ilovice is a place for practical education of those interested in organic agriculture. This is of great importance for conducting applied research, acquiring new knowledge and helping producers to promote organic agricultural production, especially in less developed regions. To the best of our knowledge, this is the first study that carried out in Bosnia and Herzegovina, where the possibility of growing a wide range of plant species, at such high altitudes, has been practically verified.

Keywords: *Organic agriculture, high altitude, environmental education, mountain farming.*

INTRODUCTION

The most intensive agricultural production is carried out in the plain up to 200 m above sea level, as well as on terrain up to 600 m. Climatic conditions enable diverse agricultural production, while hilly and mountainous areas are suitable for fruit production. Above this height, there is a decrease in the number of crops that

can be grown, there are less cultivable areas and yields are lower. At altitudes above 1000 m (hilly-mountainous areas), the configuration of the terrain is even more unfavorable for the development of farming. This represents a transition zone between the fruit and grass belt (Lazić et al., 2014). At higher altitudes, light intensity is greater, the utilization of solar radiation is higher and spectral light composition is altered. Also, with an increase in altitude, temperatures decrease, and the amount and frequency of precipitation increase. Another important factor at high altitudes is the thinness of the atmosphere, and as a consequence, water evaporates faster from the ground.

In Bosnia and Herzegovina, mountainous areas account for 35% of agricultural land (Volk, 2010). These areas have short summers, with temperature up to 35 °C, and long harsh winters. Dominant in those regions are sheep farming, potatoes production, cereals, fodder plants, medicinal herbs, mushrooms and forest fruits (Lazić et al., 2014). Agriculture, and especially organic vegetable production, under these conditions represents a real challenge. However, unpolluted land and water are the most important potential of these regions for organic agriculture. As these are often the least developed regions, the additional value represents a possibility of economic development and reduction in the unemployment rate. Hence, organic farming can play an important role for socio-economic development and to make villages self-sustainable. Degradation of environmental quality and food safety concerns due to excess use of fertilizers and pesticides promoted organic farming in recent decades (Mishra et al., 2015).

In Bosnia and Herzegovina, only 3.9% of arable land is under vegetable production, including potato as a dominant crop (Kaba, 2017); in Sarajevo region it is 1.41% (Kaba 2014). According to the available literature, number of crops and vegetables that can be grown at higher altitudes is significantly limited, mainly to cereals (Plećević, 1985). In order to provide better conditions, vegetable growing is recommended in greenhouses or other indoor places. Also, vegetables that require a growth stage before producing seeds and fruits (tomatoes, zucchini, peppers, green beans) require more time and therefore are more risky.

This research was carried out in order to evaluate the possibility for organic production of a wide range of vegetables and herbs at high altitudes.

MATERIAL AND METHODS

The experimental field was formed on an area of 4500 m^2, in the village of Ilovice, municipality of Trnovo (Bosnia and Herzegovina), on the southern slopes of Jahorina mountain, at 950 m above sea level (Figure 1). In this garden, agricultural production has not been implemented for the last 50 years, and pesticides and fertilizers have not been applied. In order to start organic production on a particular land, it is necessary to adequately clear it and prepare it for healthy, organic production. By clearing and plowing, the completely grounded land has been turned into a field with crushed land suitable for agricultural production (Figure 2). A reduced soil tillage was applied, which did not deteriorate the soil characteristics but contributed to the improvement of fertility.

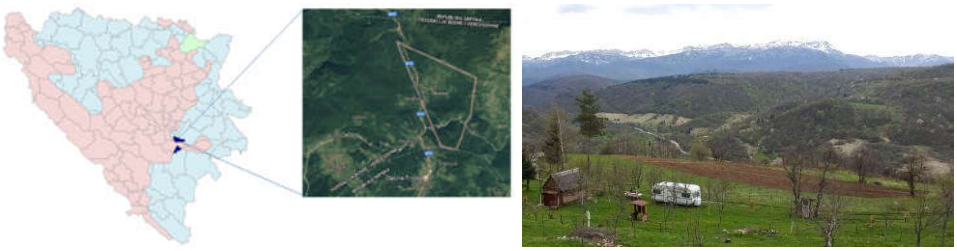

Figure 1. Geographical position of the experimental field
Source: *GoogleMaps;* photo*: D. Močević*

Before the agricultural production, the soil fertility and chemical properties of the surface soil layer from a depth of 0-30 cm were determined. The pH value (ISO 10390: 2005), $CaCO_3$ content (ISO 10693: 2005), total N (ISO 11261: 1995), humus content, P_2O_5 and K_2O content were determined. For the analysis, the standard methods were applied. At the location of the experimental field, weather conditions were monitored; during the growing season (May – October) the average temperature was 16.5 °C, while the precipitation ranged from 80 to 120 mm (Federal Hydrometeorological Institute, B&H).
On the experimental garden in Ilovice, the organic production of vegetables (cherry tomato, pepper, potato, eggplant, onion, garlic, parsley, carrots, white radish, asparagus, green beans, cucumbers, red beet, celery, pumpkin varieties hokkaido and stambolka, zucchini), as well the cultivation of spices and medicinal herbs (basil, dill, fennel, lemon balm) was planned. Some typical Mediterranean species, such as artichoke and kale, were sown/planted, as well. Only certified organic seeds were used, while vegetable and herb seedlings were obtained from the certified organic producer "PPI Ahmići", Vitez.
The geographical position, climate and altitude in such areas led to the postponement of the beginning of the agricultural season. Due to late frosts, sowing/planting was carried out in the period 15 - 30 May.
Agricultural production started in the beds (200 × 100 cm) and in the open field (Figure 2), without additional fertilization. For irrigation, only spring water was used, and in the beds and in the field there was a drip irrigation system.

