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Multiannual growing of remontant strawberries (opportunities for biological production)

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Abstract

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The study purpose was to determine the influence and to evaluate the addition of different fertilizer sources on the growth and yield of strawberry in the conditions of vegetation experiment during 3 year period. Simultaneously, the impact of the fertilizer sources on the major groups of soil microorganisms was monitored and the relations with the plant yield were examined.

Compost-only treatment provided the highest yields over the three years of the experiment. A consistent increase in the yield of strawberries after the first and second year was found for all variants. It was maximum in the 3-rd year in the treatment with the compost. Consequently, the introduction of compost into the soil contributed to a longer term effect on soil fertility compared to the application of only mineral fertilizers and manure. Compost addition to soil or compost-only substrate could be recommended for biological production and high fruit yields of remontant strawberries.

Microorganisms responded sensitively to changes in the soil environment as a result of imported fertilizers. In the different variants, alterations in the microbial amount relative to the control were specific. The mineral NPK-fertilization and compost-only treatments caused a short time negative impact on the amount of most microbial groups at the beginning of the experiment, which was overcome at maturity stage. The long time effect of compost-only treatment was characterized by the highest amount of almost all microbial groups in all the three years. Positive correlations between the amount of microbial groups and strawberry yields were found.

Key words: compost; manure; soil microorganisms; yield; remontant strawberry

Introduction

Strawberry is a perennial plant and it lifespan depends on the conditions in which it grows, its health and care. In the field strawberry usually lives up to 6–7, and in mountain over 10 years. However, the economic benefit of its cultivation usually does not exceed 2–3 years. Strawberry is not very demanding for soil conditions. In suitable agro-technology it can be grown on soils of different mechanical and chemical composition. Nevertheless, it has been found that very heavy and light sandy soils are less suitable for cultivation. Therefore, clay-sandy and sandy clay soils with medium mechanical composition are best suited for strawberries. Strawberry prefers soils well-stocked with humus and mineral nutrients, but can also be cultivated at poorer soils. The most suitable exhibitions are the North, Northwest and Northeast. At the other exhibitions strawberry can be grown with irrigation during the summer months. This culture is not demanding for climatic conditions and could be grown successfully in gardens, courtyards, unheated greenhouses, and in appropriate boxes on the balconies. The natural conditions everywhere in our country are suitable for successful strawberry growing, provided with regular irrigation. Cultivation technology is traditional, easy to implement and widely known. Having in mind all useful qualities of strawberries, the consumption of fruits is very valuable and important for people‘s healthy lifestyle. Organic production of strawberries is easy and it is possible to obtain ecologically clean and good quality fruits. Organic strawberry growing is possible with the use of plant residues and other organic waste materials from households and agriculture after pre-composting. This is a way to incorporate the nutrients contained in these materials into the circle. There is good interconnection of agricultural production with the environment.

The aim of the study was to highlight the influence of different fertilizers and to determine the efficiency of the used compost and manure and their effect for 3 years on the quantity of strawberry yields in the conditions of vegetation experiment. At the same time, the impact of the used fertilizer sources on soil microorganisms was monitored and relations between microbial amount and the yield were investigated.

Material and Methods

In the period 2014–2016 a pot experiment with a multiannual remontant strawberry was provided on soil type-Leached Smolnitza (WRB 2006) (Shishkov, 2011). The soil is representative of the widely distributed strong clay loam soils around Sofia. It is characterized by a powerful black, very loamy humus horizon. Humus content (made according to Tjurin method) was 3.85%, which characterized the soil as moderately humus content type (Kononova, 1963). Due to the moderately content of humus the soil had high sorption capacity. The soil had a slightly acidic reaction – pH (H_2O) 6.31–6.41. The mineral nitrogen content before testing was 11.0–13.88 mg/100 g of soil, available phosphorus 2.5–3.0 mg/100g and potassium 10.2–12.2 mg/100 g of soil. The experiment was conducted in 4 kg pots with 3 replicates. Norms of the used manure and compost were 150 g/pot.

According to scheme of the experiment variants were: 1) control – non-fertile, 2) soil + N15P12K10, 3) soil + compost, 4) soil + manure, 5) soil + compost + fenugreek (*Trigonella foenum-graecum*), 6) compost-only, without additional soil. The compost used was produced by mixing 30 kg straw with 150 kg of soil and adding the required amount of ammonium nitrate to achieve a C: N = 25: 1 ratio in the substrate. The wheat’s traw was taken from field trials and cut at 2–3 cm in length. It was characterized by a total C content of 37.5% and 0.41% total nitrogen. Agrochemical analysis of compost after one-year composting of the described materials showed 0.63% total nitrogen and 7.47% total carbon and C:N = 11.85. The manure used in the experiment had the following characteristics presented in Table 1.

