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ORIGINAL ARTICLE / ORIGINALBEITRAG

Effect of Sawdust and Foil Mulches on Soil Properties, Growth and Yield of Black Currant

Svetlana M. Paunović[1] · Mira Milinković[1] · Marijana Pešaković[1]

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Abstract

The objective of this study was to determine the effect of sawdust and black foil mulches on soil properties, growth and yield of black currant (*Ribes nigrum* L.). A control (bare soil) was also included in the experiment. During three-year research, in all cultivation systems, there were changes in soil physical and chemical characteristics, including soil pH reduction, a decrease in coarse sand, silt and clay fractions, and an increase in fine sand fractions. The soil covered with sawdust had a stimulating effect on nutrient content (humus, N, P and K) and microbial count in the soil. Sawdust mulch favoured the modification of soil microclimate through temperature reduction and maintenance of moderate soil moisture throughout the growing season. The relationship of physical, chemical and biological properties of the soil in black currants under sawdust mulch contributed to an increase in fruit yield and bush growth compared to bare soil and foil mulch. On the other hand, black foil mulch allowed early soil warming and caused an increase in soil temperature and moisture during the growing season, which had not a positive effect on the tested parameters. The results indicated that mulching with sawdust is an effective method for growth and yield improvement in black currants.

Keywords Black currant · Sawdust mulch · Foil mulch · Soil properties · Growth · Yield

Einfluss der Mulchmaterialien Sägemehl und Folie auf Bodeneigenschaften, Wachstum und Ertrag der Schwarzen Johannisbeere

Schlüsselwörter Schwarze Johannisbeere · Sägemehl-Mulch · Folienmulch · Bodeneigenschaften · Wachstum · Ertrag

Introduction

In Serbia, the most common soil management system used in black currant plantings is continuous tillage. In the last several years, there has been a tendency to intensify currant production by establishing new orchards using modern growing technology incorporating covering the soil with different types of mulches. Mulching is an agricultural horticultural technique that uses organic material (sawdust, straw, leaves, compost, peat etc.) and synthetic material (paper, polyethylene film, foil etc.) to improve soil productivity. Mulching is used to retain moisture in the soil, modify soil temperature, supply nutrients, improve soil structure and control weeds. Organic mulches (Younis et al. 2012; Mupangwa et al. 2013) increase soil organic matter content, improve soil characteristics and maintain the water holding capacity and nutrients in the soil, whereas inorganic mulches (Kumar and Dey 2011; Liu et al. 2014) increase soil temperature, conserve soil moisture and control weeds. Generally, mulching facilitates soil moisture retention, increases water use efficiency by reducing evaporation, protects against seasonal fluctuations in soil temperature, improves physical, chemical and biological properties of the soil, and minimises weed infestation. Also, numerous studies have shown that mulching contributes to plant growth and yield increase (Kher et al. 2010; Shiukhy et al. 2014; Pandey et al. 2016).

Given the above, the objective of the study was to evaluate and compare the effect of mulching on agro environmental conditions in the soil, bush growth and yield of

✉ Svetlana M. Paunović
svetlana23869@gmail.com

[1] Fruit Research Institute Čačak, Department of Fruit Growing Technology, Kralja Petra I 9, 32 000 Čačak, Serbia

black currant to determine the need for mulching in currant orchards and recommend its implementation in currant production.

Materials and Methods

Plant Material

The research was conducted at the Fruit Research Institute, Čačak, Western Serbia, during 2015–2017. The experiment was laid out in a Randomised Block Design with three treatments: sawdust mulch, black foil mulch and bare soil (control). All treatments were replicated thrice, each containing 10 bushes. Standard cultural practices (pruning, fertilisation and drip irrigation) were used for all treatments. Drip irrigation system was installed at 30 cm dripper spacing.

Soil Temperature and Moisture

Soil temperature and moisture were measured at ten-day intervals starting from the growing season (March) until the end of the growing season (October). Soil temperature at 0–30 cm depth was determined by a thermometer with a measuring range –20 °C–+50 °C (Fig. 1), and

