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RESPONSE OF YIELD COMPONENTS OF PEPPER (*CAPSICUM ANNUUM* L.) TO THE INFLUENCE OF BIOFERTILIZERS UNDER ORGANIC FARMING CONDITIONS

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Abstract: Organic agriculture is one among the broad spectrum of production methods that are supportive of the environment. One of the proposed solutions to environmental and human health protection issues is the implementation of natural technologies of plant cultivation and fertilization through applications of biofertilizers. The objective of this research was to identify impact of certain biofertilizers, applied as basic fertilization and as additional soil feeding during vegetation, on biological productivity and standard yield of pepper. This experiment was carried out in the period from 2009 to 2011 on the experimental fields of the Agroecological Centre at the Agricultural University - Plovdiv (Bulgaria) with pepper of the variety of "Sofiiska Kapiya". The research focused on following biofertilizers- Boneprot, Lumbrical, Baikal EM-1Y and Bio One. The study used following parameters: standard yield and economic productivity of plants including number of fruits per plant, mass of fruits and pericarp thickness. A higher standard yield was reported upon the combined fertilization with Baikal EM-1Y and Lumbrical, as the increase comparing to the non-fertilized control was by 31.9%, (2009), 45.3% (2010) and 32.2% (2011). The dynamics of the total number of fruits per plant showed higher values upon the application of microbial biofertilizers, i.e. Baikal EM-1Y and Bio One, when in combination with Lumbrical, as the results were identical for all three experimental years. The largest mass of the fruits was found for the variant characterized with the combined application of the Baikal EM-1Y with Lumbrical (2009 and 2011). The roles of the microbial biofertilizers are to strengthen the processes in the agroecosystem, to allow the crops with long vegetation, such as pepper, to show its good biological potential upon preservation of the soil fertility at the same time. The applied biofertilizers protect and preserve the environment by having an impact on the enrichment of the soil cenosis with nutritional substances, by increasing the soil fertility and by ensuring the agroecosystem stability.

Keywords: biofertilizers, *Capsicum annuum* L., organic agriculture, productivity, standard yield.

INTRODUCTION

Organic agriculture is one among the broad spectrum of production methods that are supportive of the environment (Ramesh et al, 2005; de Ponti et al, 2012). Sustainable crop production depends much on good soil health (Boraste et al., 2009). The soil fertility can be increased by using appropriate crop rotation, cultivation and fertilization (organic and mineral) (Gałązka et al., 2017). Nutrients are the most important limitation to growth and development of plants (Sabbagh et al, 2017). This necessitates to explore alternative potential sources of plant nutrients (organic) with the minimum use of mineral fertilizers (Shah et al., 2001). Pepper (*Capsicum annuum* L.) is one of the most important vegetable crops in Bulgaria (Yankova and Todorova, 2011) and the word (El-Fawy and Ahmed, 2015). Organic fertilizers are beneficial to improving the efficiency of nutrients uptake (Mansour et al, 2007; Dintcheva et al., 2009; Stoyanova et al., 2014; Nayak and Patangray, 2015) and are good sources of nutrients for crop production and improvement of the physical and chemical properties of the soil (Chrispaul et al., 2010; Muthaura et al., 2010; Olowoake, 2014; Karunarathna and Seran, 2016). One of the proposed solutions to environmental and human health protection issues is the implementation of natural technologies of plant cultivation and fertilization through applications of biofertilizers (Derkowska et al., 2015; Boteva and Yankova, 2017). These can be considered an element of integrated nutrient management in organic agriculture also because of their environmental safety (Ghumare et al., 2014) and can applied to the soil, thus enriching it with no detrimental effects on the environment (Ofoefule et al, 2014). Biofertilizers are eco-friendly and are now most necessary to support the development of organic agriculture and sustainable agriculture (Chwil, 2014; Churkova and Bozhanska, 2016; Enchev and Kokindonov, 2016; Arabska and Velikova, 2017). They can provide an eco-friendly viable weapon to small and marginal farmers in order to attain the ultimate goal of increasing crop productivity (Moorthy and Malliga, 2012; Hoza et al., 2016; Poşta et al., 2016), to improve soil fertility (Reddy et al., 2011), and to improve the growth of plants (Araújo, 2014; Tošić et al., 2014). Biofertilizers are a microbiological fertilizer that contains selected, highly effected bacteria and fungal strains isolated from the soil (Tošić et al., 2014) and are organic products containing living cells of different types of microorganisms that have emerged as an important component of the integrated nutrient supply system and hold a great promise to improve crop yields through better environmental nutrient supplies (Muthaura et al., 2010, Badzhelova et al., 2016). Higa (1991) has isolated some beneficial microorganisms from the soil calling them “effective microorganisms” (Hu and Qi, 2013). Effective Microorganisms (EM) consists of mixed cultures of naturally-occurring beneficial microorganisms (i.e. bacteria, fungi, actinomycetes and yeast) that are applied as inoculants to change the microbial diversity and interaction in soil and plants. In return, EM has been shown to improve soil health and the growth, the yield and quality of crops over a wide range of agro-ecological conditions (Higa and Parr, 1994; Yadav, 2002; Javaid, 2011; Olle and Williams, 2013).

