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Organic Production of Horseradish (*Armoracia rusticana* Gaertn., Mey., Scherb.) in Serbian Metropolitan Regions

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Abstract

This article shows complete data of the means to grow ″organic horseradish″ in open field conditions in serbian metropolitan regions. In developed countries demand for organic productions grows, day in day out. That means that these cultures must be produced without appliance of additives, mineral fertilizers, pesticides, different hormones, and especially herbicides, that may biologically misbalance production environment. That's why it is necessary to find the way and develop methods to produce medically clean food and to preserve natural resources. Horseradish is one of the ideal cultures for this kind of production.

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Keywords: horseradish, organic production, cuttings, competition, calculation production;

Introduction

Intensive production on farms and large areas of fertile soil in metropolitan areas provides a large portion of fresh meat, milk, fruits and vegetables for urban markets and retail chains, as well as cereals, industrial and forage crops for livestock feed, food industry and export (Popović et al., 2013). It is necessary to strictly control the further occupation of fertile land for non-agricultural purposes through legal regulation and harmonisation of spatial and agricultural policy (Nica and Potcovaru, 2014), with the involvement of local stakeholders. In this respect, the

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situation is particularly acute in the suburbs of large cities, especially in Belgrade (Popović and Živanović Miljković, 2013).

Sustainable agriculture has a particularly significant role in the sustainable development of cities (Glac, 2014) and the establishment of a new development balance between the urban and the rural. Urban agriculture contributes: (1) to the shortening of the chain of production and of the process of food market placement, (2) to the increase of its health safety (Popescu, 2014) and quality, (3) to the reduction of production expenses, (4) to the conservation of natural resources and environmental protection, (5) and to the growth of employment and poverty reduction, especially of women and socially marginalised groups (Koplyay et al., 2014) of the population in suburban areas. Urban agriculture contributes to the shortening of the chain of production and of the process of food marketing (Nica, 2014), to the increase of its health safety and quality, to the reduction of production expenses, to the conservation of natural resources and environmental protection, and to the growth of employment and poverty reduction (Dan, 2014), especially of women and socially marginalised groups of the population in suburban areas (Popović, 2009). Urban agriculture has serious positive and negative influences that stipulated ecological goals. It can be located within (intra-urban agriculture) the build-up city, ie metropolitan area, or on its periphery (peri-urban agriculture) and implies the presence of various production systems and a range of public urban gardens and agricultural enclaves in the areas of Intensive, conventional and/or organic production on family holdings and large commercial farms, depending on ecological, economic and social space capacities (Mijajlović and Popović, 2011). Organic production of grain and industrial crops for processing, as well as of organically produced fruits and vegetables, honey, and medicinal plants and spices have good sales prospects in metropolitan market niches. But, small organic family farms, poorly equipped and insufficiently integrated into the value chain (Boling et al., 2014), still generate low profits that discourage new entrants to the sector. Most of the produced organic products (about 90% of them) are exported, mainly in the EU. Domestic demand is concentrated in the metropolitan areas of Serbia (Filipović et al., 2013). According to the statistics by the National Association for the Development of Organic Production "Serbia Organica" (NASO, 2013), in large cities, mainly due to the market placement of fresh vegetables and imported goods, there is a trend of the increase in their consumption and consumer awareness of "healthy" diet. The size of the domestic market (Misra and Mohapatra, 2014) is also limited by the asortment variety and insufficient quantity of products offered.

Therefore, the aim of this paper is presenting environmental, technological and economic feasibility (Mccahery and Vermeulen, 2014) of growing horseradish by organic production methods and the opportunities for the market placement of its fresh and processed root in metropolitan area markets of the Republic of Serbia.

Nowadays, horseradish is increasingly grown in an industrial manner as a perennial, but also, as an annual plant. Most of it is grown in Europe, North America and Russia. The world's largest producers of cultivated radish are: Russia (about 5,000 ha), USA (about 3,500 ha), and, in Europe, those are Latvia and Ukraine. The yields of pungent root vegetables are in direct correlation with agro-techniques and agro-ecological conditions, and usually have a limit of 15 to 26 t ha^{-1}. In the USA, it is estimated that 11,000 tons of horseradish is annually grown for the production of approximately 27 million kilograms of processed horseradish. The need for horseradish is increasing, primarily, because of its multiple nutritional and medicinal effects.