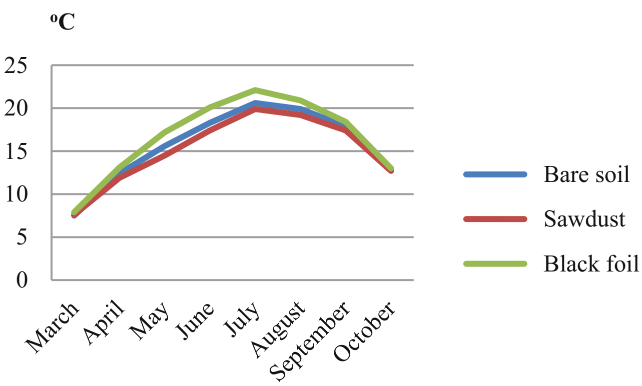

Fig. 1 Soil temperature at 0–30 cm depth

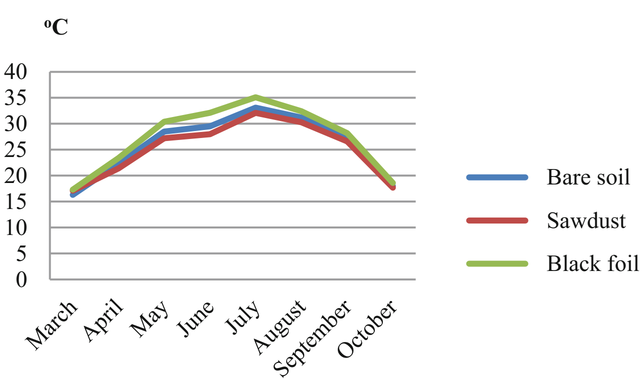

Fig. 2 Soil surface temperature

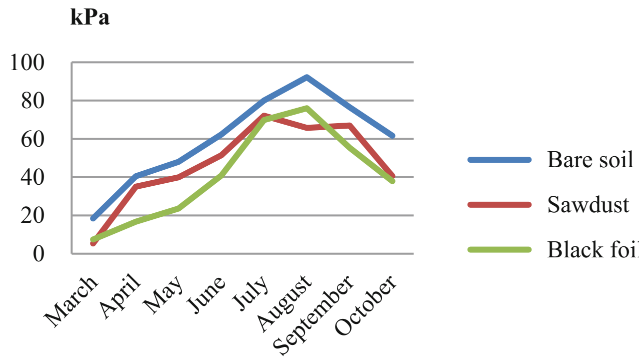

Fig. 3 Soil moisture at 0–30 cm depth

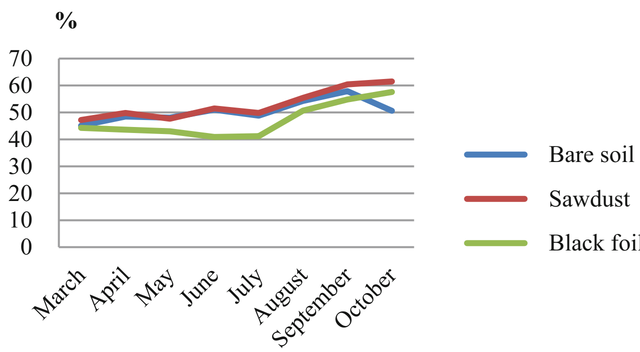

Fig. 4 Soil surface moisture

soil moisture was measured by a tensiometer—Watermark Sensor—with a measuring range of 0–200 kPa (Fig. 3). Temperature and moisture at the soil surface were measured by a P330 thermo-hygrometer with a measuring range of –40 °C–+70 °C for temperature and 0–99% for moisture (Figs. 2 and 4, respectively).

Agrochemical Characteristics Of Soil

Soil samples for testing agrochemical and textural characteristics were taken after fruit harvest. Chemical analyses were conducted using the following methods: pH value was determined potentiometrically with a combined glass electrode, by mixing soil with 1 M KCl solution (ratio 1:2.5) (CyberScan pH 510, Eutech Instruments, Singapore); $CaCO_3$ content was determined volumetrically, by a Scheibler calcium-meter; humus levels were measured by the Kotzmann method; nitrogen content was determined by the Kjeldahl method (Bremner and Mulvaney 1982); readily available phosphorus was assessed colorimetrically, and readily available potassium was measured by flame photometry (the AL method according to Egner et al. 1960). The analysis of soil texture involved examination of soil aggregate composition by sieving and sedimentation of size fractions at 0–30 cm soil depth. The interpretation of soil textural classes was presented using the textural triangle method of the WRB (2014).

