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Mulch type and application of manure and composts in strawberry (*Fragaria* × *ananassa* Duch.) production: impact on soil fertility and yield

Ranko CABILOVSKI[1], Maja MANOJLOVIC[1], Darinka BOGDANOVIC[1], Nenad MAGAZIN[1], Zoran KESEROVIC[1], Bishal K. SITAULA[2]

[1]University of Novi Sad
Trg Dositeja Obradovica 8, Novi Sad, Serbia
E-mail: ranko@polj.uns.ac.rs

[2]Norwegian University of Life Sciences
Ås, Norway

Abstract

The objective of this research was to quantify the effect of the application of organic fertilizers: farmyard manure, vermicompost, spent mushroom compost, under two different ground cover management systems (black polyethylene and wheat straw mulch) on soil nutrient levels and strawberry yield during a two-year production cycle. The application of organic fertilizers, in the amounts equivalent to 170 kg ha^{-1} N, had the greatest impact on the concentration of available phosphorus, which was significantly higher on fertilized plots than on the control even two years after the application. The plots fertilized with farmyard manure and mushroom compost had higher concentrations of available potassium than the control, while the application of vermicompost did not affect the concentration of available potassium in the soil. The application of composts did not affect the concentration of available microelements in the soil, while the concentrations of Fe, Zn and Cu in the year of the organic fertilizers application were significantly higher on farmyard manure fertilized plots than on the control. The application of all three organic fertilizers had a significant effect on the mineral N concentration in the soil only in the year of the application and the following spring. However, the plots covered with polyethylene mulch had a higher mineral N concentration than the control at all sampling times. The concentration of available microelements was significantly higher in soil covered with black polyethylene mulch than in soil covered with straw mulch. Preplant application of organic fertilizers led to increase of yield, ranging from 14.3% in vermicompost treatmet to 17.3% in the farmyard manure treatment in relation to the control, only in the 1st fruiting year. However, the application of polyethylene mulch facilitated a higher strawberry yield than straw mulch in both fruiting years.

Key words: nutrient availability, organic fertilizer, residual effects.

Introduction

Growing environmental concern and spreading of production systems such as organic, biodynamic or sustainable agriculture, where the usage of synthetic fertilizers is limited or completely excluded, has led to increased public and scientific attention to organic fertilization. The application of organic fertilizers not only supplies the plants with necessary elements but also plays an important part in the process of enhancing soil fertility by improving its structure and hydro-physical properties, increasing organic matter concentration and reducing the application of synthetic fertilizers (Grandy et al., 2002). Unlike mineral fertilizers, organic fertilizers have a longer-lasting impact on chemical properties of the soil and consequently on the yield of grown crops, even several years after application (Gutser et al., 2005). Depending on their chemical composition, organic fertilizers mineralize at different rates (De Neve et al., 2004), which is why their effectiveness as sources of nutrients is also different (Pansu, Thuries, 2003). Uncontrolled and excessive use of organic fertilizers can lead to adverse effects such as nitrogen (N) leaching into ground water, release of heavy metals and harmful organic substances into soil, spread of weeds, soil pollution with harmful microorganisms, etc. This is why EC Regulation 1804/1999 of organic production and Nitrates Directive (Council Directive 91/676/EEC, 1991) limit the maximum annual incorporation of organic fertilizers to the amount equivalent to 170 kg ha^{-1} N.

Due to its low height and shallow root, strawberry is one of the fruit species most sensitive to weeds (Johnson, Fennimore, 2005). Since in strawberry production it is necessary to suppress weeds during the whole vegetation period, which requires a high number of man-hours and increases production costs, especially in organic systems, where the application of herbicides is not allowed, one solution was to cover the soil with different types of mulch. Mulching in strawberry production not only has a positive effect in weed management but, depending on the sort of material used, can have other effects on the crop and physical and chemical properties of the soil (Neuweiler et al., 2003; Obalum, Obi, 2010).

Plowing under organic fertilizers in autumn is a common method of their application (Smith et al., 2001). However, the results of some authors (Hansen et al., 2004) show that spring application of organic fertilizers, due to better synchronization of crops needs and the release of nutrients has a greater impact on crop yield in the year of application. If strawberry is grown as a perennial crop, on the same plot for two or three consecutive years, the only opportunity to apply solid organic fertilizers is at planting time, which in agroecological conditions in Serbia commonly occurs in the second half of the year (July–August).

The objective of this research was to quantify the effect of the application of organic fertilizers in amounts equivalent to 170 kg ha^{-1} N at strawberry planting time on the chemical properties of the soil and strawberry yield during a two-year production cycle, under two different ground cover management systems.