Figure 2. The experimental field 'before and after'
(photo: D. Močević)

RESULTS AND DISCUSSION

Immediately before agricultural production, the soil fertility was determined (Table 1). Soil fertility is fundamental in determining the productivity of all farming systems, and it is most commonly defined in terms of the ability of a soil to supply nutrients to crops (Watson et al., 2002). The soil on the experimental field is of a poorly acidic reaction, as such it is suitable for growing vegetables. Humus content of 5.27% indicates good soil quality, while the amount of total nitrogen shows that content of this element in soil is sufficient. The soil on the field on which the organic production of vegetables was started is poorly phosphorous, but with a very significant amount of potassium.

Table 1. Chemical properties of soil on experimental plot

pH	6.67
$CaCO_3$	0%
Humus content	5.27%
Total N	0.33%
Available P	4.28 mg/100 g
Available K	41.55 mg/100 g

When weather conditions allowed, in the second half of May, sowing, i.e. planting of the vegetables and herbs, started (Figure 3). As organic production always implies growing of more crops at the same time, the appropriate choice of plants species and varieties, adapted to agroecological conditions, must be made (Filipović et al., 2010). Although, referring to the time of sowing/planting, vegetation was delayed, as early as the beginning of August the first fruits began to ripen. At the end of August and during September, the garden was rich in fruits (Figure 4 and 5). All plant species formed healthy fruits, and the yield was well above the expected. The production of vegetables such as zucchini, peppers, cherry tomatoes, green beans at high altitudes is risky however, in the garden in Ilovice these plants kept giving fruits until the appearance of stronger frosts.

The most suitable species for these agroclimatic conditions is definitely potato; high yields and healthy fruits have been achieved with the complete absence of its most significant pests, colorado potato beetle (*Leptinotarsa decemlineata* Say.).

Figure 3. The experimental organic garden in June and August (photo: D. Močević)

During August, the first fruits of tomatoes, peppers, hot peppers, potatoes and onions were picked. Expectedly, red beet had also a very good yield, as it is easily grown and tolerant to cold weather. However, pumpkins and zucchini, that require higher temperatures, also provided an extraordinary yield in the organic garden in Ilovice. Green beans, a plant of warmer areas, gave a particularly good yield. It is also known that at temperatures above 35°C and less than 6°C green beans lose flowers (Lazić, 2008). However, by selecting the appropriate varieties, at an altitude of almost 1000 m, a good yield and healthy fruits were obtained (Figure 5). The eggplant is also a species of warm climates; on the experimental plot, growing in the beds, healthy fruits were formed at the end of September (Figure 4).

Figure 4. Healthy fruits grown in organic garden in Ilovice (photo: D. Močević)

As a special part of this research, artichoke was planted. *Cynara scolymus* L. (artichoke) is a plant originating from the Mediterranean (Reolon-Costa et al., 2015), and requires specific growing conditions. It is a perennial plant, but in colder regions it is grown as an annual plant. Artichoke was planted at the end of May in the open field, on a sloping terrain, with a distance of 1 m between rows and among plants, and a drip irrigation system was applied (Figure 4). When it comes to cultivating artichokes, irrigation was paid extraordinary attention, as due to the terrain configuration, the plants are often suffocated. At the end of September, in the experimental garden in Ilovice, flower developed on healthy plants of artichoke (Figure 4).

Figure 5. The experimental field in September (photo: D. Močević)

The typical brassicae of the coastal and island areas, kale (*Brassica oleracea* L. *var. acephala* DC) was grown at almost 1000 m above sea level, in the organic garden in Ilovice. A slightly forgotten vegetable, recently kale has increased popularity, as a result of its high nutritional properties (Batelja et al., 2009, cit. Dumičić et al., 2014). Among all the brassicas, it is the richest in carotene, provitamin A and Ca, especially its older leaves (Lefsrud et al., 2007). In kale cultivars, the content and amount of secondary metabolites vary significantly depending on endogenous developmental factors such as genetic expression and protein modification, as well as environmental conditions (Jeon et al., 2018). The cultivation of kale in colder climates increases their quality; anthocyanin accumulation in purple kale is strongly induced by cold, the total anthocyanin content of purple kale exposed to cold was approximately 50-fold higher than those of plants grown in a greenhouse (Zhang et al., 2012).

