

## ENERGETIC EFFICIENCY OF RASPBERRY PRODUCTION IN PROTECTED AREA FACILITY TYPE TUNNEL<sup>1</sup>

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### Abstract

In recent time, raspberry production, both in the open field and in protected areas, has been expanding. The rapid growth in demand for this fruit species either as fresh or frozen, encourage the producers to intensify its production, initiating certain, not so small investments. This research is focused on raspberry production organised at farm that has available a production capacity embodied in 13 identical greenhouses settled at the one-hectare plot located at the territory of the municipality of Požega, Republic of Serbia. The greenhouses are 15x50 m in size, while they are connected in a block system. The research was carried out during the 2020. The analysis has covered primary data obtained at the selected farm that are linked to third year of raspberry plantation use, i.e. the second year of full yielding. The main goal of the paper is to assess the energetic efficiency of raspberry production organised in protected area (type tunnel). Derived results have been indicated that this type of production in a protected area generates low energy value, as well as it shows adequate energy efficiency, while ensuring the high yielding.

**Key words:** Raspberry, energetic efficiency, protected area.

**JEL<sup>4</sup>:** Q12, Q16, Q49

### Introduction

In line to its production and nutritional characteristics, raspberry represents a very specific fruit. Raspberry is a highly important fruit species in terms of its nutritional composition and health benefits, which contains a high level of antioxidants (Beekwilder et al., 2005; Rao, Snyder, 2010). Raspberries are rich in vitamins (primarily C and E). They are mostly used as fresh, but also as a frozen agro-food product (Štrbac, 2009).

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Focusing to technological and dietary aspects, fruits of raspberry have great utility value, i.e. they are suitable raw material for industrial processing, or processing at farm gate (such as production of jams, juices, sweets, confectionery, liqueurs, etc.), (Džoljić, 2021).

Raspberry is a perennial deciduous plant that belongs to rose family (lat. Rosaceae). It usually occurs in the form of a bush. It is characterised by perennial root, while the over-ground part is primarily made up from one-year and two-year shoots (Jančić, 2004). It starts yielding in the second year after planting, while under satisfactory production conditions plantation could be exploited for more than 15 years (Graham, Jennings, 2009). This is one of the most profitable crops (Kljajić, 2014). Also, it represents a fruit species that generates constantly increasing economic benefits, so today exist permanent growth in its production intensity (Keserović et al., 2014; Keserović et al., 2016). Raspberry characterises generally short period to full yielding, pronounced seasonality, lower production risks, and good adaptability to various climate and soil conditions, while it could be produced up to 1,000 m a.s.l. (Subić et al., 2017). In average, yields reached in production conditions of Serbian are around 5.5 t/ha, while in ideal conditions they can be over 24 t/ha. Almost 97% of production areas are concentrated within the region of Šumadija and Western Serbia (Grčak et al., 2019). Vilamet is dominantly produced variety of raspberry in Serbia, covering around the 95% of the overall production areas. As second is ranked the Miker variety (Keserović et al., 2016; Kljajić, 2017).

Observing the value of export, raspberry is most often ranked as one of the top 10 export products of national agriculture, whereby the Serbia is marked as one of the globally recognizable producers (Parausić, Simeunović, 2016).

Raspberry is grown in Serbia at more than 11 thousand hectares, what ranks Serbia as third producer in Europe (RZS, 2013). Among the berry fruits, according to the volume of production, total area under plantations and export potential, raspberry dominate in Serbia for the last two decades (Bošković Rakočević et al., 2021).

It should be mentioned the high sensitivity of raspberry towards the many diseases that could cause significant damage in current production, i.e. raspberry requires the application of significant quantity of agro-chemicals (Stevanović et al., 2014). Regardless if it will be consumed as fresh or used as a raw material in the food industry, raspberry is characterized by significant level of perishability, requiring as short as possible sales channels (Radosavljević, 2014). Annual production in Serbia is around 90,000 t, while over the 70% is later exported as frozen. In last several decades frozen raspberry has become important export item. Its high price and secured marketability more and more drive the producers to export. It is

mainly exported to EU, specifically Germany, France and Belgium (Stevanović et al., 2019).