The amount of nitrogen input in the different variants was determined on the basis of the results of the agrochemical analysis of the soil samples and the organic fertilizers used (Bremner & Keeny, 1965).

Major groups of soil microorganisms in the strawberry rhizosphere were determined shortly after the addition of fertilizers at the 1-st year (short time effect) and at the end of the vegetation period every year (long time effect). The number of microorganisms involved in the mineralization of organic matter and the nutrient transformation in the soil (ammonifying bacteria, actinomycetes, spore-forming bacteria, fungi, cellulolytic microorganisms, mineral nitrogen utilizing bacteria, phosphate solubilizing microorganisms, oligonitrophilic microorganisms) were determined by plate counts method on selective agar media (Grudeva et al., 2006). The results were presented as a number of colony-forming units per 1 g of absolutely dry soil (CFU /g).

Data were processed through ANOVA. In order to distinguish values by variation, the standard deviation and the least significant differences (LSD) between the means were used. The relationships between microbial amounts at the end of vegetation and strawberry yield were assessed by Pearson correlation coefficient.

Results and Discussion

During the first year of the survey the obtained data on the agrochemical condition of the soil in the different variants are presented in Table 2. From these it can be seen that the pH in soil samples from the control variant was slightly higher than in the other variants. The introduction into the soil of both mineral fertilizers and manure and compost increased soil acidity. The pH values were slightly lower in treatment where the compost was used compared to treatments with manure, but the difference was insignificant.

In general, the variation in the values of pH in the different variants was low. A similar trend was also noted in the

Table 1. Agrochemical characteristic of manure

	Total C, %	NH_4-N, mg/100g	NO_3-N, mg/100g	Sum, g/100g	pH, kcl	pH_{H2O}	P_2O_5, mg/100g	K_2O, mg/100g	Total N, %
Manure	37.5	4.80	3.72	8.52	6.0	7.0	30.72	184.34	0.59
Leached Smolnitza	-	3.8	10.01	13.81	6.1	6.4	3.0	12.2	0.165

data on the amount of mineral nitrogen in the soil at the start and end of the experiment. Its quantity was also the lowest in the control and varied in different degree in the ammonia and nitrate form of nitrogen. Almost in all treatments the amount of ammonium nitrogen predominated. Only in 5th variant (soil + fenugreek + compost) was observed a higher amount of nitrate nitrogen – 16.03 mg/kg against 8.26 mg/kg for ammonium nitrogen and in sum was about 2 times higher than the quantity of the mineral nitrogen in the control variant.

Consequently, the fenugreek developing in this variant was likely to contribute to soil enrichment with easily accessible nitrogen to the plants. As a leguminous crop, the fenugreek has an irreplaceable agro technical significance mainly because of the ability to enrich the soil with nitrogen. This is due to the specific symbiosis between legume plants and so-called nodule bacteria (Rhizobium) which live freely in the soil. They have the ability to infect legume roots and form nodules by which the plant absorbs nitrogen from the air. This makes leguminous crops an excellent precursor for most of the next crops and, on the other hand, involves a reduction in nitrogen fertilization in crop rotation.

In our experiment the fenugreek grew well together with strawberries while reducing the weeds.

It could be seen in Figure 1 that the amount of available nitrogen is not sufficient to provide the plants with nutrients in the control (less than 13 mg/kg soil). In the other treatments the available N increased. The amount of mineral nitrogen was the highest in the variant with compost – about 22 mg/kg. In all treatments, the mineral nitrogen available to plants decreased at the end of the growing season. Its quantity was 2.78 in the control variant and 5.29 mg/kg in the treatment with best nitrogen-conserved in October. This confirmed that the strawberry variety studied required more available nutrients in the soil.