Microbiological Analysis Of Soil

Soil samples for microbiological analysis were taken at the end of the growing season. Total numbers of microorganisms, ammonifiers, fungi, actinomycetes and oligonitrophils were enumerated using soil agar, MPA medium, Czapek's medium, Krasilnikov's medium and Fyodorov's medium, respectively. *Azotobacter* numbers were determined on Fyodorov's medium by the drop plate method (Pochon and Tardieux 1962). Total microbial count and numbers of fungi, ammonifiers, actinomycetes, *Azotobacter* and oligonitrophils were determined as colony forming units (CFUs) on agar plates by Serial Dilution Plate method. The incubation for total microbial count and numbers of actinomycetes took 7 days, 3 days for ammonifiers, and 5, 4–5 and 2 days for fungi, oligonitrophils and *Azotobacter*, respectively, at 28 °C. Total microbial count was calculated per 1.0 g of absolutely dry soil.

Plant Growth and Yield

Bush height and bush width were measured by a metre at the end of the growing season, and expressed in cm. Yield per bush was determined by weighing harvested fruit on an ACS system electronic scale, whereas yield per unit area was the result of multiplying yield per bush by number of bushes per hectare.

Statistical Analysis

The experimental data obtained during the three-year period were subjected to statistical analysis using Fisher's two-factor analysis of variance–ANOVA. Significant differences between the means of the tested factors and interaction means were determined by LSD test at a significance level of $P \leq 0.05$.

Results and Discussion

The results of the analysis of soil texture before black currant orchard establishment showed that the soil was classified as sandy clay loam (Table 1). At the end of the experiment, in all soil management systems, there were changes in soil textural characteristics (Table 2).

In both unmulched and mulched soils, the content of fine sand increased and that of the other size fractions (coarse sand, silt and clay) decreased. Sawdust mulch led to an increase in fine sand content (7.7%), and a decrease in clay (6.4%) and silt (1.3%) contents, whereas changes in the content of coarse sand (0.01%) were in minimum. Foil mulch caused a decrease in coarse sand (0.94%) and clay (4.1%) contents, and an increase in silt (2.8%) and fine sand (2.2%) contents. Changes in soil textural characteristics were also found in bare soil, where the contents of coarse sand (0.44%), silt (0.7%) and clay (4.0%) decreased, and the content of fine sand increased (5.1%). Overall, in all soil management systems used in the black currant orchard, there was an increase in physical sand fractions and a decrease in physical clay fractions. Due to changes in soil texture during the experiment, the soil under foil mulch and bare soil at the end of the experimental period remained sandy clay loam (53.2–56.6% physical sand and 43.4–46.8% physical clay), whereas the soil under sawdust mulch was classified as sandy loam (59.6% physical sand and 40.4% physical clay).

As far as agrochemical characteristics are concerned, before orchard establishment, the soil was slightly acid and moderately supplied with humus and N, and had high levels of P and K, without $CaCO_3$ (Table 3).

At the end of the experimental period, the soil exhibited changes in agrochemical characteristics, both under saw-

Table 1 Textural characteristics of the soil before black currant orchard establishment

Soil characteristic	Coarse sand % 2–0.2 mm	Fine sand % 0.2–0.02 mm	Silt % 0.02–0.002 mm	Clay % <0.002 mm	Physical sand >0.02 mm	Physical clay <0.02 mm
0–30 cm	1.04	50.9	23.5	24.6	51.9	48.1

Table 2 Textural characteristics of the soil at the end of the experimental period

Soil characteristic	Coarse sand % 2–0.2 mm	Fine sand % 0.2–0.02 mm	Silt % 0.02–0.002 mm	Clay % <0.002 mm	Physical sand >0.02 mm	Physical clay <0.02 mm
Bare soil	0.60	56.0	22.8	20.6	56.6	43.4
Sawdust	1.03	58.6	22.2	18.2	59.6	40.4
Black foil	0.10	53.1	26.3	20.5	53.2	46.8

Table 3 Agrochemical characteristics of the soil before black currant orchard establishment

Soil characteristic	pH	$CaCO_3$ %	Humus %	N %	P_2O_5 mg 100 g^{-1}	K_2O mg 100 g^{-1}
0–30 cm	6.14	0.00	3.95	0.20	26.50	27.00

Table 4 Agrochemical characteristics of the soil at the end of the experimental period

Soil characteristic	pH	$CaCO_3$ %	Humus %	N %	P_2O_5 mg 100 g^{-1}	K_2O mg 100 g^{-1}
Bare soil	4.21	0.00	2.74	0.14	25.57	26.87
Sawdust	4.66	0.00	4.95	0.25	36.04	44.63
Black foil	3.82	0.00	2.56	0.13	21.18	25.58

dust and foil mulches and on bare soil (Table 4). In all cultivation systems, there was a decrease in soil pH, which is a major chemical property of the soil directly affecting the uptake of nutrients and soil microbiological activity (Liu and Hanlon 2012). The highest decrease in soil pH was found in foil mulched soil (2.32), and the lowest in the soil mulched with sawdust (1.48). These results can be supported by the findings of Billeaud and Zajicek (1989), who observed that soil pH decreases when organic mulches are used and that this decrease is proportional to the depth of these mulches. In contrast, Broschat (2007) determined that most soil mulching materials had no effect on soil pH.