It is believed that horseradish originates from South-Eastern Europe and Western Asia, where, even nowadays, one can meet its wild ancestors. However, it is typically considered to be a Russian medicinal plant species, for it had not been grown in other European countries for a long while. Even 1,500 years before Christ, Egyptians knew about it, and Greeks used it against pains in the back and as an aphrodisiac. In the 14th century, Germans started to grow it, and in the 16th century, the French and the British, who grew it only as a medicinal plant. Because of certain similarities in the taste of horseradish and radish itself, this medicinal plant used to be equalised. Hence the following proverb: "A horseradish is no sweeter than a garden radish." In the descriptions of the court meals from the 16th century, horseradish is said to be served as an irreplaceable spice with aspic and various grilled meals.

Pharmacopoeias of some countries prescribe horseradish root Armoraciae radix as an officinal drug. Horseradish has antibacterial and antiseptic properties. It is an effective diuretic, digestant, expectorant, antibiotic, antiseptic, carminative, laxative, rubifaciens and stimulant. Studies have shown that horseradish displays inhibitory effects on colon cancer and stomach cancer (Savić and Popović, 2008). Because of its medicinal effects, it is increasingly being used to treat respiratory tract, gastritis, rheumatism, festering wounds, sciatica and pleurisy. Horseradish is a high-energy plant, which, by its chemical composition, resembles the black mustard, contains sinigrin, a crystalline glucoside which decomposes in the presence of water, under the influence of mirosin, an enzyme that is also located

in the root, the main product being a volatile oil, allyl isothiocyanate, which is identical to that of the black mustard seed (Vučetić et al., 1994). This volatile oil becomes by grinding the fresh root. It does not actually exist in the root, and the reaction cannot take place under normal conditions, because sinigrin and mirosin exist in separate cells, and only under the influence of grinding do they get in contact. It also has a beneficial effect on blood vessels and blood pressure. Diluted horseradish juice is used in therapy in the treatment of periodontal disease (Coleman, 1995). In the medicine of certain countries, it is described as an agent that increses potency. As a prevention of colds, it is used with garlic and echinacea, acting on the immune system of man. A high percentage of allyl isothiocyanate allows the antimicrobial activity of horseradish that has been proven in agriculture, in its mutual relations with other plants. It has also been used as an antiseptic, diaphoretic, diuretic, stimulant and an agent against worms, scurvy, ulcers, venereal diseases and cancer. These features are there in horseradish owing to sinigrin content.

Horseradish occurs as an ingredient in many products in supermarkets and specialty food stores. In addition to the most popular lightly processed horseradish, there are a number of other products from horseradish, including spread with horseradish, sauce with horseradish, beetroot with horseradish and dehydrated horseradish. Sauce, mustard and many other sauces, dressings and spreads also contain horseradish. Lightly prepared horseradish is grated (fresh) root of horseradish mixed with „distilled“ vinegar. For a milder taste, vinegar is added immediately. Can also include Other ingredients or condiments (salt, sugar, cream or vegetable oils) can also be added, in order to increase or preserve the taste. It is used as an addition to meat, hot and cold appetisers, and as a sauce for seafood specialties.

In the system of organic production horseradish has taken its place in crop rotation, in plant protection as a bioagent and outstanding competitor. For instance, in the shape of integral plant protection, in potato pest management, it is used as protection against the Colorado potato beetle in the fight against bedbugs on potatoes. Also, in the production of potato, it affects the obtaining of healthier tubers, and, in the growing of cherry, it prevents the occurrence of monilia, a disease that causes fruit rotting.