Objectives

The objective of this research was to identify impact of certain biofertilizers, applied as basic fertilization and as additional soil feeding during vegetation, on biological productivity and standard yield of pepper variety “Sofiiska Kapiya”.

MATERIALS AND METHODS

This experiment was carried out in the period from 2009 to 2011 on the experimental fields of the Agroecological Centre at the Agricultural University - Plovdiv (Bulgaria) with pepper of the variety of "Sofiiska Kapiya" according to the method of long plots, in four replications, with a size of the test plot of 9.6 m^2, on a high-levelled seed-bed (to the scheme 120+60 x 15 cm). The study included following biofertilizers- Boneprot, Lumbrical, Baikal EM-1Y and Bio One, which belong to the list of permitted biofertilizers in accordance with the EU Regulation (EC) No. 889/2008.

The treatments in the experiment consisted of the following: Control (non-fertilized) and combined applications of the following bofertilizers: Boneprot + Baikal EM-1Y; Boneprot+ Bio One; Lumbrical + Baikal EM- 1Y; and Lumbrical + Bio One. Two basic fertilizations were used, namely: solid Boneprot and Lumbrical, applied into the soil through incorporation prior to planting of the seedlings on the field. They were applied in concentration, i.e. 35 kg/da for Boneprot and 200 L/ha for Lumbrical. During the vegetation the liquid biofertilizers Baikal EM- 1Y and Bio One were introduced into the soil twice as feeding, at the stages 'flower bud' and at the 'mass fruitset', in following concentrations: Baikal EM- 1Y - 1:1000 and Bio One- 165 mL/da (Vlahova, 2013). Boneprot (Arkobaleno, Italy) is a pellet organic fertilizer, consisting mostly of cattle manure. Lumbrical (Bulgaria) is a product obtained from processing of natural manure and other organic waste by Californian red worms and consists of their excrements. Baikal EM-1Y (Ukraine) consist of: effective microorganisms, mixed crops of useful microorganisms, bacterial inoculation includes *Lactobacillus casei*, *Lactobacillus lactis*, *Rhodopseudomonas palustris* and *Saccharomices cerevisiae*. Bio One (USA) consists of living microorganisms - aerobic (*Azotobacter vinelandii*) and anaerobic (*Clostridium pasteurianum*).

Study parameters

Standard Yield- (kg/da); Economic productivity of plants: Number of fruits per plant- (pcs/plant) 10 plants per treatment were analyzed; Mass of fruits (g) - 10 fruits per treatment were analyzed; Pericarp thicknesses (mm) - 10 fruits per treatment were analyzed. *Statistical data- processing used* MS Office Excel 2007, SPSS and ANOVA (SPSS treatment 7.5). Differences between mean values were tested by using Duncan's multiple range test (Duncan, 1955) at the $P<0.05$ level. A factorial analysis of variance (ANOVA) was used to analyse the differences between treatments.

