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Economic effect of foil mulching in organic raspberry production

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Abstract

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The present study was conducted in an experimental biologically managed plantation, created in the autumn of 2010 in the experimental station field at Kostinbrod, affiliated to the Institute of Agriculture (Kyustendil, Bulgaria), during the period 2017–2018. The experiment was set up with raspberry plants of the Willamette variety by the method of the long plots. Four treatments, each in four replicates, were investigated: V0, control (flat bed, no mulching); V1, high bed, no mulching; V2, high bed, gray polyethylene mulching; V3, high bed, black polyethylene mulching. Foliar spraying with registered by the Bulgarian Food Safety Agency (BFSA) organic fertilizers were performed during the growing season. The purpose of this study was to investigate the effectiveness of an innovative technology for organic raspberry production with the use of polyethylene foil mulching and its impact on yield structure and economic performance. The additional costs incurred for the polyethylene foil mulching in the organic production of raspberries were estimated at 119 lv/da. Higher average yield was obtained in the mulching treatments. In the black polyethylene mulching, the additional fruit production reached 157 kg/da. The gross production of the experimental treatment was also higher than that of the control: 4.4% in the high-bed treatment; 32.7% in the high-bed treatment mulched with silver-gray polyethylene, and 53.8% in the high-bed treatment, mulched with black polyethylene. Therefore, from an economic point of view, the organic production of raspberries of the Willamette variety with black polyethylene mulching was the most effective among the treatments examined in this study. The findings of the present investigation can serve as a foundation and complement for further research on improving the economic performance parameters of organic raspberry production in Bulgaria through optimization of alternative agricultural management practices and contribute to the database of experimental results obtained on that topic across different agro-ecological, species, and varietal conditions in Europe and globally.

Keywords: organic raspberry; production; mulching; economic parameters; cost-effectiveness

Introduction

Agri-food production has been widely acknowledged to exert environmental impact on a global scale and various methods for assessment of that impact have been proposed (Beccali et al., 2009; Girgenti et al., 2013). Therefore, the adoption of less impactful strategies based on evaluation of the costs of environmentally friendly solutions is highly desirable in response to the economic–social–environmental crisis of recent years (Blanc et al., 2018, Blanc et al., 2019). Furthermore, a whole new paradigm is required to promote a more sustainable processing system and consumption, which will guarantee balanced and long-lasting development while complying with environmental and social aspects, along with consumer overall well-being and health awareness (Bovea & Vidal, 2004; Schwartz, 2017; Neugebauer et al., 2016; The World Bank, 2015). This novel approach has been supported by a number of European and worldwide intergovernmental programs and institutions, including the United Nations Environment Program

(UNEP), the Organization for Economic Cooperation and Development (OECD), and the World Bank (Jolly & Ray, 2007; OECD, 2011; The World Bank, 2012). In addition, the Europe 2020 Strategy as well as other initiatives of the European Union have clearly stated the commitment the to the development of sustainable economic growth system for the Eurozone, including a 30% reduction of emissions by efficient resource use, transition to renewable energy utilization, and combating poverty and social exclusion (European Commission, 2007, 2010, 2012). In this respect, organic production methods are becoming increasingly relevant, given the European Commission's "Green Deal" and the accelerated greening of CAP 2020+ (Yovchevska, 2019).It is noteworthy that the global ever-increasing consumer demand for organic products has led to constant annual market growth of the sector, largely supported by governments (Willer et al., 2009). Furthermore, a considerable worldwide increase in the agricultural area under organic management is observed, with an area of 50.9 million ha in 2015, compared to 11 million ha in 1999 (Willer & Lernoud, 2016, 2017). This trend clearly outlines the growing need for in-depth research on organic farming and other alternative agricultural production methods. The results of studies on the topic would contribute to wider promotion of organic farming and to a significant increase in its production capacity.

The awareness of the significance of organic farming methods and the demand for organic products are large worldwide as well as in Bulgaria. They are a distinct expression of the ever-increasing interest in and preference for the production and consumption of high quality, environmentally friendly, and healthy foods.