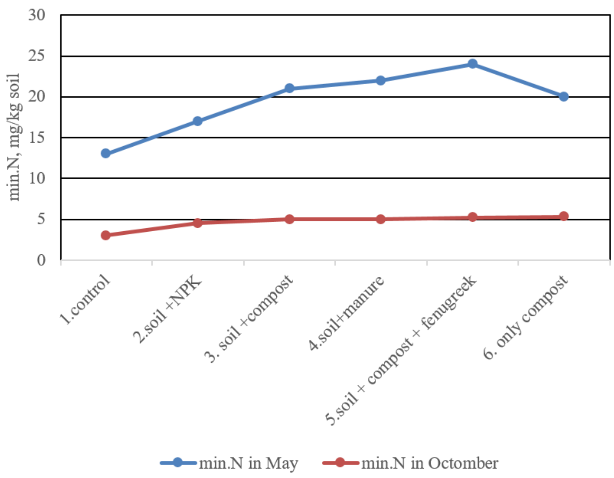

Fig. 1. Dynamic of mineral nitrogen (mg/kg) in a pot experiment of strawberry with Leached Chernozem (start of experiment – May and end of vegetation – October)

According to the data of the obtained yields (Figure 2) and the phenological observations during the first year of the experiment the highest yield was obtained in the compost and manure variants (3 and 4 variant) but the differences are not statistically proven.

The compost used as fertilizer norm into the soil gave a little bit higher yields of strawberry compared to the compost of straw only. So one-year composting of wheat straw was a sufficient period for the mineralization processes and the creation of good substrate for favorable development of strawberries. In principle, higher yields on the remontant strawberry varieties required more nutrients as they were fruitful from the end of May to the end of October.

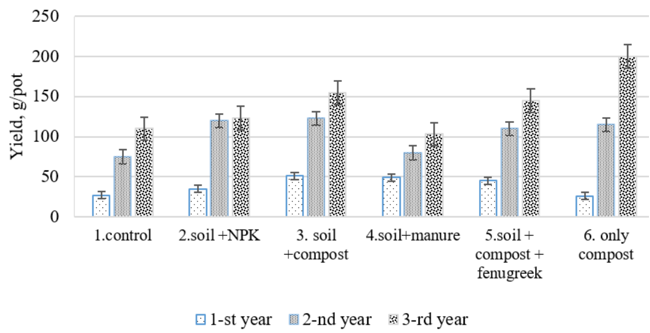

Fig. 2. The yield of strawberry (g/pot) in a pot experiment with Leached Smolnitza (2014–2016). The standard deviation from the mean is shown at P < 0.05 for each of the three years

Compared to the first year, the yields in the second and third year were higher in all variants, including the control. This is understandable, strawberry planting reaches the maximum in fruit-bearing depending on the care taken on the 2nd or 3rd year after planting.

In our experiment. a maximum yield of strawberries was obtained in the 3rd year. During the second and the third year of the trial, the yield of strawberries from a container from all variants increased considerably. The highest yield was obtained during the third year in the 6^{-th} variant – only compost. This was evidence that the mineralization of the organic matter imported for composting in the third year had reached its maximum and provided an optimal nutrient regime of the plants reflecting respectively the highest strawberry yield.

There are many researches about the mineralization of organic matter from different manures and composts (Abbasi et al., 2007; Vladeva et al., 2008; Ali et al., 2015; Andreeva et al., 2015; López-Calderón et al., 2015; Mantovani et al., 2017).

Microorganisms in the soil play a significant role in the degradation of organic residues and in providing a vailable nutrients to crops. They respond sensitively to changes in the soil environment. Imported organic or mineral substances in the soil serve as a substrate for the development of microorganisms and undoubtedly affect their amount and the intensity of mineralization-immobilization and humification processes in which they participate. Depending on the type and the rate, imported fertilizers can stimulate or suppress microbial numbers. In the present study the amount of microorganisms was considered an indirect indicator of soil microbiological activity.

Changes in the amount of soil microflora due to fertilizing (mineral and organic) are demonstrated in Figures 3–7. Data showed that at the beginning of the experiment mineral fertilization (variant 2) reduced the amount of almost all groups of microorganisms comparing to the control soil (Figure 3), i.e. the short-time effect was somewhat suppressive. Compost addition (variant 3) increased the amount of fungi which can be explained by the added straw residue with the compost. Fungi play essential role in the lignocellulose decomposition (Boer et al., 2005; Perfanova et al., 2012; Berger et al., 2013.).

The introduction of manure (variant 4) stimulated the growth of fungi and spore-forming bacteria. Manure was characterized by high content of mobile phosphorus (Table 1) which has had a suppressive effect on phosphate-solubilizing microorganisms (Figure 4). At the beginning of the experiment in the compost-only treatment (variant 6) a large part of the studied microbial groups had lower amount than the control. Data obtained confirmed that microorganisms reacted sensitively and specifically to changes in the soil environment when mineral or organic fertilizers were introduced.