RESULTS AND DISCUSSION

Impact of biofertilisers on the standard yield

The realized feeding by biofertilizers is of significant importance for the technology of growing pepper under field conditions in the bioproduction system. The reporting of the standard yield includes some of the most primary parameters for assessing the realized biological potential of the crops under the influence of the applied fertilization. It was established that there was dynamics in the obtained values of the standard yield between the different variants throughout the vegetation year, as well as between the separate years of the experiment. A higher standard yield was reported upon the combined fertilization with Baikal EM-1Y and Lumbrical, which remained unchanged throughout the period of the experiment, i.e. 1476 kg/da (2009); 2041 kg/da (2010) and 1877 kg/da (2011), as the increase comparing to the non-fertilized control was by 31.9%, (2009), 45.3% (2010) and 32.2% (2011) (Figure 1). Such a tendency towards a significant realized standard yield, which was of a confirmative nature throughout the three-year period, could be seen upon the combined fertilization with Baikal EM-1Y and Boneprot. This unconditional effect was probably due to the rich composition of efficient microorganisms in the composition of Baikal EM-1Y, and respectively due to the favorable composition of Lumbrical and Boneprot.

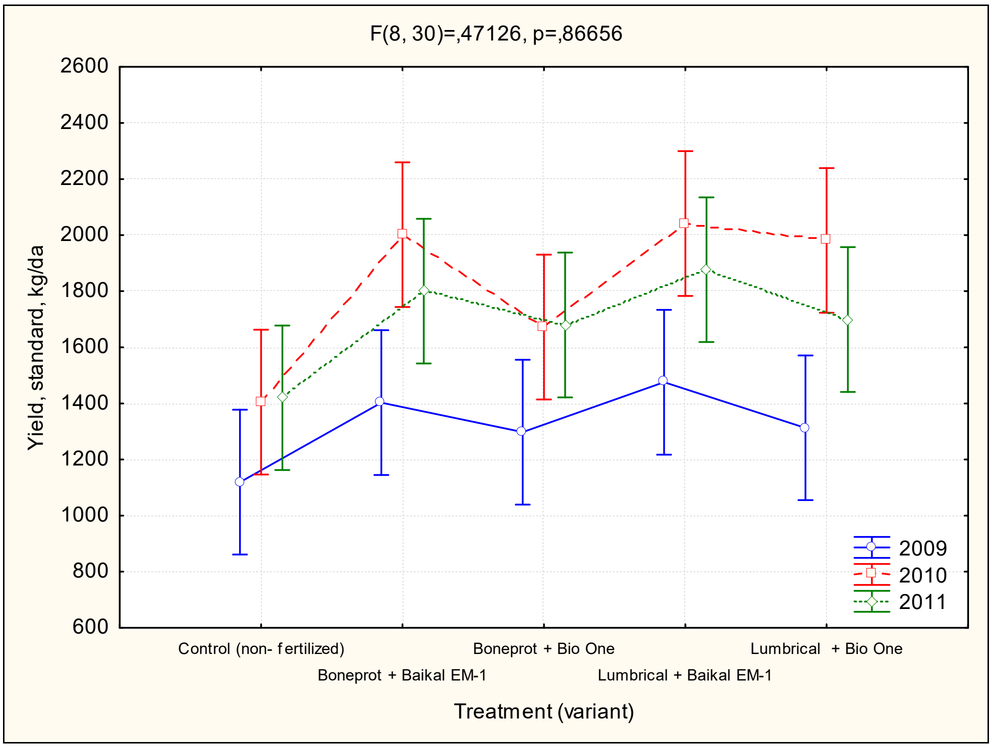

Figure 1. Standard yield of pepper plants, variety "Sofiiska Kapiya" from 2009 to 2011 (kg/da)