The consumer demand for red raspberries (*Rubus idaeus* L.) has been high due to their pleasant taste and nutritional qualities as well as potent health promoting benefits. The fruits and other plant parts contain a spectrum of important nutrients and powerful bioactive compounds and phytochemicals, such as antioxidants, flavonoids, phenolic compounds, anthocyanins, ascorbic acids, and tannins (Beattie et al., 2005; Valls et al., 2009; Rao & Snyder, 2010; Kafkas et al., 2008; Zafra-Stone et al., 2007; Maro et al., 2013; Corradini et al., 2011; Zia-Ul-Haq et al., 2014).

The productivity, profitability, and the quantitative and qualitative bioactive properties of various raspberry cultivars grown under different management systems have been extensively studied (Brun & Mosso, 2014; Papaioanou et al., 2018). However, the control of weed vegetation remains a major challenge to effective organic raspberry production in Bulgaria and abroad. The restrictions imposed by the ban on the use of most registered chemicals for conventional weed control and the high production costs incurred due to the mechanical in-row control of weeds during the first three years after crop planting significantly increase the cost of production.

One of the main approaches for weed control in organic raspberry production is mulching, which leads to many biological and economic benefits, and positively influences plant productivity (Mazur et al., 2018). It is noteworthy that in previous investigations, the use of mulching with organic materials in raspberry production significantly improved physical and chemical fruit quality, reduced evaporation, prevented weed growth, provided organic matter input, and increased productivity (Lepaja et al., 2016 a, 2016 b; 2017). Furthermore, mulching with black plastic influenced directly the evolution of soil moisture and temperature both in the field and in tunnels, and positively influenced the effectiveness of the control measures against pests and diseases (especially fungal) in organic strawberries (Maxim et al., 2019).

A three-year study was conducted in Poland to establish the influence of the use of different materials for in-row mulching on the vegetative and reproductive manifestations and the quality of the fruits of three remontant raspberry varieties (Polana and Polesie). The treatments examined included the application of perforated polyethylene film, plant materials, young shoots, and control (non-mulched) (Konopińsk & Żuber, 2013). The use of perforated polyethylene accelerated considerably the ripening of the fruits of the studied varieties by approximately two weeks and significantly increased the yield and profitability of the early fruit harvest (in July and August) as compared to the control treatment. The conclusion was that foil mulching can be implemented in large-scale early-fruiting raspberry production to prolong the summer-autumn harvest period, as has also been confirmed by other findings (Lewandowski et al., 2015). Experiments with raspberries mulched with a polyethylene film in Sweden evidenced that, with adequate control of major crop pests, the organic raspberry production of both non-remontant and remontant raspberry varieties was economically viable (Svensson, 2016).To maximize economic returns, many researchers have recommended optimization of the use of raw materials (Coelli, 1998; Thanassoulis, 2001; Onut & Soner, 2006). In this respect, Manolova (2005) identified the significance of production area size and proposed growing raspberries on areas larger than 10 da for achieving economies of scale.

The purpose of this study was to investigate the economic effectiveness of an innovative technology for organic raspberry production using different types of polyethylene mulching film and its impact on yield structure and economic performance of raspberry plants of the Willamette variety.

Materials and Methods

The study was conducted during the period 2017–2018 in a biological (i.e., organic) raspberry plantation of the Willamette variety, established in the autumn of 2010 in the experimental station field at Kostinbrod, affiliated to the Institute of Agriculture (Kyustendil, Bulgaria). The experiment was set up with raspberry plants of the by the method of the long plots (Shanin, 1965), each with an area of 10 m^2, with four treatments in four replicates: V0, control (flat bed, no mulching); V1, high bed, no mulching; V2, high bed, gray polyethylene mulching; V3, high bed, black polyethylene mulching. Foliar spraying with registered by the Bulgarian Food Safety Agency (BFSA) organic fertilizers was performed during the growing season.