Materials and methods

Experimental site. The studies were conducted at Research Field for Fruit Growing of the Faculty of Agriculture, University of Novi Sad, Serbia (45°20′24.44″ N, 19°50′22.32″ E) from 2009 to 2011. The soil of the experimental site is *Haplic Phaeozem* (*PHh*), formed on loess terrace, which is the main soil type in Vojvodina (northern part of Serbia), covering 60% of agricultural land. The experiment plot had not been fertilized for the previous five years, and the basic physical and chemical properties of the soil were as follows: 1.26 g cm^{-3} bulk density, 0.27% coarse sand, 40.0% fine sand, 35.9% silt, 23.8% clay, pH 7.92 (in H_2O), 0.83% $CaCO_3$, 2.05% organic C, 0.181% total N, 11.32 C:N, 57 mg kg^{-1} AL-P_2O_5, 215 mg kg^{-1} AL-K_2O. The concentrations of available micronutrients in the soil extracted with diethylenetriaminepentaacetic acid-triethanolamine (DTPA-TEA) were: 2.06 mg kg^{-1} Fe, 18.56 mg kg^{-1} Mn, 0.89 mg kg^{-1} Cu and 1.26 mg kg^{-1} Zn. The experiment was conducted in the conditions of drip irrigation, without any additional fertilization during the growing seasons. The drip irrigation system was operated periodically during the period April–September (in each year) to maintain soil moisture tension between 15 and 25 kPa (measured by a tensiometer with the ceramic tip at 15 cm below the surface of the bed between two plants in a row). The total monthly precipitation and average air temperature during the experiment are given in Figure 1.

Experimental design and treatments. The experiment was conducted using a two-factorial split-plot completely randomized design, with ground cover management (mulch) as whole-plot factor and fertilization treatments in split-plots. Each split-plot consisted of ten uniform June-bearing strawberry (*Fragaria × ananassa* Duch.) plants cultivar 'Senga Sengana' in four replicates. Besides the control treatment (no fertilization), three different organic fertilizers: farmyard manure, vermicompost and spent compost from mushroom production, were incorporated into the surface soil layer (0–30 cm) one week before strawberry planting (23 July, 2009). Organic fertilizers were applied in amounts which were equivalent to 170 kg ha^{-1} N. The chemical compositions of the applied organic fertilizers are presented in Table 1.

Two lateral drip lines with drippers providing water (2 dm^{-3} h^{-1}) were installed and 50 µm-thick black polyethylene mulch and wheat straw were applied to cover the entire surface around the strawbery plants. The experiment was set up on raised beds 0.8 m wide and 15 cm high.

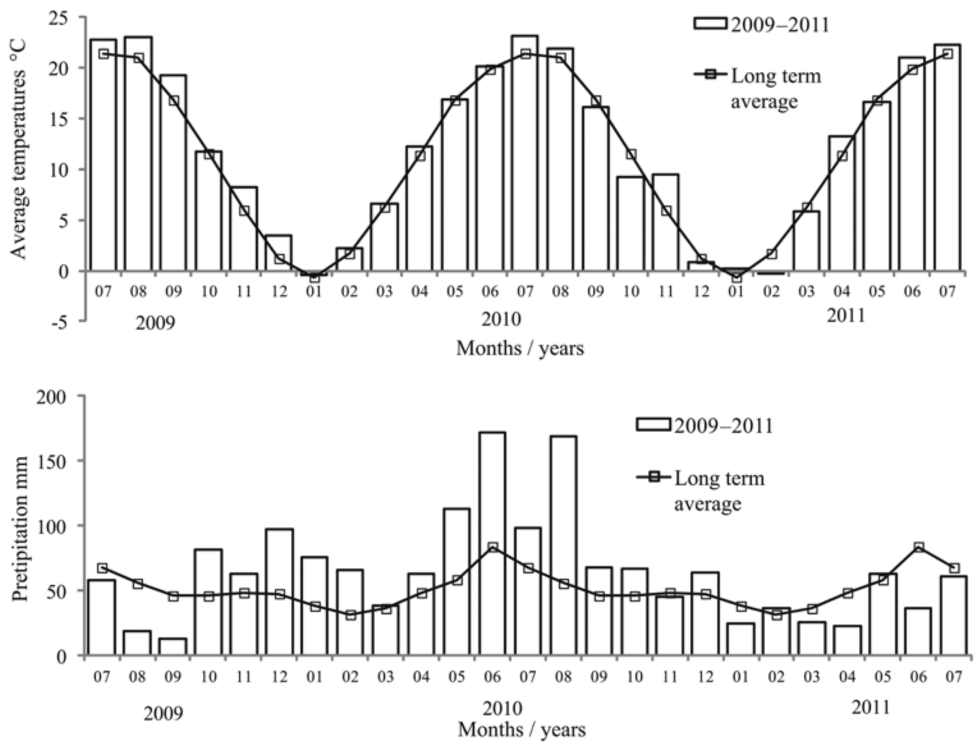


Figure 1. Total monthly precipitation and monthly average air temperature (2009–2011)