In general, ammonifying bacteria, actinomycetes, spore-forming bacteria and fungi had higher numbers in the treatments with different organic matter sources than in mineral fertilized variants. Similar data were reported in other studies. Malusa et al. (2010) found increased numbers of cultivable bacteria and fungi in strawberry rhizosphere after application of manure and bio-products “BF Quality” and “Vinasse”. Derkowska et al. (2015) reported that biopreparations “Micosat F” and “Humus UP” increased the numbers of bacteria and fungi in the rhizosphere of three strawberry cultivars compared to mineral NPK- fertilized plants.

At the end of vegetation in the same year, 2 to 2.5 times reduction of the amounts of ammonifying bacteria, cellulolytic and phosphate-solubilizing microorganisms in the control and all inoculated variants and significantly increased amount of microscopic fungi was found comparing to those at the beginning of the experiment. Such alterations are typical for the end of the growing season and are related to the reduction of the root exudates which serve as a substrate for most microorganisms, and to the presence of dying plant residues that are colonized by fungi.

At the end of the growing period the most of microbial groups had overcome the suppressive effect of mineral fertilization and compost-only treatments. The increase was higher in the compost-only variant (Figure 4).

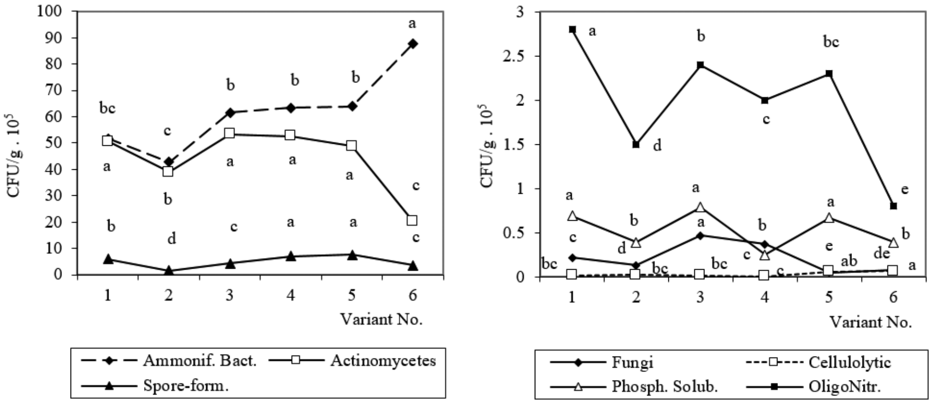

Fig. 3. Amount of different microbial groups (ammonifying bacteria, actinomycetes, spore-forming bacteria, fungi, cellulolytic microorganisms, phosphate-solubilizing microorganisms, oligonitrophilic microorganisms) in strawberry rhizosphere at the beginning of the experiment Variants: *1*) control. *2*) soil + NPK. *3*) soil + compost. *4*) soil + manure. *5*) soil + compost + fenugreek. *6*) compost only. The significant differences between meansin each curve are denoted by different letters (LSD at $p < 0.05$)

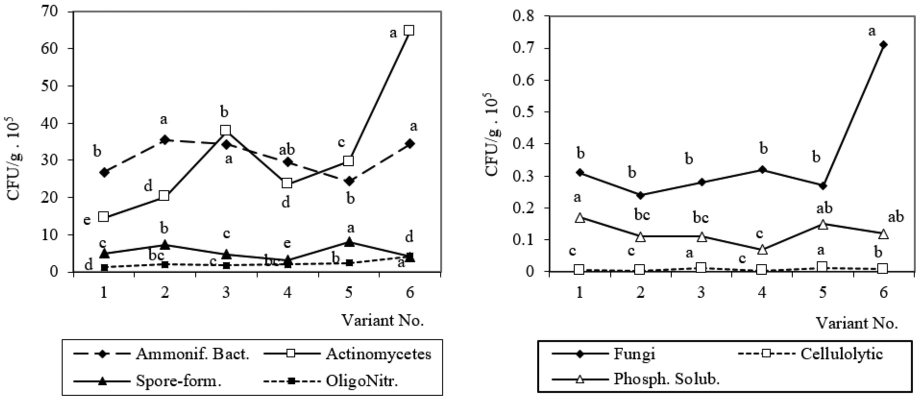

Fig. 4. Amount of different microbial groups (ammonifying bacteria, actinomycetes, spore-forming bacteria, fungi, cellulolytic microorganisms, phosphate-solubilizing microorganisms, oligonitrophilic microorganisms) in strawberry rhizosphereat the end of growing season at 1-st year
Variants: *1*) control. *2*) soil + NPK. *3*) soil + compost. *4*) soil + manure. *5*) soil + compost + fenugreek. *6*) compost only. The significant differences between means in each curve are denoted by different letters (LSD at $p < 0.05$)

Figures 5–7 show the mean amount of each microbial group at the end of growing season for the three years studied by variants (A) and in dynamics by years (B).