Growing conditions and morphological properties

Horseradish is a long-day plant, whose favourable conditions are those of moderate climate, with average rainfall for such regions. In the climate conditions in this country, the root tolerates low temperatures and does not freeze at lower temperatures. Sunny positions with a large amount of moisture are favourable to it. According to the content of soil moisture, soils with 70% humidity suit it most. On the occasion of large fluctuations of moisture in soil and air, the whole plant becomes very sensitive. The areas with cold winters provide the needed rest period for roots, and long summers make favorable conditions for their growth. The highest yields are achieved in fertile, moist soils with good drainage. The most suitable soil types are: chernozems, meadow black soils, alluviums and cambisols with a pH reaction of between 5.5 and 7.0. Physical component of soil structure is very important, and it is supposed to be crumbly, which allows permeability and good soil moisture accumulation. The suitable soils for it are those with groundwater level of about 150 cm. In heavy soils, the root is branched, curved, becomes fairly pungent, and in too light soils, it becomes tasteless. Subarable layer should also be permeable for normal growth and development of horseradish. A certain amount of organic matter in the soil is also preferrable (Filipović and Jevđović, 2004). Shallow soils with a hard substrate are not suitable for its cultivation. In the climatic conditions inn this country, the vegetative growth stage lasts from March until the beginning of November.

Botanically, it is a biennial species in which, an underground fleshy outgrowth (so-called underground tree) is used as the nutrient, and the outgrowth is commonly called the root. The root is spindle-shaped, well-developed, up to 6 cm thick and very long, up to 1 m. In its upper part, it is thicker, and has several heads, and its lower part has sleeping buds, which to form new roots or young leaves. The suction power of the root is rather good. Outside, it is yellow-greyish, and inside, it is white. In old plants, the root is very rough and prone to decay, which makes it unsuitable for human consumption. Therefore, for feeding, annual and biennial horseradish roots are used. The leaves are wrapped in a rosette, and with leaf petioles. They are large, elongated, with a notched lamina. They build strong innervation and mild creases. It holds an upright position. In the second year of life, and rarely and exceptionally in the first one, it develops phanerogamic tree. The tree is upright, 60 to 120 cm high, branched in the upper part, angularly furrowed, hollow, without downs (naked). It is covered with leaves of different sizes and constitution. The lower leaves are with a shorter handle, lobular and jagged, whereas the upper leaves are sessile, whole, elongated and finely serrated. The leafedness of a tree depends on the weather conditions, soil and

agricultural practices. The flowers occur in inflorescences, which have combed constitution. Flowering is gradual, and takes 25 to 40 days. Horseradish is pollinated by insects (xenogamously). The fruit is a globular, slightly wavy, brown in colour. The seed is oval, dark and very tiny (300 to 500 seeds in 1 g). Darker coloured and larger seeds are better quality. Seed germination is very low (20 to 25 %).

Varieties. The best known are the Russian varieties Atlant, Valkovsky and Tolpuhovsky, from the American ones, Maliner Kren, Big Top and Hybrid Horseradish are grown, then, the Hungarian Debrecen horseradish, and also, the varieties from the horsradish populations of this country. The Atlant variety is very widespread, and is characterised by a plump white root, 20 to 50 cm long, with the diameter of 4 to 5 cm. It is a medium-stature, non-blooming variety, with the vegetative growth stage of 86 to 129 days. The root mass is in the range of 190 to 380 g.

The Valkovski variety is characterised by yellowish cylindrical root with juicy white meat, pleasant taste and aroma. The root length is 50 to 60 cm, a the diameter is 2 to 3 cm. Its length of the vegetative growth stage is 182 to 198 days. The variety is a blooming one. The root mass is 150 g.

In Serbia, the most frquently grown horseradish varieties are the Hungarian ones and the ones from local populations. They are characterised by moderate pungency and high yield. The root length of these variants is 50 to 70 cm, with a diameter of 4 to 5 cm. The mass of a single root reaches up to 200 g.

Crop rotation. This is a very important agro-technical measure of organic farming in general. Horseradish is produced as an annual or biennial, rarely as a perennial crop, by planting an annual underground stem (cuttings). In annual production, horseradish comes in the first place in the rotation. Horseradish, as a root plant, is grown after small grains, corn, and fruiting and stalk vegetables and potatoes. Good pre-crops are legumes as well, and, to follow horseradish, grasses should be grown, so as to kill wild-growing horseradish plants. In growing horseradish as a perennial species, it is grown away from crop rotation, on separate plots. Poor pre-crops for growing horseradish are the plants from the family of brassicas, because, like horseradish, they are endangered by the same pests and diseases. Because of its distinct regeneration, horseradish is not a suitable pre-crop.