Table 1. Chemical composition of the organic fertilizers used in the experiment

Chemical properties	Organic fertilizers		
	vermicompost	mushroom compost	farmyard manure
Dry mater %	75.46	80.26	71.36
pH (in H_2O)	7.56	6.92	7.72
Total N %	1.99	1.65	1.71
Total C %	25.2	18.37	32.5
C:N	12.7	11.13	19.01
Total P_2O_5 %	3.02	2.27	2.03
Total K_2O %	1.26	1.81	2.81
Fe mg kg^{-1}	1054	1342	986
Mn mg kg^{-1}	171	230	126
Cu mg kg^{-1}	8.9	26.8	5.54
Zn mg kg^{-1}	45.2	53	35.8

Measurements and analytical determination. The pH value of the soil was determined in a suspension of soil and H_2O (1:2.5) using a meter Metrel MA 3657 pH ("Metrel", Slovenia). $CaCO_3$ content was determined volumetrically using a Scheibler calcimeter (HEDAS, Serbia). Total N and C content in soil was determined using an analyzer CHNS ("Elementar Vario EL", Germany). Plant-available phosphorus (P) and potassium (K) in the soil were extracted with a solution of 0.1 M ammonium lactate and 0.4 M acetic acid (pH 3.75), at a soil to solution ratio of 1:20 (w/v). The concentration of P was measured by spectrophotometry, while the concentration of K was measured by flame photometry. Mineral N concentration under field conditions during the vegetation was determined by the Wehrmann and Scharpf (1979) method. For the determination of plant-available fractions of Fe, Mn, Cu and Zn in the soil, samples were extracted with diethylenetriaminepentaacetic acid-triethanolamine (DTPA-TEA) buffer solution (0.005 M DTPA + 0.01 M $CaC1_2$ + 0.1 M TEA). For each sample, 20 mL of DTPA-TEA solution was added to 10.0 g of soil, shaken for 2 h on an orbital shaker, gravity filtered through filter paper, and analyzed by atomic absorption spectrometer "Shimadzu 6300" (Japan) with flame technique. Dry matter content of organic fertilizer was determined gravimetrically (70°C for 24 h). Total C and N contents were determined using an analyzer CHNS. After wet-digestion with a mixture of HNO_3:$HCIO_4$ (4:1, v/v), the concentrations of K, Fe, Mn, Cu and Zn concentrations in the organic fertilizer were determined using an atomic absorption spectrometer "Shimadzu 6300" with flame technique, while P concentration in the solutions was measured colorimetrically by spectrophotometer "Jenway 6105" (USA). Soil samples used to determine mineral N, available P and available K contents in the soil during strawberry vegetation consisted of two individual samples taken from every treatment repetition. The samples were taken two months after organic fertilizer application (10 October, 2009), and subsequently in spring, summer and autumn in 2010 (28 March, 10 June, 8 October), and spring and summer in 2011 (31 March, 6 June). The concentrations of available microelements (Fe, Mn, Zn and Cu) were determined in the samples taken two months after organic fertilizer application (autumn 2009), in summer 2010, and in summer 2011.

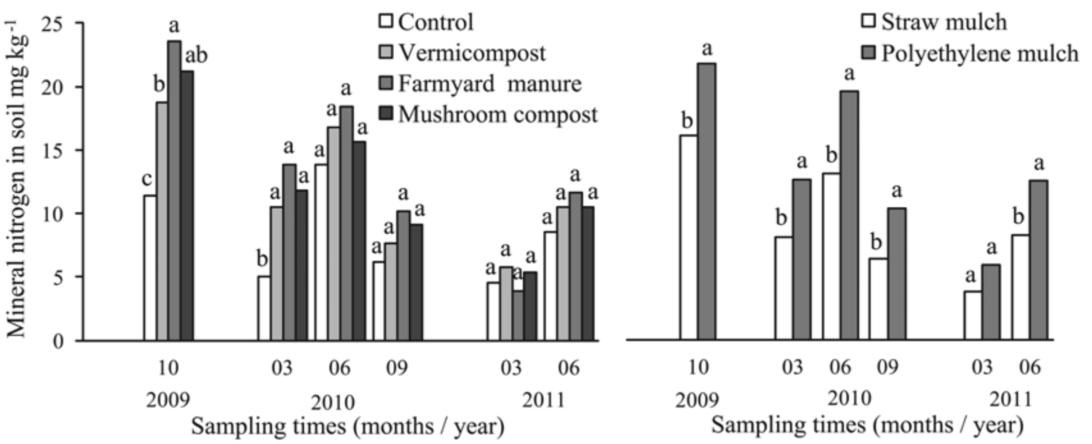
Total number of flowers was measured at the end of flowering of secondary flower series (12 April, 2010 and 16 April, 2011) by counting the flowers buds, open flowers and small-green fruits on three randomly selected plants per replicates. Total fruit yield was calculated by taking all the harvested fruit and thereafter, randomly selected 30 normal fruits (subsample), taken from each replicate at each harvest time, were used to calculate mean berry weight.