Before soil with polyethylene film, the experimental plants were cut to the soil surface. In the row, pre-planting organic fertilization with Vita Organic fertilizer (ECORE Ltd., Novi Iskar, Bulgaria), certified for organic production application, was carried out at a dose of 250 kg/da. High beds (15–20 cm) were manually formed, and then the pre-perforated polyethylene canvas was laid under the form of two-row strips. The distance between two adjacent strips was 250 cm; it was 35 cm between the rows of the strips and 35 cm between the plants in a row.

Analysis of the economic performance was done by determination and comparisons of the values of the following indicators: production costs, gross production, and net income and net cost.

Results and Discussion

Sustainability can be assumed as the result of past experience, the adoption of agricultural production approaches that achieve high yields and profits while preventing degradation of natural resources (Kovačević & Milošević, 2015). Furthermore, profitability in organic agriculture is usually higher than that of conventional, which is caused by the larger returns due to the higher price of organic produce on the basis of preferences of consumers to pay more because of health or environmental awareness. More importantly, that better profitability originates from overall holistic benefits of the sustainability of organic farming rather than being its main purpose.

High fruit quality and yields of raspberries can be obtained by the introduction of new cultivation technologies, including covering (covers and tunnels), cultivation on raised beds, mulching, and optimal fertilization and irrigation. The identification and improvement of such management methods is even more important due to the lack of registered herbicides for dicotyledonous weed control, especially for organic production, leading to cost-consuming hand weeding (Król-Dyrek & Siwek, 2015). In this respect, the use of different types of mulches in the cultivation of many species is valuable and warrants further investigation due to their positive impact on plant growth and yield (Briassoulis, 2007; Moreno & Moreno, 2008). Sredojević et al. (2013) reported the dependence of profitability of investing in raspberries on a number of factors, including market conditions, supply, demand, input and output parities, among others. Moreover, Kljajić et al. (2017) found that the profitability level achieved in raspberry production depended on the aggregate production volume and the purchase prices, and could thus be increased by production cost reduction, increased yield per unit area, and by optimized organization of raspberry production and purchase. An important specificity of this production was the greater labor force required, which contributed to achieving positive social effects by the employment of the local population.

In the present study, we found that the average total production costs for the experimental period for growing of 1 da of raspberry plantation of the Willamette variety ranged from 384 to 928 lv/da (Figure 1). Although, the mechanized costs in all treatments were equal, differences were found in the labor costs, which were originated from the variations in the conditions of the specific treatments examined and the sizes of the average yields. The material costs also varied, which was associated with the differences in the values of the investments made.

Our detailed analysis showed that the costs incurred for the purchase of polyethylene foil and labor during the mulching with a plastic canvas amounted to 119 lv/da. In the

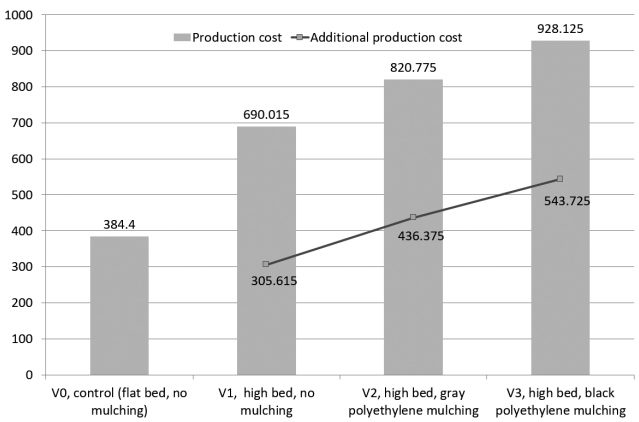

Fig. 1. Production costs of the studied treatments, lv/da. The red dots and line denote the additional costs incurred as compared to those in the control treatment

high-bed treatment, additional production costs of 306 lv/da were made, which were higher than those in the control; in the gray polyethylene mulching these costs were 436 lv/da, whereas in the black polyethylene treatment they reached 544 lv/da.