Upon comparing the impact of both tested microbial biofertilizers, i.e. Baikal EM-1Y and Bio One, the better effect on the standard yield was found upon the application of the biofertilizer Baikal EM-1Y. And upon comparing the combinations we may point out the leading role of Lumbrical evidenced by the higher values of the Lumbrical-containing variants. The results showed that Lumbrical might improve the provision of soil nutrients and their composition and might stimulate the absorption of nutrients and the better realization of the production capacities of pepper. The varying values showed a significant difference from a statistical point of view in the combined variants and the unfertilized control, which was established in 2010 and confirmed in 2011. A much better achieved standard yield could be seen in the variants with combined fertilization as compared to those with the unfertilized control.

The ANOVA analysis of the standard yield during the period of the experiment is presented in Figure 2 below.

As regards the standard yield (as a mean value of the study period), a statistically significant difference was found (at $P<0.05$) between the variants. The ANOVA investigating the two major factors, i.e. biofertilizer (applied as basic fertilization and additional vegetative soil feeding), and years (the averaged differences between the three study years), showed that the highest standard yields were measured upon the application of the combinations of Lumbrical and Baikal EM-1Y, followed by Boneprot and Baikal EM-1Y. Thus, the positive impact of the application of the biofertilizers on pepper growth was proven. It could be attributed to improvement of the agroecological conditions for pepper growth, i.e. nutritional elements from the applied biofertilizers were better assimilated, thus reflecting in better crop productivity as compared to the non-fertilized plants.

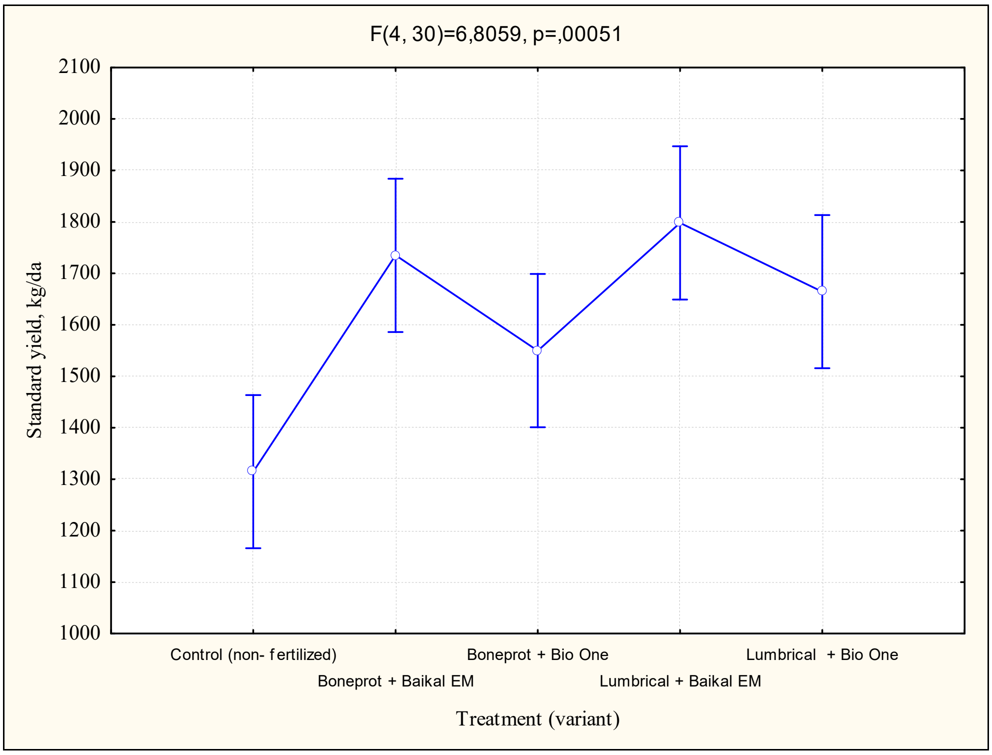

Figure 2. Effect of the interaction of the main fertilization factors on the standard yield (mean value of the study period, i.e. 2009- 2011)