Statistical analysis. The results were subjected to analysis of variance (*ANOVA*) according to their experimental design, and treatment means were compared using the Turkey test ($P < 0.05$) with *STATISTICA 9* (StatSoft Inc., USA).

Results and discussion

Fertilization and mulch impact on concentrations of available N, P and K in the soil. Two months after the organic fertilizer application, in October 2009, the concentration of mineral forms of N (NH_4-N and NO_3-N) in the soil was significantly higher on the plots treated with organic fertilizer than on the control, and it ranged from 18 to 24.23 mg kg^{-1} N of the soil. In 2010 (the 1st fruiting year), mineral N concentration in the soil on the fertilized plots was significantly higher than the control only at the first sampling time, while in 2011 mineral N concentration on the fertilized plots did not differ significantly from the control. Significant differences among individual fertilization treatments were found only at first sampling time (October 2009), when mineral N concentration in the soil treated with farmyard manure was significantly higher than in vermicompost treatment, while at the other sampling times no significant differences were found (Fig. 2). After organic fertilizers are incorporated into the soil, the process of mineralization releases mineral forms of N and P. Because of their favourable chemical composition and primarily because of their C:N and C:P ratios (Gutser et al., 2005), all the three organic fertilizers released mineral forms of N and P in the year of application. However, the residual effect of the organic fertilizer on mineral N concentration was significant only at the first sampling time the following year (Fig. 2). Relatively short-lasting residual effect can be explained by the fact that the total amounts of applied fertilizers (170 kg ha^{-1} N) are relatively low when compared to those used by other authors (Ginting et al., 2003; Gutser et al., 2005), who obtained significantly longer-lasting effects of organic fertilizer application on mineral N concentration.

In the present study the fertilizers were applied in the second half of summer, when temperatures were very favourable for mineralization (Fig. 1). As soil humidity was maintained at 70–80% of field water capacity, most of N in organic fertilizer was mineralized in the year of application. Eghball (2000) suggests that only 11% of organic N from composted manure and 21% from noncomposted manure applied in autumn mineralized in the following year. Besides, a large amount of precipitation in the first half of 2010 could cause part of mineral N to run off into deeper layers of the soil, beyond the plants' root zone (Fig. 1), so the differences among individual fertilizer treatments from the second sampling time in 2010 till the end of the experiment were not statistically significant.



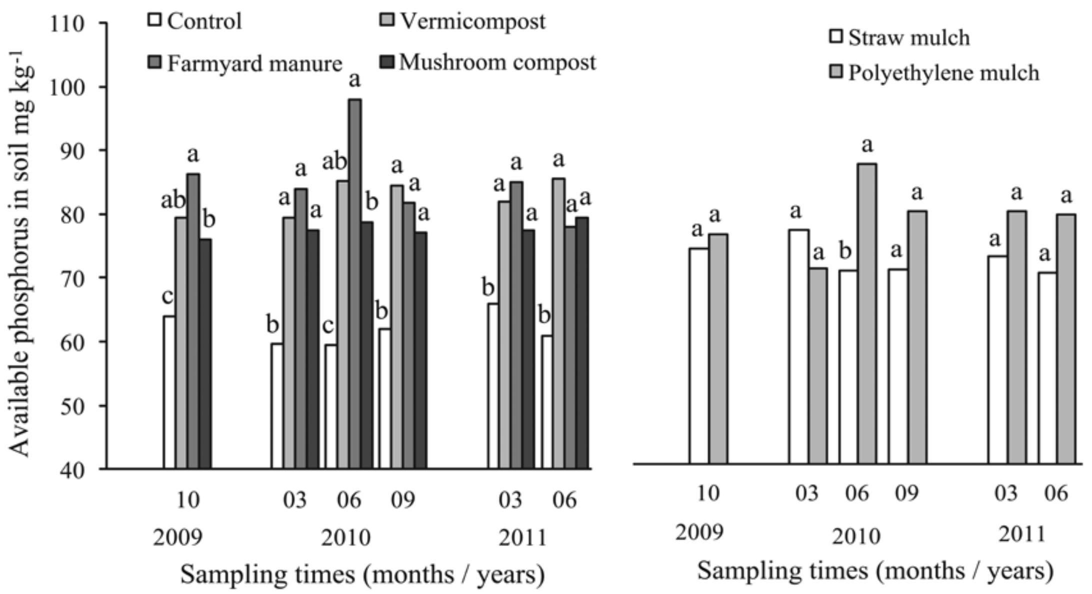
Note. Within one sampling time, values followed by different letters are significantly different at $P < 0.05$.