The soil mulched with sawdust showed an increase in humus content (1.0%) and N levels (0.05%), whereas their decrease was registered in bare soil and foil mulched soil. The results are in agreement with the findings of Muhammad et al. (2009) and Kumar and Lal (2012), who observed that organic mulches affect the soil nutrient relationships and are effective in reducing nutrient leaching and improving the nitrogen balance. However, the results are inconsistent with Billeaud and Zajicek (1989) and Sønsteby et al. (2004), who found that organic mulches reduce nitrogen availability in the soil compared to unmulched soil. As regards P and K contents, at the end of the experimental period, the content of P increased by 9.44 mg 100 g^{-1} and that of K by 17.63 mg 100 g^{-1} under sawdust mulch treatment, whereas their content in bare soil and foil mulched soil did not significantly change, despite showing a decreasing tendency. Larsson (1997) found that the release of nutrients during organic mulch decomposition increased the levels of available P and K in the soil. The author associated the increased availability of soil P with the texture of the mulch, while the increased amount of available K was associated with both rapidly decomposing mulches and slowly decomposing materials, such as sawdust and straw. Also, Sønsteby et al. (2004) and Broschat (2007) reported that organic mulches (straw, grass, cypress, bark and eucalyptus) significantly increased the levels of available phosphorus and available potassium in the soil. The conclusions of these authors are in agreement with the results of the present research.

Mulching stimulates microorganisms in the soil (algae, fungi, bacteria, actinomycetes) as the result of well-aerated soil conditions and moisture and temperature uniformity, thus facilitating the decomposition of organic matter in the soil and the release of nutrients required for crop growth (Kumar and Lal 2012). During the three-year experimental period (Table 5), there was no difference between bare soil and sawdust mulch in the numbers of *Azotobacter* (28.31 and 30.34 CFU · 10^2 g DM $soil^{-1}$, respectively), ammonifiers (58.15 and 60.82 CFU · 10^5 g DM $soil^{-1}$, respectively) and oligonitrophils (31.00 and 33.16 CFU · 10^5 g DM $soil^{-1}$), nor in total microbial count (79.17 and 85.50 CFU · 10^6 g DM $soil^{-1}$, respectively). Low temperature and moderate moisture of the soil mulched with sawdust during the growing season had a stimulating effect on the numbers of fungi (37.31 CFU · 10^5 g DM $soil^{-1}$) and actinomycetes (33.68 CFU · 10^5 g DM $soil^{-1}$). Microbial activity was lowest in the soil mulched with black foil, most likely due to high soil temperatures and higher soil moisture throughout the growing season.

Table 5 Numbers of microorganisms in the soil

	Total microbial count CFU10^6 g DM $soil^{-1}$	Numbers of microorganisms				
		Azotobacter CFU10^2 g DM $soil^{-1}$	Ammonifiers CFU10^5 g DM $soil^{-1}$	Oligonitrophils CFU10^5 g DM $soil^{-1}$	Fungi CFU10^5 g DM $soil^{-1}$	Actinomycetes CFU10^5 g DM $soil^{-1}$
Bare soil	79.17 ± 5.42 a	28.31 ± 1.53 a	58.15 ± 8.93 a	31.00 ± 3.01 a	22.83 ± 3.66 b	22.64 ± 1.51 b
Sawdust	85.50 ± 1.27 a	30.34 ± 0.77 a	60.82 ± 1.00 a	33.16 ± 1.31 a	37.31 ± 1.50 a	33.68 ± 1.46 a
Black foil	43.68 ± 6.04 b	19.68 ± 0.58 b	24.83 ± 1.27 b	26.15 ± 1.28 b	33.67 ± 2.71 a	26.65 ± 0.92 b

These results can be supported by the findings of Shashidhar et al. (2009), who reported more numbers of bacterial, fungal and actinomycete colonies in mulched plots than in the other treatments. Also, Aguero et al. (2008) found an increased content of microbial flora and its enhanced activity in mulched soil in relation to non-mulched soil. The ensuing changes in the structure of microbiological characteristics and processes in the soil may be attributed to changes in soil physical and chemical properties (Stark et al. 2007). Changes in the numbers of some systematic and physiological groups of microorganisms in the soil and their activity can be used as indicators of potential and effective production capacity of the soil (Hole et al. 2005).