Economic productivity of plants

Number of fruits per plant

The differences between the variants upon the reported number of fruits per plant were sensitive. There was yet, however, the explicit distinction of the influence of the role of the applied fertilizers, for the reported values exceeded those of the control plants. The highest value was reported upon the combined fertilization with Baikal EM-1Y and Lumbrical, i.e. 7.9 pcs/plant (2009); 8.0 pcs/plant (2010 and 2011), as the increase compared to the control was by 46.3% (2009); 60.0% (2010) and 53.8% (2011) (Figure 3). The efficiency of the microbial biofertilizer Baikal EM-1Y was leading with some very good results also reported when applied in combination with Boneprot, even though the confirmation was only in the vegetation years of 2010 and 2011, where the increase as compared to the control was by 44.0% (2010) and 51.9% (2011), respectively.

The dynamics of the total number of fruits per plant showed higher values upon the application of microbial biofertilizers, i.e. Baikal EM-1Y and Bio One, when in combination with Lumbrical, as the results were identical for all three experimental years. The larger number of fruits per plant (on average for a three-year study period) - Figure 4 below - was reported upon the combined application of the biofertilizers Baikal EM-1Y and Lumbrical. This could be attributed to the higher organic substance content of 45 - 50% and the higher content of huminous and fulvo acids in the biofertilizer Lumbrical, as well as the presence of effective microorganisms (EM) in the composition of the biofertilizer Baikal EM-1Y imported by means of vegetation. There was a statistically significant difference between the variants as regards the number of fruits per plant (at $P<0.05$), as a mean value of the period of study. The above proves the hypothesis that variants treated with biofertilizers show a higher efficiency of utilization of additional nutrients received from biofertilizers as compared to non-fertilized plants.

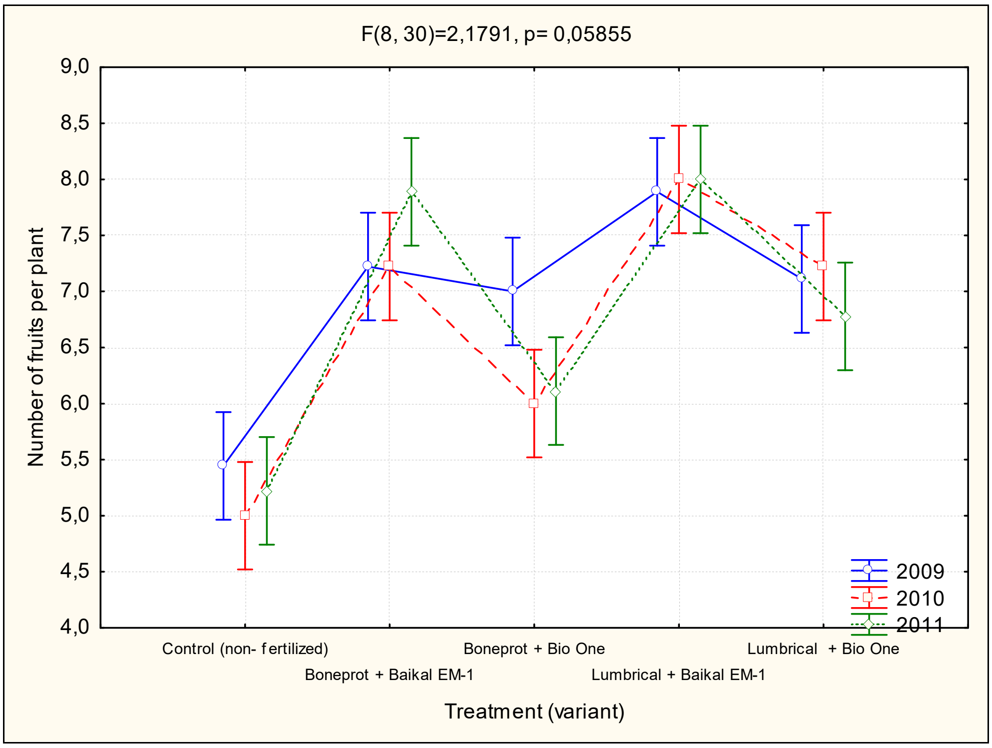

Figure 3. Number of fruits per plant, variety of "Sofiiska Kapiya" (pcs/plant)