Figure 2. Concentration of mineral nitrogen (NH_4-N and NO_3-N) in the soil (0–30 cm)

From the first sampling time through to the end of the experiment, concentration of available P was higher on fertilized plots than on the control treatment. At the same time, only at some sampling times (October 2009 and June 2010) P concentration on the farmyard manure fertilized plot was significantly higher than on that fertilized with mushroom compost (Fig. 3).

Through the application of organic fertilizer different amounts of P were introduced into the soil (203 kg ha^{-1} P_2O_5, farmyard manure, 233 kg ha^{-1} P_2O_5, mushroom compost, 256 kg ha^{-1} P_2O_5, vermicompost). Due to a good C:P (Dao, Schwartz, 2010) of all three organic fertilizers, significant amounts of available P were released into the soil, but, unlike N, P concentration was significantly higher on fertilized plots than on the control even at the last sampling time (two years after the application of the organic fertilizer). This can be explained by the fact that fertilization introduced more P than N into the soil (Table 1), while N uptake by strawberry plants can be up to five times higher than P uptake (Tagliavini et al., 2005). Besides, the mobility of available forms of N in the soil is greater than that of P so possible losses are also greater (Zeng et al., 2008). Mohammadi et al. (2009) observed prolonged effects of available P five years after the application of organic fertilizers. Higher concentrations of available P on the plots fertilized with farmyard manure than on the plots fertilized with composts are probably caused by different availability of P in these fertilizers. Eghbal (2000) reports, that P availability in the first year after application was 85% for beef cattle manure and 73% for composted feedlot manure. Slightly lower P availability from composted manure indicates a chemical reaction of P during composting, which caused P to become less plant-available.

Mulching had a greatest impact on the concentrations of mineral forms of N in the soil. For the duration of the experiment, except in spring 2011 (2nd fruiting year), mineral N concentrations on the polyethylene mulched plots were significantly higher than on the straw mulched ones (Fig. 2). However, polyethylene mulching had a positive effect on available

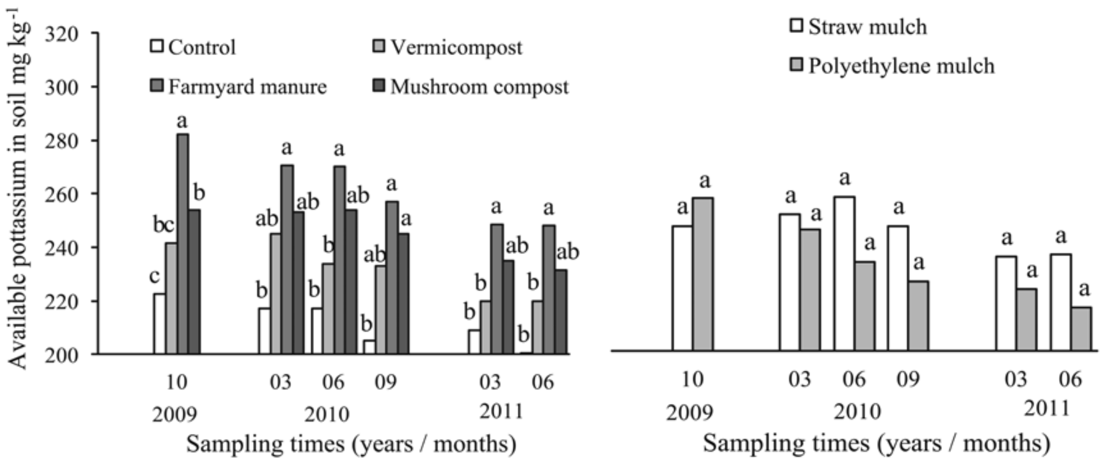


Explanation under Figure 2

Figure 3. Concentration of available phosphorus (P_2O_5) in the soil (0–30 cm)

P concentrations in the soil only at one sampling time (summer 2010); while at all the other sampling times there were no significant differences between the individual treatments (Fig. 3).