Although its production is primarily linked to higher altitudes, the constant growth in demand for raspberries at global level, as well as the stability in its sale and usually higher market price of this fruit caused the increase in its growing in lowlands. It is usually grown at open field (Nikolić et al., 2012). Besides, the raspberry production in protected area is also widely used worldwide, especially in countries where it is traditionally consumed as fresh, such as in the USA, the Netherlands, Great Britain, Belgium, Canada, etc., or in countries that are net exporters of raspberries, such as Spain or Italy (Šundeč et al., 2016).

Currently, the vegetable and fruit production in facilities of protected area, primarily greenhouses, is increasingly common. Farmers are deciding to this system of production due to several advantages, such as possibility to ensure the availability of certain crop throughout the whole year, achieving of stable and high yields, easier production management, as well as easier control of the microclimate parameters of production, etc. (Chang et al., 2011). As the basic microclimate parameters linked to production in protected area, temperature and relative air and soil humidity, air quality and soil fertility, or solar irradiance are usually observed (Dimitrijević et al., 2014).

Crop production in protected area represents the most intensive form of production in agriculture. It implies huge energy consumption in order to achieve the high and stable yields of good quality agro-products. Technologically, this is a production system that does not allow major mistakes (Dimitrijević et al., 2016). According to shape, dimensions, material used for construction, installed equipment, etc., there are many types of protected area production facilities (Iribarne et al., 2007).

One of the mostly used forms is the tunnel-type production facilities. Its construction and maintenance surely requires certain level of investments. As the most commonly used mechanism for reducing the level of investment in exploitation of such a facilities is the decrease in energy consumption during the overall production processes of certain crop (Ahamed et al., 2019).

Production in a tunnel-type protected area is mainly used in order to extend the production cycle over the entire year. Production area is usually protected by the high tunnel facility. It requires not so high investments, so it is the most often choice of producers. Usually, this kind of facility does not have installed heating system, while if it is implemented, its utilisation is only in extreme weather cases (in paper observed production system does not include the heating systems). Besides, another advantage of analysed production facility is possibility to apply the natural ventilation

by the opening of the front doors, or side walls. It represents relatively the most economic type of protected area facility. High tunnels have been widely used in plant production, while their utilisation in small fruit production started in USA, where they are primarily used as multi- or single-bay facilities (Demchak, 2009; Pritts et al., 2009).

The specificity of raspberry production in protected area is the achievement of adequate energy efficiency. Besides, it is characterized by significantly higher yields compared to production in open field, i.e. higher profitability, as the raspberry reaches the market out the regular season when prices are much higher (Pritts et al., 1999; Dimitrijević et al., 2016).

The main paper goal is to present all steps within the energetic efficiency analysis in raspberry production organised in tunnel-type greenhouse. Analysis is based on relation between energy inputs and outputs.

There could be defined the next hypothesis: Raspberry production in a protected area facility affects the energy-efficient production.

### **Methodology**

Collecting of data necessary for the techno-economic analysis has been carried out through the in-depth interview with a raspberry producer from the territory of the municipality of Požega. The research was completed in third year after raspberry planting, and includes the data for production year 2020. It should be mentioned that raspberry plantation usually needs three years to reach its full yielding capacity (Bojkovska et al., 2021). Farm is oriented to raspberry production in protected area, specifically in greenhouse. Used greenhouses are the tunnel-type and they are installed in a block system. The size of each greenhouse is 15x50 m, while there are 13 greenhouses settled at the production plot of about 1 ha. Raspberries are planted with planting density of 2.5x0.25 m.

**Table 1.** Technology chart in raspberry production - third year of crop exploitation (full yield)

no	Operation	Agro-technic period	Volume		Working days (total) <sup>5</sup>	Working hours (daily) <sup>6</sup>	Coefficient of working time utilisation	Working hours (total) <sup>7</sup>	Effective working hours <sup>8</sup>
			UM	Q					
1.	Land cultivation	15-31 <sup>st</sup> March	ha	1	15	12	0.70	180	126
2.	Pruning	15-31 <sup>st</sup> March	ha	1	10	16	0.80	160	128
3.	Chemical protection	20-30 <sup>th</sup> April	ha	1	10	16	0.70	160	112
4.	Irrigation and fertirrigation	1-10 <sup>th</sup> May	1	400	10	24	0.80	240	192
5.	Land cultivation	1-15 <sup>th</sup> May	ha	1	15	16	0.70	240	168
6.	Chemical protection	10-20 <sup>th</sup> May	ha	1	10	16	0.70	160	112
7.	Harvesting	20 <sup>th</sup> May – 20 <sup>th</sup> October	ha	1	110	8	0.90	880	792
8.	Transport of raspberry (25 t/ha)	20 <sup>th</sup> May – 20 <sup>th</sup> October	t	25	110	8	0.40	880	352
9.	Irrigation	25 <sup>th</sup> July – 10 <sup>th</sup> September	1	300	45	24	0.80	1080	864
10.	Land cultivation	5-15 <sup>th</sup> August	ha	1	10	16	0.70	160	112