Tillage. The soil for planting horseradish cuttings must be well prepared, with crumbly structure and good porosity, flat, without crop residues and weeds. The primary treatment should be carried as early as possible during autumn, most commonly at 30 to 40 cm depth, in order to simultaneously retain moisture in the soil near the surface, and to destroy weeds. Depending on the previously planted species, peeling should be performed too (usually at 15 cm depth). A ploughed plot remains through winter until spring, when preseeding preparation is done. It is very important that preseeding preparation and planting are performed in a quality manner, so as to ensure the growth and development of the plant.

Soil fertility. In the organic production of horseradish, fertile soil is considered to the one that it is composed of at least 1.5% of humus, where organic fertilisers are exclusively utilised for the improvement, maintenance and feeding of the soil. From permitted fertilisers, the applied ones are: compost, manure and poultry manure (Filipović et al., 2004), green manure, liquid manure, vermicompost, ashes, blood meal and others. In the preparation of these fertilisers, one must be careful with the maximum allowable quantities of heavy metals in compost and organic fertilisers. On the market, there are already certified fertilisers, which are mainly obtained as by-products from farms where organic farming is applied. In the feeding, specific organic preparations are used, made mostly of medicinal plants and vegetables, so they have a protective role at the same time. Generally speaking, for horseradish, as a root variety, the most appropriate fertilisers are those in which potassium is the dominant component. In annual production, fertilisation is most commonly conducted with 80 to 200 kg N, 100 to 120 kg P_2O_5 and 150 to 200 kg K_2O per hectare. Most often, 50% of P and K fertilisers are applied in autumn, and the other half with 50% of N in spring prior to planting. In the development phase of the rosette, the feeding of nitrogen fertilisers is carried out. The same amount of fertiliser is given in the second and in other years. With a perenial crop, manure is used for fertilisation every three years.

Propagation and planting. Horseradish is propagated vegetatively through the means of cuttings. The length of a cutting has a large impact on the yield of horseradish (Cobalas and Jidav, 1980). According to the Agricultural Academy of Latvia (Rubenis, 2001), the highest yield is obtained from the cuttings which are 25 to 30 cm in length. When planting those saplings, during plant growth, it mainly comes to an increase in the size of the main root, which is formed from the planted sapling. The highest quality cuttings are located at the bottom of the root, and are 1 to 2 cm in diameter. Typically, from one root, 3 to 4 cuttings are obtained. The topmost part of the cutting is cut straight,

and the bottom one, diagonally for the purpose of more proper development. Upon the extraction of the root and the removal, as the planting material for the next season, the cuttings are stored in underground silos with wet sand.

Planting is done at a inter-row spacing of 80 cm and an intra-row spacing of 20 cm (Filipović and Jevđović, 2004). A larger spacing within a row makes possible a safer yield and better quality roots (Poniedzialek, 1978). Planting is usually performed in spring (less often in autumn) laying cuttings into soil at an angle of 45°, and with their tops in the same direction. This is an important measure for obtaining strong roots. The depth of a drill is 20 cm, and cuttings are laid into it, with their tops left above the soil surface (the American method), or with the tops below the surface (the Russian method). After the planting, the soil is compacted to a certain extent because of a better reception of the cuttings. For 1 ha, 600 to 1200 kg ha-1 is needed, which is provided by the production on 30 ares. In recent years, the planting method of „horseradish sleeve-planting“ is increasingly applied, and it represents the use of cuttings wrapped in plastic foil. By this sort of production, a more uniform root is obtained with less superficial veins on the cuttings, as well as by some twenty percent higher yield of fresh roots compared to the standard method of production. If conditions exist, horseradish plantation irrigation is desirable, because horseradish requires plenty of water.

Protection. In organic production, human labour occupies a key position in crop protection. What is primarily meant here is the use of physical and mechanical measures in the destruction of weeds, which represent the severest problem in organic agriculture. The protective measures for horseradish crop include: defeating soil crusts, mechanical weed control, crop feeding with some of the liquid ecological products. The protection is also carried out by a corresponding plant density, mulching, multiple cropping and a series of physical and biological measures. The products that can be used include the preparations registered in the list of plant nutrients and soil conditioners and plant protection products which can be used in organic production, which is updated annually and published by the competent body for inspection correctness, control and certification of the Ministry of Agriculture and Environmental Protection of the Republic of Serbia.