In our research, the application of organic fertilizers had a positive effect on the concentration of available K in the soil, which is in agreement with findings of Wen et al. (1997). They reported that K in composted manure is 100% plant available, while Motavalli et al. (1989) indicated a somewhat lower figure (73% on average) for injected dairy manure. However, concentrations of available K that were significantly higher than the control were recorded on the plots fertilized with farmyard manure and mushroom compost, while the application of vermicompost did not significantly affect the concentration of available K in the soil (Fig. 4). Through the application of organic fertilizers in such amounts as to introduce 170 kg ha^{-1} N, the soil received different amounts of K (Table 1). Through the application of farmyard manure, 318 kg ha^{-1} K_2O was incorporated into the soil, which is about 200 kg ha^{-1} K_2O more than through the application of vermicompost and 120 kg more than mushroom compost, which may be a reason for the fact that the concentrations of available K with farmyard manure treatment were significantly higher than with the other treatments throughout the experiment (Fig. 4).



Explanation under Figure 2

Figure 4. Concentration of available potassium (K_2O) in the soil (0–30 cm)

Mulching did not affect available K concentrations in our experiment. Polyethylene mulch could have positively affected the temperature of the soil (Ghosh et al., 2006) and reduced evaporation (Li et al., 2013), which created more favourable conditions for the mineralization of organic matter and release of higher amounts of mineral N, than was the case with straw mulch. Our results are in agreement with those of Neuweiler et al. (2003), who also found a significantly lower mineral N concentration on straw mulched plots than on those covered with polyethylene mulch. However, available K concentration was not affected by mulch (Fig. 4), while available P concentration in soil was significantly higher under polyethylene mulch only in summer 2010, when the difference in pH values between different mulches was highest (0.37 pH units).

Organic fertilization and mulch impact on micronutrients availability and soil pH. In the present study the application of organic fertilizer did not affect pH values of the soil (Table 2). Other studies have found a significant decrease (Chang et al., 2007), or increase (Zaller, Koepke, 2004) in soil pH with long-term application of organic fertilizer, depending on initial soil pH. However, our results are in agreement with Mohammadi et al. (2009), who reported that differences in pH were not significant for one- and two-year applications of organic fertilizer when compared to the control, probably because of the buffering capacity of the soil. On the other hand, pH values on the polyethylene mulched plots were significantly lower than those of straw mulched plots during the first two years of the research (Table 2). Two months after the application of farmyard manure, the concentrations of available forms of Fe, Zn and Cu were significantly higher than the control treatment. Although the application of composts did increase the concentrations of available forms of microelements in relation to the control, the differences were not significant (Table 2). In 2009 and 2010, the concentrations of available forms of microelements were significantly higher on plots covered with polyethylene mulch than on those covered with straw mulch, while in 2011 no significant differences were found (Table 2).

Even though the organic fertilizers used in the present research had relatively similar total micronutrient concentrations (Table 1), the application of composts did not affect the concentration of available micronutrients in the soil, while in the farmyard manure treatment in the first year of application (2010), the concentrations of Fe, Cu and Zn were significantly higher than the control. Richards et al. (2011) found that the application of fertilizers for several years significantly increased organic matter content and the concentrations of available forms of Fe, Cu, Mn, Zn and Mo in the soil and also find significant correlations between total amounts of micronutrients applied through organic fertilizer and available forms of those micronutrients in the soil. As organic fertilizer did not impact soil pH, which greatly affects the availability of micronutrients, the increase of micronutrient concentrations is probably a result of the interaction between metal ions and various organic acids created during the mineralization of applied organic matter, and formation of chelated complexes (Leita et al.,

Table 2. Soil pH and concentrations of available micronutrients in the soil (mg kg^{-1})

Fertilization	pH	Fe	Mn	Zn	Cu
2009 (planting year)					
Control	7.76 a	2.19 b	20.63 a	1.34 b	1.13 b
Vermicompost	7.80 a	2.76 ab	21.59 a	1.59 ab	1.43 ab
Mushroom compost	7.75 a	2.50 ab	21.14 a	1.37 b	1.36 ab
Farmyard manure	7.78 a	2.93 a	22.42 a	2.98 a	1.58 a
Mulching					
Polyethylene mulch	7.67 B	2.83 A	23.25 A	1.72 A	1.54 A
Straw mulch	7.84 A	2.14 B	19.25 B	1.37 B	1.25 B
2010 (1st fruiting year)					
Fertilization	pH	Fe	Mn	Zn	Cu
Control	7.46 a	3.42 a	27.98 a	1.90 a	2.53 a
Vermicompost	7.54 a	3.83 a	29.00 a	2.16 a	2.82 a
Mushroom compost	7.49 a	3.56 a	28.61 a	2.28 a	2.68 a
Farmyard manure	7.52 a	3.81 a	28.21 a	2.20 a	2.90 a
Mulching					
Polyethylene mulch	7.35 B	4.36 A	33.06 A	2.31 A	3.30 A
Straw mulch	7.65 A	3.08 B	24.37 B	1.87 B	2.08 B
2011 (2nd fruiting year)					
Fertilization	pH	Fe	Mn	Zn	Cu
Control	7.58 a	3.15 a	25.07 a	2.34 a	2.03 a
Vermicompost	7.68 a	3.40 a	25.44 a	2.28 a	1.98 a
Mushroom compost	7.64 a	3.10 a	26.78 a	2.33 a	1.93 a
Farmyard manure	7.62 a	3.38 a	26.54 a	2.50 a	1.78 a
Mulching					
Polyethylene mulch	7.58 A	3.34 A	26.95 A	2.31 A	1.98 A
Straw mulch	7.67 A	3.19 A	28.90 A	2.22 A	2.24 A