Source: According to Marina, 2021.

- 5 Number of working days represents the number of days required for appliance of certain agro-technic activity, while it is previously reduced compared to optimal agro-technical period, due to possible occurrence of unfavourable weather events.
- 6 Daily working time represents the number of hours that could be directed with great probability to realisation of certain production activity in each working day.
- 7 Working hours represent the entire fund of working hours available to this production line.
- 8 Effective working hours represent the working hours that could be effectively used in certain production line/activity (relation between the coefficient of working time utilisation and total available fund of working hours).

Raspberry plantation is established at the soil type vertisol. The grown raspberry considers the Heritage variety. This is a very productive variety, which requires 5-6 cycles of harvesting per year (starting from the end of May to the end of October). The achieved yields were around 25 t/ha, what definitely fits the globally recorded yields of raspberry produced in high-intensity production systems (12-25 t/ha), (Pritts et al., 1999; Linnemannstöns, 2019). During the observed year, managing the production in raspberry plantation has required several production activities, such as inter-row (land) cultivation, pesticide treatment, physical protection against diseases and pests, fertigation, pruning, preparation of plantation for harvest, harvest and manipulation with raspberry fruits, etc. Use of installed system for fertigation (drip system) requires several power-ups per day, while it implies relatively low electricity consumption. In order to avoid spring frosts, pruning is usually done in March. In previous table (Table 1.) is presented the technology chart of raspberry production used at observed farm.

In order to evaluate energetic efficiency of raspberry production in protected area, next energetic parameters of production are covered by following formulas:

$$\text{Specific energy input (EI)} = \frac{\text{Energy input in production cycle } \left(\frac{\text{MJ}}{\text{ha}}\right)}{\text{Output } \left(\frac{\text{kg}}{\text{ha}}\right)} \text{ (in MJ/kg)}$$

$$\text{Energetic relation (ER)} = \frac{\text{Energetic value of product } \left(\frac{\text{MJ}}{\text{ha}}\right)}{\text{Energy input in production cycle } \left(\frac{\text{MJ}}{\text{ha}}\right)}$$

$$\text{Energetic productivity (EP)} = \frac{\text{Output } \left(\frac{\text{kg}}{\text{ha}}\right)}{\text{Energy input in production cycle } \left(\frac{\text{MJ}}{\text{ha}}\right)} \text{ (in kg/MJ)}$$

Method used for calculation of energetic efficiency of raspberry production (Đević, Dimitrijević, 2009a) implies the analysis of energy inputs (defining of direct and indirect inputs), energy spending due to used system of production, as well as analysis of energetic efficiency by itself (Đević, Dimitrijević, 2009b).

Direct energy inputs usually involve the monitoring of diesel consumption due to use of all agricultural machines in certain production line. In specified case, the farm has a Deutz Fahr 5105 fruit tractor (engine power of 75 kW and optimal traction force of 11 kN). As indirect energy inputs are considered the monitoring of material consumption of agrochemicals, such are fertilizers, or pesticides. The energy output is linked to total yield of fruit from certain production process, while it is explained through the achieved yield and products' calorific value (Đević, Dimitrijević, 2009b).