Soil temperature during the growing season significantly varied depending on soil management system. At the beginning of the growing season (March) and at its end (October), temperature differences between mulched and unmulched soil were lowest (Figs. 1 and 2).

Sawdust mulch reduced soil temperature during the growing season. From March until October, sawdust mulched soil at 0–30 cm depth was colder by 0.6 °C on average, and soil surface temperature was reduced by 0.9 °C on average compared to bare soil temperature. The temperature difference between bare soil and sawdust mulch at the root growth zone was highest at fruit set during May (1.1 °C), whereas the highest difference at the soil surface was at fruit harvest during June (1.5 °C). A high temperature difference at the soil surface was also observed during May (1.3 °C) and July (1.0 °C). From August until October, there was a gradual decrease in soil temperature difference; at the end of the growing season (October), soil temperature difference was 0.1 °C at 0–30 cm depth and 0.3 °C at the soil surface. The results are consistent with the results of Larsson (1997), who found an increase in soil temperature in unmulched control compared to organic mulch treatment. As observed by the author, organic mulches delay the onset of heat transfer through the soil, minimise the diurnal temperature variation, lower the maximum temperature reached and reduce the initial cooling rate. On the other hand, black foil warmed up the soil and increased soil temperature faster. Soil temperature at 0–30 cm depth was increased by 1 °C on average throughout the growing season compared to bare soil temperature. The temperature difference between bare soil and black foil mulch was highest at fruit harvest (1.8 °C). However, higher soil temperatures were also measured in May (1.6 °C) and July (1.5 °C). Temperature at the black foil mulch surface was also significantly higher than the control treatment. As foil mulch can absorb more heat, temperature was directly increased by 1.4 °C on average during the growing season. The highest difference in temperature was recorded in June (2.6 °C), followed by July (2.0 °C), whereas the temperature difference between foil mulch and bare soil decreased in August to 1.2 °C, in September to 1.1 °C and in October to 0.6 °C. The present results are comparable with those of Larsson (1997), who recorded that soil temperature under black foil was higher than that of bare soil throughout the season, with the largest difference (3.2 °C) occurring in mid-June. In a study by Shiukhy et al. (2014), bare soil was 7.4 °C colder on average compared to the soil mulched with foil, whereas Kumar and Dey (2011) reported an increase in soil temperature from 0.4 to 2.5 °C in black foil mulch treatment. In strawberry and raspberry orchards, foil mulch treatment increased soil temperature by 17 °C compared to unmulched soil (Pinkerton et al. 2002).

Mulching affected soil moisture during the experimental period 2015–2017 (Figs. 3 and 4). Sawdust mulch had a positive effect on soil moisture in spring and summer. The average difference in soil moisture between bare soil and sawdust mulch treatment at 0–30 cm depth throughout the growing season was 12.8 kPa. The difference was highest in August (26.5 kPa), and lowest in July (7.9 kPa). During the experimental period, moisture at the sawdust surface increased by 2.47% on average. At the beginning of the growing season in March and April, a 1.7% increase in moisture was recorded at the sawdust mulch surface compared to the control. In May, moisture at the sawdust mulch surface decreased by 0.4%, and increased on bare soil. However, the increase in moisture in the control was observed only in May, whereas moisture at the sawdust mulch surface steadily increased after May until the end of the growing season. The maximum difference in moisture of 10.9% between bare soil and sawdust mulch was found in October. As reported by Kuotsu et al. (2014), soil profile moisture content, water infiltration rate and hydraulic conductivity in mulched soil are significantly higher than in soil without cover.