Notes. * – values followed by different upper- (mulching) and lowercase (fertilization) letters are statistically significantly different at $p < 0.05$. Interactions *mulch × fertilization* were not statistically significant.

1999). Eghball et al. (1997) remark that in comparison to farmyard manure, a considerable part of readily degradable organic C and N in composts is lost during composting, while remaining C and N are found in more stable forms which are more resistant to mineralization and have weaker affinity to metal ions in the creation of chelated complexes. Besides this, by applying farmyard manure significantly more organic C was incorporated into the soil than was the case with compost (mushroom compost and vermicompost) treatments (Table 2), which could also have led to farmyard manure having a higher impact on available micronutrient concentrations than composts (Richards et al., 2011). The differences between the two mulching methods could have arisen from higher soil temperatures, more intensive mineralization (Fig. 2) and the creation of larger amounts of organic acids and CO_2 under polyethylene mulch (Moreno, Moreno, 2008). As polyethylene mulch is considerably less gas permeable than straw, this may have caused higher amounts of CO_2 to remain in the soil and led to the formation of carbonic acid, which in turn resulted in lower soil pH. This is why at first two sampling times (2009 and 2010), due to a lower soil pH value, the concentrations of available forms of all four micronutrients were significantly higher in the soils covered with polyethylene mulch than in those covered with straw mulch.

Strawberry yield. In the 1st fruiting year (2010), the application of all three organic fertilizers had a considerable impact on the total number of flowers per plant and total strawberry yield. The total yield on fertilized plots was 118 g plant^{-1} (vermicompost) to 150 g plant^{-1} (farmyard manure) higher than on the control, while the differences among the individual fertilization treatments were not significant (Table 3). A similar trend was observed in the total number of flowers per plant: a significantly higher number of flowers were recorded on fertilized plots, while the differences among the individual fertilization treatments were not significant. In the 2nd fruiting year, a number of flowers significantly higher than on the control were obtained only on farmyard manure treated plots, but the total strawberry yield did not differ significantly from the control. In both years, the total number of flowers and yield was significantly higher on polyethylene mulched plots than on straw mulched plots. During the two years, average berry weight did not differ significantly between the treatments or mulching methods (Table 3).

Concentrations of available P (with all fertilizer treatments) and K (farmyard manure treatment) were significantly higher than in the control for three consecutive years of the research. At the same time the differences in the yield in the 2nd fruiting year were not significant, so it can be concluded that N content in the soil was a limiting factor in increasing yield in 2011. Acuna-Maldonado and Pritts (2008) have indicated that perennial strawberry plants use N uptaken in the autumn to form flowers and develop flowers and berries the following year. In the

Table 3. Total number of flowers, yield of fresh strawberries and average berry weight

	2010			2011		
	total number of flowers plant^{-1}	yield g plant^{-1}	average berry weight g plant^{-1}	total number of flowers plant^{-1}	yield g plant^{-1}	average berry weight g plant^{-1}
Fertilization						
Control	84.7 b	0.708 b	11.98 a	96.3 b	530.1 a	8.83 a
Vermicompost	95.3 a	0.826 a	12.54 a	98.3 ab	561.1 a	9.17 a
Mushroom compost	93.5 a	0.842 a	12.45 a	100.5ab	580.3 a	9.13 a
Farmyard manure	100 a	0.858 a	12.28 a	105 a	593.2 a	8.98 a
Mulching						
Polyethylene mulch	100.2 A	0.857 A	12.18 A	106.4 A	607.8 A	9.17 A
Straw mulch	86.50 B	0.760 B	12.45 A	93.65 B	524.5 B	8.88 A

Notes. Values followed by different upper- (mulching) and lowercase (fertilization) letters are statistically significantly different at $p < 0.05$. Interactions *mulch × fertilization* were not statistically significant.

present study, mineral N concentration on fertilized plots was significantly higher than on the control in the year of application of organic fertilizer (autumn 2009). It is possible that plants formed larger N reserves, which led to a higher number of flowers per plant in the following year and eventually to a higher yield due to a larger number of berries (as average berry weight was not significantly different from the control). This is further supported by the fact that polyethylene mulched plots, where for three years we recorded higher mineral N concentrations than on straw mulched plots, produced a higher yield and had a higher number of flowers per plant. Our results are in agreement with findings of Opstad et al. (2007). They reported that fertilizer utilization in relation to productivity was highest when fertilizer was available at the time of flower differentiation. Also, Strik et al. (2004) and Tagliavini et al. (2005) reported that in late autumn, crowns and roots accumulate significant amounts of N, which become remobilized the following spring.