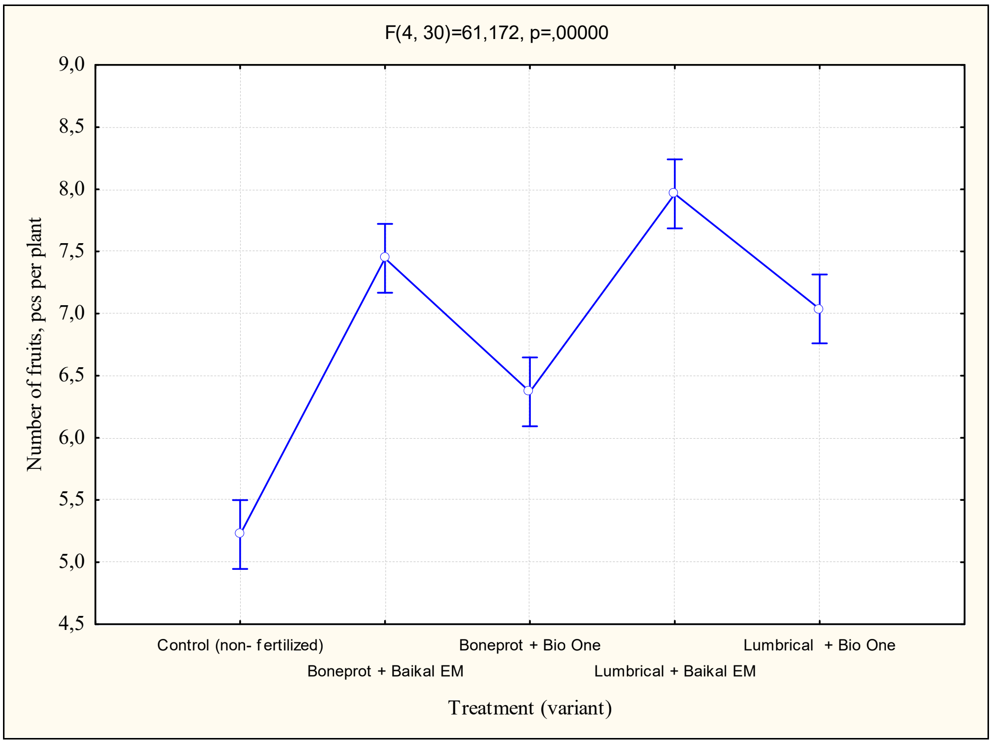

Figure 4. Effect of the interaction of the major factors on the number of fruits per plant (mean value of the study period, 2009- 2011)

Mass of fruits

The study performed led to the establishment that there was significant dynamics between the separate variants and that there was no unilateral tendency applicable throughout the three-year period. The results from the combined fertilization with Baikal EM-1Y and Lumbrical were realiable as established in 2009 and confirmed in 2011 (Figure 5).