During the growing season, soil moisture content under black foil mulch at 0–30 cm depth was significantly higher than under bare soil. The average difference in moisture between bare soil and foil mulch at 0–30 cm depth was 20.2 kPa. The highest difference was recorded in May (24.4 kPa), and the lowest in August (10.2 kPa). Soil surface moisture decreased by 5.27% on average during the growing season under foil than on bare soil. The lowest moisture values at the foil mulch surface were measured during summer (June and July), as attributed to a high degree of impermeability of foil mulching material and, hence, its direct effect in conserving soil moisture and reducing water loss through evaporation. The present results can be supported by Liu et al. (2014) and Bakshi et al. (2015), who showed that plastic mulch reduces water evaporation. In strawberry orchards, Kumar and Dey (2011) evaluated moisture content in unmulched soil and soil mulched with straw and

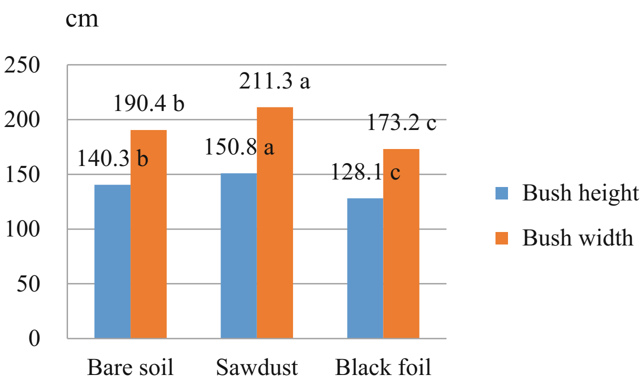

Fig. 5 Bush height and bush width

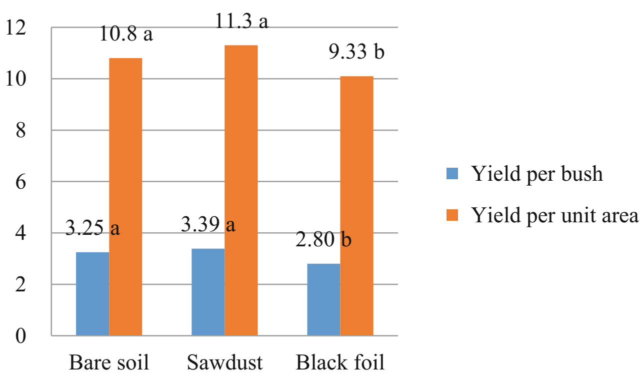

Fig. 6 Yield per bush (kg bush^{-1}) and per unit area (t ha^{-1})

foil mulch and determined that foil-mulched soil increased moisture content from 2.8 to 12.8%.

Black foil mulch allowed early soil warming, increased soil temperature and prevented evaporation, thus contributing to moisture conservation in the soil throughout the growing season compared to bare soil and sawdust mulch. On the other hand, sawdust mulch decreased soil temperature and temperature variations in the soil during spring and summer and ensured moderate soil moisture. Also, sawdust mulch stimulated an increase in nutrient levels and microbial activity in the soil. The relationship of physical, chemical and biological properties of the soil in currants grown under sawdust mulch led to an increase in bush yield and bush growth of black currants (Figs. 5 and 6).

The highest values for bush height (150.8 cm) and bush width (211.3 cm) were recorded under sawdust mulch, and the lowest in plants grown under foil (bush height—128.1 cm and bush width 173.2 cm). As regards bush yield, there was no significant difference between bare soil and sawdust soil, whereas the lowest yields per bush and per unit area were produced under foil. The results indicated that black foil mulch, due to its ability to increase temperature and moisture in the soil, did not favour the tested parameters. Larsson (1997) reported that black currant yield increased under plastic mulch although the values did not significantly differ from those obtained for bushes grown under organic mulch. However, the author stressed that the prolonged use of sawdust and plastic mulches causes a reduction in bush growth and bush yield in later years of cultivation. The 26% increase in yield per bush in black currants grown under foil mulch, as compared to bare soil, was also recorded by Dale (2000). The author recommended the use of black foil for mulching in northwestern parts of Europe given the ability of foil mulch to reduce the loss of water from the soil, resulting in increased yields. Higher values of yield under black polythene mulch indicate a greater role of elevated soil temperature as a catalyst for root activities, including the uptake of water and nutrients (Pandey et al. 2016). Moreover, Kivijarvi et al. (2005) determined an increase in bush volume in black currants grown under foil mulch compared to bare soil. Positive effects of black foil mulch on fruit yield and quality were recorded in blueberries (Magee and Spiers 1995), strawberries (Kher et al. 2010; Shiukhy et al. 2014) and raspberries (Neuweiler and Heller 2000), when compared with bare soil or organic mulches. The conclusions of these authors are not in agreement with the results of the present research.

Conclusion

The results indicated that sawdust mulch is the most suitable mulching material in commercial black currant orchards given its potential to improve physical, chemical and biological properties of the soil, thus directly leading to an increase in bush growth and yield of black currants.

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Conflict of interest S.M. Paunović, M. Milinković and M. Pešaković declare that they have no competing interests.

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