Nevertheless, it is noteworthy that the additional costs of mulching with polyethylene in each of the years and on average for the whole study period were associated with an increased average yield, which is in agreement with the results of an earlier studies, where the application of mulches and other covers improved the vegetative and reproductive manifestations, resulting in increased height of canes and higher weight of raspberry fruits (Król-Dyrek & Siwek, 2015; Mladin et al., 2008; Xu et al., 2014). Another study on blackberry also established the high effectiveness of mulching; the annual canes in the first year of the experiment in the mulched plants were19.4% more than those without mulch, and approximately 54% more annual canes were obtained in the second year in the mulched ones (Rom, 2001). Krawiec et al. (2013) confirmed that more canes per plants were formed by 'Polka' raspberries covered with flat covers with polypropylene (PP) non-woven fabrics as compared to those that were not covered.

In the black polyethylene mulching treatment of our investigation, the additional fruit production was 157 kg/da, followed in a descending order by that in the gray polyethylene mulching treatment – 93 kg/da, and the one in the treatment with high bed without polyethylene mulching – 13 kg/da.

As expected, the value of the gross production in the treatments studied followed the trend of the change in the average yield. Compared to the control, the value of this indicator was 4.4% higher in the high-bed treatment, 32.7% in the high bed mulched with gray polyethylene, and 53.8% higher in the high bed mulched with black polyethylene. Xu et al. (2014) also established that the application of high tunnel in the 'Polka 'raspberry variety increased the yield by 56.6% as compared to an umbrella-like structure; moreover, 2.3-fold increase was observed as compared to the yield measured in the open field. Importantly, the use of reflective mulch in this examination significantly increased the yield: by 13.6% in the high tunnel, 14.8% under the umbrella-like structure, and 29.5% in the open field.

Interestingly, the net income in the present study did not follow the trend of the change in the gross production since the cost incurred for the setting up of each of the specific treatments was much higher than that for the establishment of the control (Figure 2). In the black polyethylene mulching, the additional costs incurred were offset and the net income was the highest (649 lv/da).

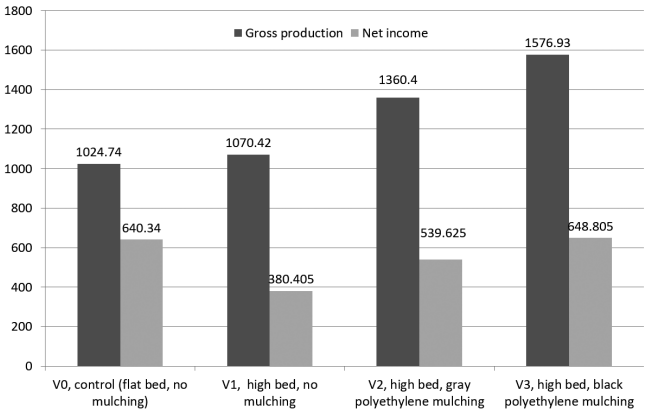

Fig. 2. Gross production and net income of the studied treatments (lv/da)

The use of mulching led to an increase in the average yield of the experimental plants from 288.9 to 445.45 kg/da, which constitutes a rise by 54% (Figure 3). On average for the study period, as well as in each of the years, the black polyethylene mulching yielded better productivity results than the other compared treatments. In 2017, the increase of the yield compared to that of the control was 47%, whereas it was 40% higher than that in the high bed and 1.3% higher than the one in the grey polyethylene mulching treatment. The yields of all treatments in 2018 were higher than those in 2017: the increase versus the control is by 154 kg, in the high bed by 157 kg., in the grey polyethylene mulching by 148 kg, and in the black polyethylene mulching the remarkable 266.9 kg. Therefore, there is a long-term, accumulating influence of mulching on the yield. In 2018, the trend for yield increase versus the control was maintained in all studied treatments.