## Results and Discussion

In order to calculate the energy potential of used fuel per unit of production area, it is necessary to know how much energy is contained in one liter of used fuel (diesel). The calorific value adopted for the 1 l of diesel is 47.8 MJ/kg (Ortiz Canavate, Hernanz, 1999; Badger, 1999), while its density is 0.84 kg/l. According to mentioned it could be calculated the value of energy contained in one liter of diesel (MJ/l), that will be later used for recalculation of used diesel from l/ha into the MJ/ha ( $47.8 \text{ MJ/kg} \times 0.84 \text{ kg/l} = 40.63 \text{ MJ/l}$ ). Multiplying the value of fuel consumption given in l/ha with the coefficient 40.63 MJ/l will derive the value of fuel energy per unit of production area (MJ/ha). The technological fuel energy contained in MJ/ha is obtained by multiplying the energy expressed in kWh/ha by 3.6, as 1 kWh has energy value of 3.6 MJ. Meanwhile, coefficient of fuel utilization shows the relative ratio between the technological and total fuel energy (Mileusnić et al., 2006).

### *Direct energy inputs*

In next table (Table 2.) are presented the spending of energy per unit of production surface for specified production activities, i.e. the direct energy inputs are determined.

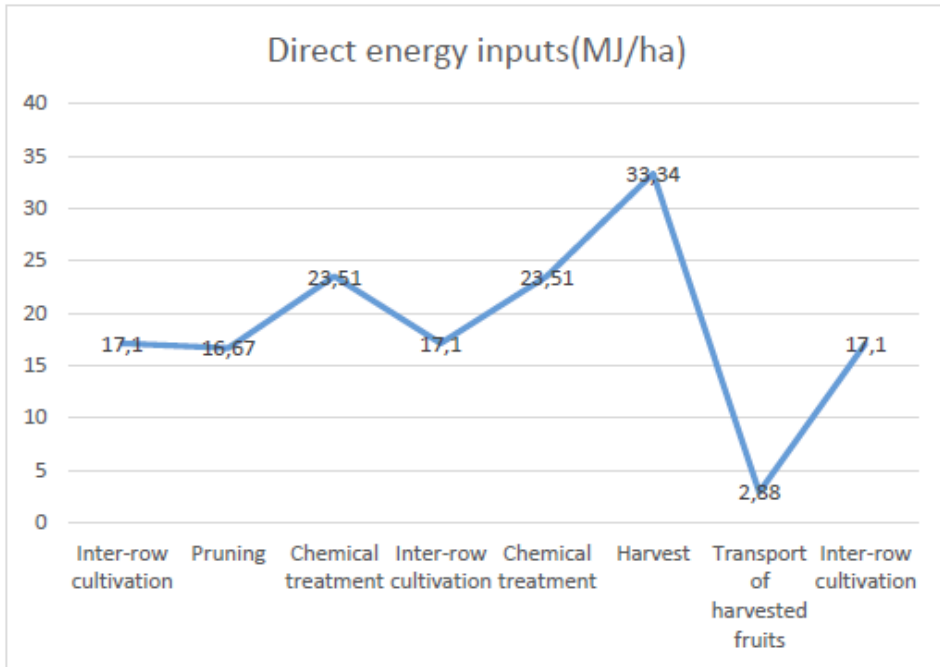
According to energy spending per unit of production area (Table 2.), it could be noted that the most energy (22.88%) is consumed during the raspberry harvesting, while the lowest sum of energy is spent for transport of harvested fruits (1.43%). High energy consumption (33.34 MJ/ha) linked to harvesting comes from the use of harvester (Graph 1.). There are few benefits of harvester use, as it is self-propelled machine, that allows harvesting based on vibrations, i.e. it initiates the harvesting (falling) just of these fruits that are technologically mature, while the damage at fruits are reduced at minimum (Dale et al., 1994).

**Table 2.** Energy spending per unit of production area for applied production activities (direct energy inputs)

Working machine	Activity	Equipment	Fuel spending (l/ha)	Total energy of fuel (MJ/ha)	Share in total energy (%)	Energy spending (kWh/ha)	Technological energy (MJ/ha)	Coefficient of fuel utilisation (%)
Deutz Fahr 5105	Land cultivation	Fruit-vine cultivator	3.02	122.70	13.14	4.75	17.1	13.94
Deutz Fahr 5105	Pruning	Agrosad Ero-elite	2.96	120.26	12.88	4.63	16.67	13.86
Deutz Fahr 5105	Treatment with pesticides	AGP 2000 EN	2.69	109.29	11.70	6.53	23.51	21.51
Deutz Fahr 5105	Land cultivation	Fruit-vine cultivator	3.02	122.70	13.14	4.75	17.1	13.94
Deutz Fahr 5105	Treatment with pesticides	AGP 2000 EN	2.69	109.29	11.70	6.53	23.51	21.51
Harvester Electronic	Harvesting	/	5.26	213.71	22.88	9.26	33.34	15.6
Deutz Fahr 5105	Transport	Majevica (4 t)	0.33	13.41	1.43	0.8	2.88	21.48
Deutz Fahr 5105	Land cultivation	Fruit-vine cultivator	3.02	122.70	13.14	4.75	17.1	13.94
<b>Total</b>			22.99	934.06	100	42	151.21	16.19

Source: Calculated according to Marina, 2021.