In Ilovice, Jerusalem artichoke (*Helianthus tuberosus*) was also planted in the open field. This species, also known as wild potato, represents a healthy alternative to potatoes, given the high content of inulin polysaccharides. Tubers contain inulin instead of starch and sucrose found in most other tubers. In addition to the high levels of inulin in the tubers, Jerusalem artichoke is also regarded as a good source of soluble and insoluble fiber (Terzić and Atlagić, 2009; Saengkanuk et al., 2011). Above-ground parts of the plant can be used as animal feed. Jerusalem arthichoke was planted from tubers in May, while the first broods were harvested in October (Figure 5).

During the second half of May, the cultivation of spices and medicinal herbs (lemon balm (*Melissa officinalis* L.), fennel (*Foeniculum vulgare* Mill.) and sweet basil (*Ocimum basilicum*)) was started (Figure 5). Lemon balm and sweet basil were planted in the field, and fennel in the beds. The first picking of lemon balm was in mid-August, and after drying, this plant has been used for tea production.

Figure 6. Jerusalem artichoke, kale and lemon balm in the organic garden in Ilovice (photo: D. Močević)

Production at the organic garden in Ilovice was conducted respecting very important principles e.g. beneficial organisms, companion crops, intercropping. In order to attract useful insects that contribute to plant production by pollination (bumblebees, bees and axes) and suppression of harmful insects (ladybirds, spiders, mantises), on the field were grown sunflower, fennel, marigold, dill, basil and

lemon balm. On the farm, i.e. on the field next to the garden, buckwheat was also grown in organic production, which additionally attracted useful insects.

Plant species were cultivated in line with the system of compatible species, which by mutual action support growth and development, play a role of protection from the causal agents of diseases and pests (Lazić, 2008). In the garden, according to this principle, parsley and white radishes, blue eggplant and marigold, and sunflower near cucumber, were cultivated.

Since it is a natural repellent, basil was considerably present in the garden. It was sown close to tomatoes and peppers, because these species shade basil, which postpones flowering, prolongs the picking and increases yield, while on the other hand, basil repels lice that lay eggs in the fruit of tomatoes and peppers. Basil was also useful in protecting cucumber and tomatoes from the attack of powdery mildew, and as a repellent of trips, flies and mosquitoes.

When it comes to plant protection, on the experimental garden in Ilovice, with the exception of mechanical weed removal, other measures, including bio-pesticides, were not applied. This was achieved using healthy plant material and appropriate resistant varieties, crop rotation, time of sowing/planting, but also by the fact that the production took place at 1000 m. At this altitude, the pressure of harmful agents is significantly reduced, and given the long and cold winters, there is no possibility of survival of their forms in the soil or old plant parts.

This study has shown that, even at high altitudes, there is a potential for the successful organic agricultural production and growing of many different vegetable varieties. In order to achieve this, one of the most important factors is the geographical position and slope of the garden. Due to the generally small fields in mountain regions, organic vegetable production is an appropriate option for the development of family farms. Often, in such regions, agriculture represents the only possibility for the economic development and unemployment reduction.

The additional and very important value of this experimental garden is the practical education of those interested in organic agriculture. Under education, it is generally assumed the acquisition of theoretical knowledge, but when it comes to agricultural production, practical advisory work is required (Filipović and Ugrenović, 2009). As organic production requires a high level of knowledge from different fields, and education plays a crucial role, organic farm in Ilovice serves as a trial field for practical training (Figure 1).

Furthermore, UNDP, UNICEF, and UNESCO, in partnership with the Presidency of Bosnia and Herzegovina, financed the "Organic Peace Building" program, within the project "Dialogue for the Future". This project aimed to link and educate young and unemployed people through education and promotion of organic production of healthy food in underdeveloped areas at high altitudes, such as the municipality of Trnovo. Within the project, in the course of several months, "Small School of Organic Agricultural Production" was realized at the experimental organic garden in Ilovice. Through a theoretical and practical part of the teaching, training provided knowledge on the basics of organic agricultural production for fifty participants, primarily young unemployed persons (Figure 6).

Figure 7. "Small School of Organic Agricultural Production" at the experimental organic garden (photo: D. Močević)

CONCLUSION

In the garden in Ilovice, the basic principles of organic agricultural production were fully met i.e. principles of health, ecology, fairness and care (IFOAM). Although the production on the experimental plot took place at altitude of almost 1000 m, results confirmed the thesis about the possibility of successful realization of organic vegetable production, including spice and medicinal herbs, in such regions. In addition, such experimental gardens are of great importance for conducting applied research, acquiring new knowledge and giving recommendations to producers, to promote of organic agricultural production. Above all, this research had the aim to point out to the possibility for successful organic farming, even in the mountain regions of Bosnia and Herzegovina. To the best of our knowledge, this is the first study that carried out in Bosnia and Herzegovina, where, unlike the assessment of the potential for organic agricultural production based on statistics and available literature data, the possibility of growing a wide range of plant species, at such high altitudes, has been practically verified.

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