The long time effect of the mineral fertilization (variant 2) for the three years tested was positive on mineral nitrogen utilizing and spore-forming bacteria and negative on phosphate-solubilizing microorganisms.

The addition of the compost (variant 3) increased the amount of actinomycetes and spore-forming bacteria and reduced the amount of phosphate-solubilizing microorganisms. In the treated with manure soil (variant 4) the amount of all groups except actinomycetes and cellulolytic microorganisms decreased as compared to the control.

In the compost + fenugreek variant (5) ammonifying bacteria, bacteria utilizing mineral nitrogen, fungi and phosphate-solubilizing microorganisms lowered. The compost only treatment (variant 6) was characterized by the highest amount of microorganisms. Significant differences with the control and other variants were determined for almost all studied groups – ammonifying bacteria, actinomycetes, spore-forming bacteria, oligonitrophils, fungi and phosphate-solubilizing microorganisms (Figures 5–7 A). Obviously, due to the presence of large amounts of organic residues in the compost the microbiological processes associated with their transformation were most intensive here.

High microbiological activity of the rhizosphere soil of strawberries fertilized with vermicomposts of food residue or paper was established by Arancon et al. (2006). In the maturity phase they reported higher microbial biomass and

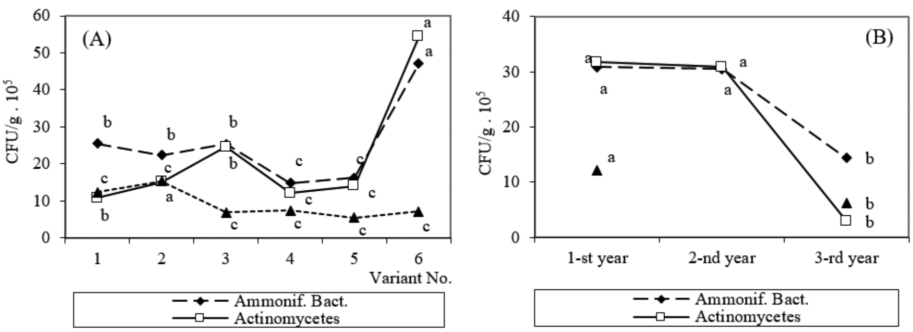

Fig. 5. Amounts of ammonifying bacteria, actinomycetes and mineral nitrogen utilizing bacteria in the strawberry rhizosphere, summarized for the three years studied: (*A*) – by variants; (*B*) – by years. The significant differences between means in each curve are denoted by different letters (LSD at $p < 0.05$)

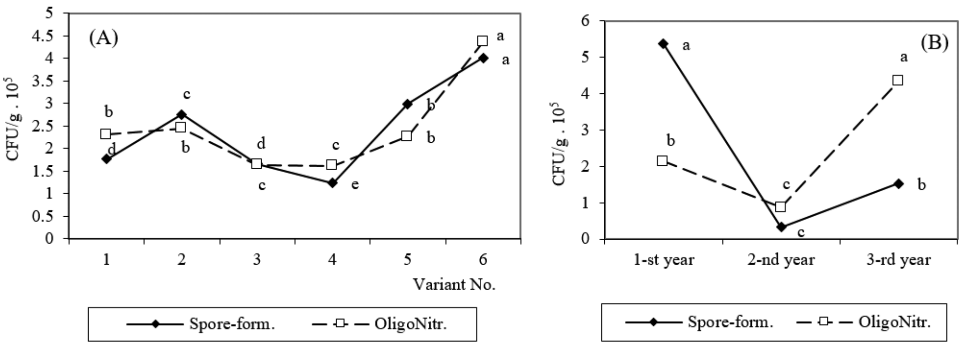

Fig. 6. Amounts of spore-forming bacteria and oligonitrophilic microorganisms in the strawberry rhizosphere summarized for the three years studied: (A) – by variants; (B) – by years. The significant differences between means in each curve are denoted by different letters (LSD at $p < 0.05$)

enzymatic activity in compost-treated variants compared to the fertilization with mineral fertilizers.