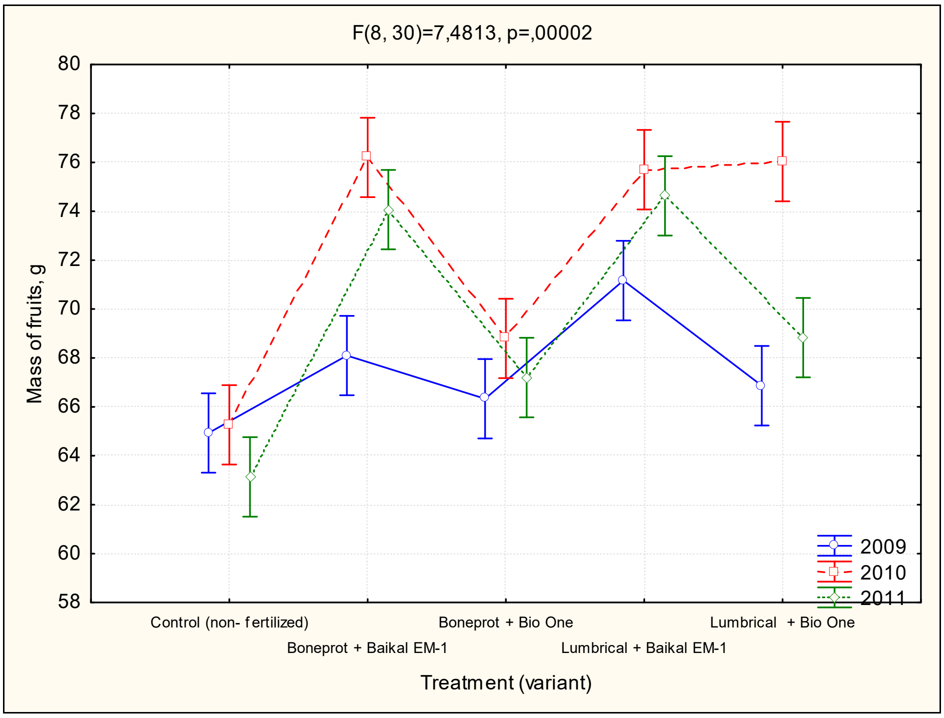

Figure 5. Mass of fruits, variety of "Sofiiska Kapiya", g

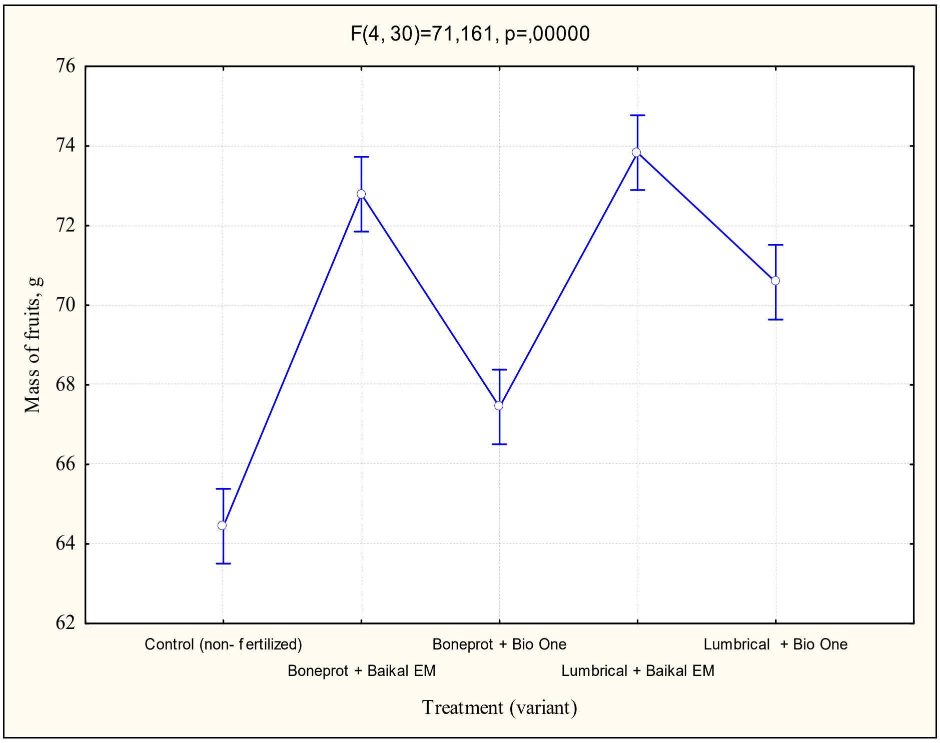

Figure 6. Effect of the interaction of the main factors on rate of the mass of fruits (mean value of the study period 2009 - 2011)

On the average for the period of the experiment, the largest mass of the fruits, i.e. 73.8 g, was found in the variant with the combined application of Baikal EM-1Y and Lumbrical, as similar results were found upon application of Baikal EM-1Y and Boneprot, i.e. 72.8 g (Figure 6). There was a statistically significant difference between the variants in regards to the parameter “mass of fruits” (at P<0.05) as a mean value for the period of study. The highest values were shown after treatment with the combination of Lumbrical and Baikal EM-1Y.