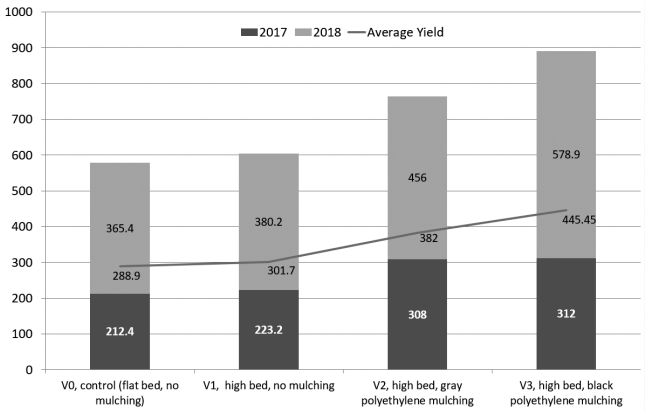

Fig. 3. Average yield of the studied treatments (kg/da)

Raspberry production is profitable, but to achieve greater returns, a number of preconditions should be fulfilled, such as proper selection of varieties based on the natural conditions in each specific location, optimal production technology, etc. (Kljajić, 2012). An important criterion for the economic evaluation of production is the cost of production, which is determined by the ratio of the average yield to the amount of the production cost. Due to the lack of additional costs in the control treatment of the present investigation, it had the lowest production cost (1.33 lv/kg). The costs in the other treatments examined was within the range 2.08–2.29 lv/kg, which in agreement with the conclusion of Kumanov (2016) that raspberry production was not profitable at a sale price under the threshold of 1.50 lv/kg. Investment is usually required to raise the production volume, reduce operating costs, increase work process performance, promote export, etc. Therefore, the ultimate goal is to enhance the operating results of a given entity and achieve a more considerable difference between current revenues and expenses (Sredojević, 2009).

Production efficiency is expressed by the revenue and cost efficiencies. The ratio of income to cost is considered an important performance indicator in business practice that characterizes the ability of a production system to profit from the invested funds. On the other hand, revenue efficiency is determined by its efficiency coefficient, which indicates the cost in lv, incurred to receive 1 lv of revenue. In all treatments examined in this investigation, the value of this indicator was lower than 1, which indicates that the revenue received was greater than the cost incurred. Its lowest value was obtained in the control (0.38), whereas the highest value (0.64) was determined in the high-bed treatment without mulching (Figure 4).

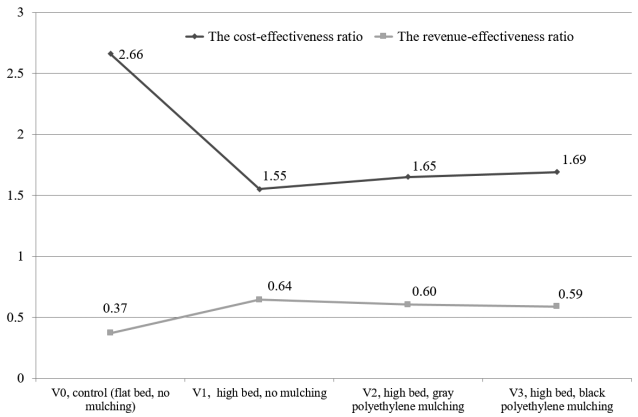

Fig. 4. The cost-effectiveness and the revenue-effectiveness ratio

The cost-effectiveness ratio is reciprocal to the revenue efficiency ratio and is expressed by unit of revenue earned by incurring a unit of cost. The size of this ratio in the present study is greater than 1, *i.e.*, the revenue generated is higher than the cost incurred. We obtained the following values of the revenues: 1.55 lv for the high bed, 1.66 lv for the mulching with gray polyethylene, and 1.70 lv for the mulching with black polyethylene.

Conclusion

In this study, the additional cost for foil mulching in organic raspberry production was 119 lv/da. In general, polyethylene mulching contributed to a higher average yield. The highest additional fruit production (157 kg/da) was produced in the black polyethylene mulching treatment. Notably, the gross production of the experimental treatments was higher than that of the control: by 4.4% in the high bed without mulching; by 32.7% in the high bed, mulched with gray polyethylene; and by the remarkable 53.8% in the high bed, mulched with black polyethylene.

Therefore, black polyethylene mulching was identified as the most economically viable treatment for organic raspberry production of the Willamette variety of all treatments examined in this study. The findings of the present investigation can serve as a foundation and complement for further research on improving the economic performance parameters of organic raspberry production in Bulgaria through optimization of alternative agricultural management practices and contribute to the database of experimental results obtained on that topic across different agro-ecological, species, and varietal conditions in Europe and globally.

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