The amount of particular microbial groups differed by years. Ammonifying bacteria, actinomycetes and mineral nitrogen utilizing bacteria retained approximately the same amounts in the first two years and in the third year their amount decreased. The reduction was bigger for ammonifying bacteria and actinomycetes (Figure 5B). Spore-forming bacteria and fungi had the highest amount in the first year and in the following years they decreased. Oligonitrophilic, cellulolytic and phosphate-solubilizing microorganisms had the highest amount in the third year (Figures 5 and 6 – B).

A correlation between the amount of some microbial groups and strawberry yields was established with coefficients varying between groups and years. Cellulolytic microorganisms were positively correlated with the yield at the 1^{-st} (r = 0.606) and 3^{-rd} (r = 0.561) years. At the 2^{-nd} year strawberry yield was positively correlated with actinomycetes (r = 0.531), oligonitrophilic microorganisms (r = 0.515) and phosphate-solubilizing microorganisms (r = 0.658). High positive correlation between the yield and ammonifying (r = 0.878) and spore-forming bacteria (r = 0.858) was found at the 3^{-rd} year. In this study, it was demonstrated that microbiological activity was closely related to the yield of strawberry. Other authors showed that microorganisms have potential to increase the nutrient availability, growth and yield of strawberry plants by production of growth promoting substances (Esitken et al., 2010).

Conclusion

The conducted studies proved that the one-year composting of wheat straw in the soil Leached Smolnitza with an adequate amount of mineral nitrogen fertilizer was successful. This compost substrate was suitable for the favorable develop-

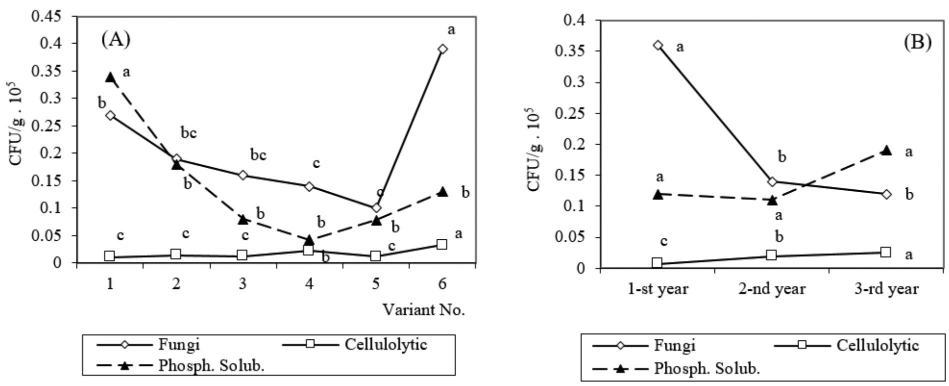

Fig. 7. Amounts of fungi, cellulolytic microorganisms and phosphate-solubilizing microorganisms in the strawberry rhizosphere summarized for the three years studied: (*A*) – by variants; (*B*) – by years. The significant differences between means in each curve are denoted by different letters (LSD at $p < 0.05$)

ment of remontant strawberries. Compost and mineral fertilizers introduced into soil did not lead to deterioration of soil acidity and improved the nutrient regime for plants.

Compost-only treatment provided the highest yields at the third year of the experiment. A consistent increase in the yield of strawberries after the first and second year was found for all variants. Consequently, the introduction of compost into the soil contributed to a longer term effect on soil fertility compared to the application of only mineral fertilizers and manure. Compost addition to soil or compost-only substrate could be recommended for biological production and high fruit yields of remontant strawberries.

Microorganisms responded sensitively to changes in the soil environment as a result of imported fertilizers. In the different variants alterations in the microbial amount relative to the control were specific. At the beginning of the experiment the mineral NPK-fertilization and compost-only treatments caused a short time negative impact on the amount of most microbial groups. At the end of the growing period the majority of groups had overcome the suppressive effect.

The longtime effect of the mineral fertilization and compost addition was positive on certain microbial groups. The manure and compost + fenugreek treatments restrained the growth of most microorganisms for all the period studied. The compost-only treatment was characterized by the highest amount of almost all microbial groups in all the three years.

The particular microbial groups had different dynamics which was probably related to the availability of an appropriate substrate for development. Close positive relations between the amount of some microbial groups and strawberry yield during the three years were found.

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