Pericarp thickness

In regard to the indicator pericarp thickness of the pepper of the variety of “Sofiiska Kapiya” there was slight variation established in the values between fertilized variants, which was applicable to all three years. The best results were reported upon the combined application of Baikal EM-1Y and Boneprot, which was found in 2009, i.e. 5.22 mm, and was confirmed in 2010 - 5.73 mm, as the increase compared to the control was by 26.1% (2009) and by 42.9% (2010), respectively. It was found that upon the application of the microbial biofertilizer Baikal EM-1Y in combination with Lumbrical there were once again very good results reported, which were valid for the period of the experiment, which was probably due to the favorable combination of the imported fertilizers and to the successful nature of the efficiency of the effective microorganisms (EM). Higher values as compared to control were reported upon the application of the biofertilizer Baikal EM-1Y on Lumbrical basic fertilization in 2009 (5.22 mm) and 2011 (5.49 mm), as the increase compared to the control was by 26.1% and by 23.6%, respectively (Table 1).

Table 1. Thickness of the pepper fruits pericarp, variety of “Sofiiska Kapiya”, mm

Treatments /variants/		2009	2010	2011	Average
		Mean; St. Dev.	Mean; St. Dev.	Mean; St. Dev.	
Control (non- fertilized)		4.14 ± 0.578 [b]	4.01 ± 0.145 [d]	4.44 ± 0.405 [c]	4.20
Combined application	Boneprot + Baikal EM- 1Y	5.22 ± 0.498 [a]	5.73 ± 0.948 [a]	5.48 ± 0.472 [a]	5.48
	Boneprot + Bio One	4.66 ± 0.394 [ab]	4.83 ± 0.379 [c]	5.13 ± 0.462 [ab]	4.87
	Lumbrical + Baikal EM-1Y	5.22 ± 0.456 [a]	5.48 ± 0.416 [ab]	5.49 ± 0.505 [a]	5.40
	Lumbrical + Bio One	4.95 ± 0.513 [a]	4.79 ± 0.316 [c]	4.88 ± 0.424 [bc]	4.87
Duncan’s Multiply Range Test (P<0.05)					

CONCLUSION

A positive effect was reported as regards the additional application of the microbial biofertilizer Baikal EM-1Y in combination with Lumbrical, which was reliable evidence of the synchronization of the influence of both biofertilizers having a positive effect on the standard yield and having the largest number of fruits formed per plant for all three experimental years.

The applied biofertilizers protect and preserve the environment by having an impact on the enrichment of the soil cenosis with nutritional substances, by increasing the soil fertility and by ensuring the agroecosystem stability. It is well-known that organic agriculture relies on own nutritional reserves in the agroecosystem and on the import of additional sources of nutritional substances, as biofertilizers are recommended in quantities that stimulate the development of the crops during the vegetation, without any risk to the soil agrocenosis.

In order to grow pepper – average early production of the variety of Kapiya, it is necessary that in the system of organic agriculture the agroecological conditions are taken into account, as well as the local varieties traditionally established in the region, the available resources of Lumbrical farms for the production of biofertilizer of *California worms*, as well as mycorhizal inoculants with efficient microorganisms that ensure faster efficiency of the applied biofertilizer. The roles of the microbial biofertilizers are to strengthen the processes in the agroecosystem, to allow the crops with long vegetation, such as pepper, to show its good biological potential upon preservation of the soil fertility at the same time.

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