Conclusions

1. The application of organic fertilizers in the amounts equivalent to 170 kg ha^{-1} N had a positive effect on the concentration of mineral forms of N in the soil only in the year of application and the following spring, while available P concentration two years after application was significantly higher on fertilized plots than on the control (27–40% depending on fertilizer treatments).

2. The application of farmyard manure resulted in a significantly higher K concentration in the soil, which remained 24.5% higher than the control throughout two-year strawberry cultivation period, whereas the application of compost had a considerably weaker effect (10.4–15.5%). Also, farmyard manure application had a beneficial effect on the concentrations of available forms of Fe, Zn and Cu only in the year of application, and the application of composts (mushroom compost and vermicompost) did not affect available micronutrients concentrations in the soil.

3. Mineral N concentrations at all sampling times during the two years of the research were significantly higher on plots mulched with black polyethylene than on straw mulched plots, while available P concentrations were significantly higher on polyethylene mulched plots only at one sampling time. Available K concentrations did not depend on the mulch type.

4. The application of organic fertilizers led to a significant increase in yield from 16.6% to 21.1% in comparison to the control only in the 1st fruiting year, while the application of polyethylene mulch significantly increased strawberry yield in relation to straw mulch for 12.7% in the 1st and 15.8% in the 2nd fruiting year.

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Mulčio rūšies ir tręšimo mėšlu bei kompostais įtaka braškės (*Fragaria* × *ananassa* Duch.) derlingumui ir dirvožemio savybėms

R. Cabilovski[1], M. Manojlovic[1], D. Bogdanovic[1], N. Magazin[1], Z. Keserovic[1], B. Sitaula[2]

[1]Serbijos Novi Sad universitetas
[2]Norvegijos gyvybės mokslų universitetas

Santrauka

Tyrimo metu siekta nustatyti organinių trąšų – mėšlo, vermikomposto, grybų komposto – įtaką maisto medžiagų kiekiui dirvožemyje ir braškių derliui dvejų metų auginimo ciklo metu naudojant dvi dirvos dangas (juodą polietileną ir kviečių šiaudų mulčią). Tręšimas 170 kg ha^{-1} N organinėmis trąšomis turėjo didžiausią įtaką judraus fosforo kiekiui, kuris buvo žymiai didesnis tręštuose laukeliuose net dvejus metus po tręšimo, palyginus su kontroliniu laukeliu. Laukeliuose, tręštuose mėšlu ir grybų kompostu, nustatytas didesnis judriojo kalio kiekis, palyginus su kontroliniu laukeliu. Tręšimas vermikompostu neturėjo įtakos judriojo kalio kiekiui dirvožemyje. Tręšimas kompostais neturėjo įtakos judriųjų mikroelementų koncentracijai dirvožemyje, o Fe, Zn ir Cu koncentracijos tais metais, kai tręšta organinėmis trąšomis, buvo žymiai didesnės mėšlu tręštuose laukeliuose, palyginus su kontroliniu laukeliu. Tręšimas visomis trimis organinėmis trąšomis turėjo didelę įtaką mineralinio N koncentracijai tręšimo metais ir kitą pavasarį. Tačiau laukeliuose, uždengtuose polietileno mulčiu, visų mėginių ėmimo atvejais nustatytas didesnis mineralinio N kiekis, palyginus su kontroliniu laukeliu. Judriųjų mikroelementų koncentracija buvo žymiai didesnė dirvožemyje, dengtame juodo polietileno mulčiu, palyginus su dengtu šiaudų mulčiu. Braškes prieš sodinimą patręšus organinėmis trąšomis, jų derlius padidėjo nuo 14,3 % patręšus vermikompostu iki 17,3 % patręšus mėšlu tik pirmaisiais derėjimo metais, palyginus su kontroliniu laukeliu. Tačiau polietileno mulčias lėmė didesnį braškių derlių abiem derėjimo metais, palyginus su šiaudų mulčiu.

Reikšminiai žodžiai: liekamasis poveikis, mikroelementų judrumas, organinės trąšos.