One of the specific measures of the care of cultivated horseradish is the “trimming” of rootlets during the vegetative season (Filipović and Jevđović, 2004). This measure is performed in such a manner that, during the vegetative season, the root is uncovered several times, and the rootlets are destroyed, followed by soil recovering. By such a “treatment”, a straight and quality root is obtained.

The most common undesirable fungi on horseradish is *Albugo candida* or white rust, which attacks all the parts of the plant. Many weeds and radishes occur as the hosts of this pathogen. To combat this disease, copper-based preparations are applied, those that are allowed in the organic production of horseradish. Another major disease of horseradish is verticillium wilt (*Verticillium dahliae*). This fungus, which occurs in soil, infects the vascular tissue of the root, which is the main reason for the decline in market quality of horseradish root (Eastburn and Weizierl, 1995). For the “avoidance” of this disease, a crop rotation is used in which plants from the cabbage family are not included.

Horseradish flea beetle (*Phyllotreta armoraciae*) is one of very frequent horseradish pests. It is a small insect, oval in shape and bright black in colour. It attacks horseradish saplings, and can cause major damage in the initial development stages. Once the leaves have strengthened, these insects passes over to the root and to the young newly formed leaves. Depending on the environmental conditions, it annually reproduces 2 to 3 times. As a preventive measure in combating these pests, in the organic production of horseradish, different preparations based on medicinal plants can be used (Filipović and Jevđović, 2004). In addition to these pests, typical of horseradish, serious damage can be caused by the larva of turnip sawfly (*Athalia colibri*) and flea beetle (*Halticinae*). In this case, competitive relationships (Coleman, 1995) between plants and their phytoncide effect prevents stronger pest attacks (for example, tomatoes repel flea beetle by their smell).

Harvest. Under the conditions of this country’s agroclimate, the harvesting of horseradish root harvest is performed in late October, at the time when the content of nutrients in it has reached the desired level. The harvest is usually done one week after the removal of the above-ground biomass, if one is present. To remove horseradish, modified potato or carrot diggers are utilised. The daily performance of such a machine ranges from 2.5 to 3.0 hectares. First, earth is cleaned off the harvested roots, and then, depending on the purpose, the roots are washed or stored.

Yield. Yield quantity depends on agricultural practices and varieties most. Thus, the Russian varieties achieve yields of up to 30 t ha^{-1}, the American ones, 15 to 20 t ha^{-1}, and the European ones, the average of about 25 t ha^{-1}.

Storage. If proper storage conditions are met, horseradish may maintain satisfactory quality in the course of 10 to 12 months at the temperature of 0 °C and the relative humidity 90 to 95 %. High humidity is the most important for maintaining quality during storage period. Perforated plastic bags and containers help to maintain high relative humidity. Roots are kept in the dark, because, when exposed to light, they might turn green. Frequent storage checkout is preferred. Horseradish can be stored over the wintertime in cold storage, trenches, underground silos, as well as in pits or storage row in the open.

The market demands horseradish root with the following characteristics: good taste, a straight root form with no side rootlets, and no mechanical damage and rot. The roots should be at least 20 cm long with a minimum diameter of 2 cm. With horseradish which is further used for processing, it is important to take into account that the final product is valuable and acceptable to the market. This means the provision of the above mentioned characteristics (root shape and length, meat color, horseradish skin type, lateral branching and others).

Standard gross margin calculation of the production of organic horseradish

The Table 1 shows the calculation of the standard gross margin of the production of horseradish in 2014 for the certified organic production. The calculation refers to an area of one hectare of seedlings. The production of horseradish is implemented in full technological maturity stage of the root on carbonate chernozem soil type. In addition to the production of the primary product, i.e. technologically mature horseradish root, a secondary product can also be obtained, which are of root cuttings, and they are utilised for further reproduction.

The establishment of horseradish plantations was carried out through vegetative means, using adequate amounts of cuttings with the recommended characteristics. The fertilisation was performed with two types of fertilisers. Mineral fertilisers (Duetto N:P:K=3:3:8 and DIX 10N 10:3:3), and organic fertilizer – cow manure. The applied amounts of fertilisers are compliant with the common standards in the production of horseradish. In the cost structure of the of machinery, dominated by the costs of ploughing, disking (harrowing), the extraction and transportation of the root, whereas, the other costs are involved in much smaller amounts. Labour costs also include the engagement of seasonal workers, especially in the period of the preparation of cuttings, hoeing and weeding, and the extraction, loading and cleaning of the root. The market demands horseradish root with the following characteristics: good taste, a straight root form, without lateral rootlets, and no mechanical damage and rot. The roots should be at least 20 cm long with a minimum diameter of 2 cm.