**Graph 1.** Direct energy inputs

Source: According to the data from Table 2.

### *Indirect energy inputs*

Indirect energy inputs are gained by multiplying the used production inputs (material) during the production cycle with the corresponding (adequate) energy equivalent (Đević, Dimitrijević, 2009b). Its value for nitrogen is 78.7 MJ/kg, phosphorus 17.4 MJ/kg, potassium 13.7 MJ/kg, pesticides 199 MJ/kg, fungicides 92 MJ/kg, or herbicides 238 MJ/kg, while for water used in irrigation they amounts 9 MJ/m<sup>3</sup>. In following table (Table 3.) there are presented the indirect energy inputs used in observed raspberry production.

**Table 3.** Indirect energy inputs

Indirect energy inputs	Quantity (kg/ha)	Energy (MJ)	Share in %
Nitrogen	50	3,935.0	72.72
Phosphorous	15	261.0	4.82
Potassium	65	890.5	16.46
Pesticides	2,6	324.8	6.00
<b>Total</b>	-	5,411.3	100.00

Source: Calculated according to Marina, 2021.

Within the structure of total indirect energy inputs dominates nitrogen with almost 73%, while the lowest share has phosphorous with slightly under 5%.

**Table 4.** Relation between direct and indirect energy inputs

Energy inputs	Energy (MJ)	Share in %
Direct energy inputs	934.06	14.72
Indirect energy inputs	5,411.3	85.25
Total	6,345.36	100.00

Source: Calculated according to Marina, 2021.

Observing the structure of total energy inputs (Table 4.) it could be seen the domination of indirect energy inputs (over 85%). In practice, such a relation is mainly interpreted by the fact that there is not heating in production facility (Babić, Babić, 2003).