In the standard gross margin, a third of the total cost involves the costs of the engagement of human labour (33.5 %), the costs of the use of manure are the second largest (23.0 %), while the cost coverage of the application of mineral fertilisers is in third place (16.8 %). The above types of costs make ¾ of the standard gross margin to be covered in the production of organic horseradish. In the rubric of revenues, the dominant position belongs to the revenue generated by the sale of roots (75.3 %). Based on the calculations from the table below, it can be noted that, in the observed calculation, a positive margin is achieved in the coverage of the production of organically certified horseradish.

Table 1 Standard gross margin calculation of the production of organic horseradish, 1 hectare

A) Revenues	Quantity	Unit of measure	Price by unit of measure	Total RSD/ha	Total €/ha***	%
Root						
Cuttings	12.000	kg	50	600000	5185	75,3
Subsidies by Ministry	3.000	kg	60	180000	1556	22,6
Total (A)	1	ha	16800	16800	145	2,1
B) Variable costs				796800	6886	100,0
Planting material (cuttings)						
Mineral fertiliser	800	kg	60	48000	415	9,2
Manure*				87500	756	16,8
Plant protection products				120000	1037	23,0

Costs of machinery				0	0	0,0
Human labour		ha		75400	653	14,5
Certification		wage		174600	1509	33,5
Total (B)	1	ha	16000	16000	138	3,1
C) Coverage Margin (C = A − B)				507500	4386	100
Standard Gross Margin – Description				**289300**	**2500**	
MINERAL FERTILISERS	Količina	Unit of measure	Cena po jedinici mere	Ukupno RSD/ha	Ukupno €/ha***	%
Duetto N:P:K=3:3:8						
DIX 10N 10:3:3	1000	kg	62	62000	536	70,9
Total	300	kg	85	25500	220	29,1
MANURE*				87500	756	100,0
PLANT PROTECTION PRODUCTS	50	t	2400	120000	1037	
Total						
MACHINERY OPERATIONS**					0	
Ploughing						
Disking	1	ha	12000	12000	104	15,9
Transport and distribution of mineral fertilisers	2	ha	6000	12000	104	15,9
Manure spreading*	2	ha	1200	2400	21	3,2
Soil preparation for planting	1	ha	5000	5000	43	6,6
Transport and planting of cuttings	2	ha	3.000	6.000	52	8,0
Inter-row cultivation	1	ha	6.000	6.000	52	8,0
Harvest	2	ha	3.000	6.000	52	8,0
Transport	1	ha	12.000	12.000	104	15,9
Total	1	ha	14.000	14.000	121	18,5
HUMAN LABOUR				75400	653	100,0
Loading and unloading of fertiliser						
Preparation of cuttings	0,25	wage	1200	300	3	0,2
Loading and unloading of cuttings	30	wage	1200	36000	311	20,6
Planting of cuttings	0,25	wage	1200	300	3	0,2
Hoeing and weeding 2x	15	wage	1200	18000	156	10,3
Ecxtraction, loading and cleaning of roots	40	wage	1200	48000	415	27,5
Total	60	wage	1200	72000	622	41,2
A) Revenues				174600	1509	100

* Note: Depending on a plot, crop rotation and manure application needs

** Note: Includes compensation for a part of human labour, fuel consumption and machinery amortisation. If an operation is repeated several times during the production, it is to enter the number of repetitions (example: inter-row cultivation x 2)

*** Note: The middle exchange rate by the National Bank of Serbia on 1 July 2014 amounted to 115.71 dinars for 1.0 € (euro)

Conclusion

Parts of metropolitan areas provide an opportunity for the sustainability of economic, environmental, technological, social and cultural development (Friedman, 2014) of the population that lives in them. The introduction of less represented plant species, such as horseradish, in the production and use, can utilised the soil whose characteristics are not favourable for the farming of certain intensive crops. For this reason, such surfaces are possible to certify in keeping with the Law on Organic Production, resulting in an added value of the production itself.

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