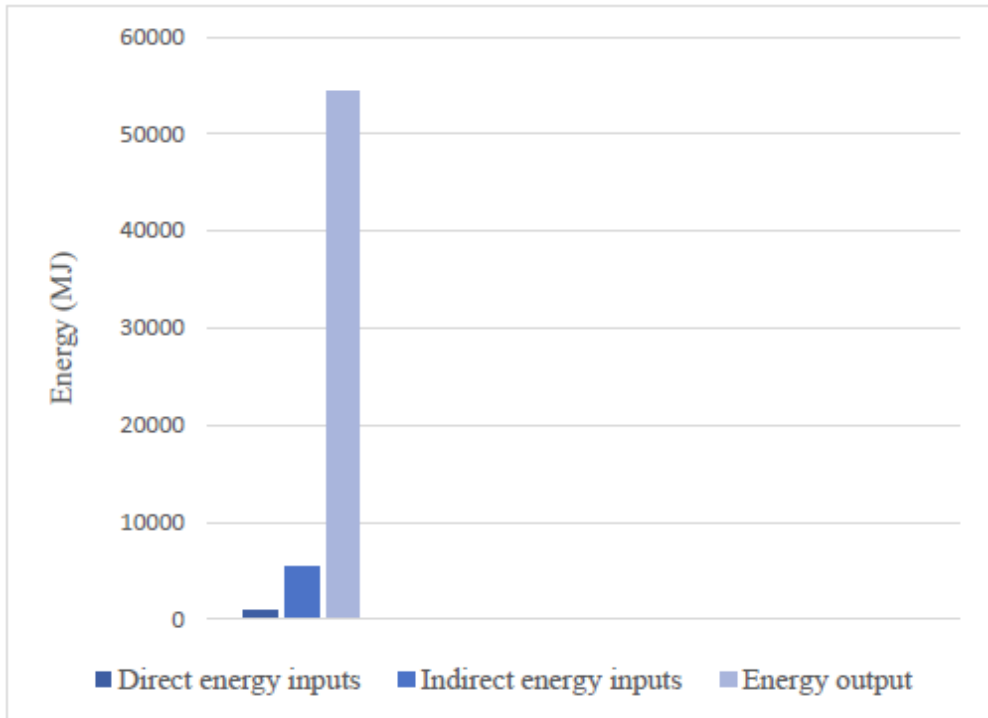
#### *Energy output*

Calculation of the energy output depends on the kind of grown crop species. In raspberry production it includes realized raspberry yields, i.e. the calorific value of the overall yield. Calculation is based on the fact that 100 gr of raspberries have an energy value of 52 kcal<sup>9</sup> (Rao, Snyder, 2010). So, energy value of 100 gr of raspberries could be considered as:  $100 \text{ gr} = 52 \text{ kcal} \times 4,1868 \text{ kJ} = 217.71 \text{ kJ}$ , or 1 kg of raspberries possesses energy value of 2,177.1 kJ. As the achieved raspberry yield at the farm is around 25 t/ha, and according its calorific value of 2,177.1 kJ/kg, the energy value of overall raspberry production could be estimated as:  $2,177.1 \text{ kJ/kg} \times 25,000 \text{ kg/ha} = 54,427.500 \text{ kJ/ha}$  (54,427.5 MJ/ha)

#### *Energy analysis*

According to obtained values (Graph 2.) all parameters required for energy analysis are determined.

<sup>9</sup> 1 kcal = 4,1868 kJ

**Graph 2.** Energy inputs and outputs

Source: According to authors calculations.

By the use of pre-defined methodology next values for energy parameters have been gained (Table 5).

**Table 5.** Energy parameters

Energy parameters	
Specific energy input (EI), (MJ/kg)	0.25
Energetic relation (ER)	8.58
Energetic productivity (EP), (kg/MJ)	3.94

Source: According to authors calculations.

Raspberry is characterized by low energy productivity, as the fruit contains a low energy value (Rao, Snyder, 2010).

The intensification of production (organising the greenhouse production) and the approach to higher yields have been affected the value of final energy parameters, which correspond to the assertion that energy productivity is higher with increase in yields. Obtaining the higher values of parameter could be explained by the higher yield of raspberries grown in protected area than those produced in the open field.

Analysis shows (Table 5.) that the production of 1 kg of raspberry fruits requires spending of 0.25 MJ of energy. Also, from the ratio between the energy value of fruits and energy inputs, it could be seen that the energy value of raspberry is for 8.58 times higher than the consumed energy inputs.

Besides, analysis shows that for each MJ of energy invested, there could be achieved 3.94 kg of raspberry. In tomatoes production organised in similar production facility (tunnel type), (Đević, Dimitrijević, 2009b) it's shown that production of 1 kg of tomatoes requires energy investment of 1.21 MJ, with the energetic relation of 0.66. From same analysis derives that energy investment of 1 MJ could generate 0.83 kg of tomatoes. Therefore, production of 1 kg of tomatoes in a tunnel-type production facility requires much more energy than the production of 1 kg of raspberry.

### Conclusion

Raspberry is a very important fruit species for the Serbia from many aspects, such are the organization of agricultural production, keeping of food security and supply at national market, as well as from the aspect of profitability both for individual producers and state. Observing the energy consumption and energetic efficiency of raspberry production in protected area during the one production cycle within the phase of full yielding, there are obtained slightly higher values of energy parameters, what is explained by achievement of higher raspberry yields. It could be underlined that there was no heating in production facility as the weather conditions were favourable for raspberry production.

The paper has shown that intensive production and high yields of raspberries could guarantee a high level of energy output. Facing the obtained energy outputs and consumed energy inputs there are derived satisfactory energy effects of the organised production. As the intensification of production under normal circumstances certainly ensures higher yields of raspberries, the energy value of the gained raspberry can certainly cover the energy consumption necessary for the continuity of production process. By mentioned, the assumed hypothesis is accepted, as the production of raspberries in tunnel type facility is energy-efficient production.

According to gained results, they could be in function of both active producers and some future research. Future research should be directed towards the analysis of same energy parameters derived from the production of same raspberry variety in different production facilities or from the production of different varieties in identical production conditions.

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