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JATROPHA SEED CAKE AND ORGANIC WASTE COMPOST: THE POTENTIAL FOR IMPROVEMENT OF SOIL FERTILITY

NAWÓZ ORGANICZNY *JATROPHA* ORAZ KOMPOST: POTENCJAŁ ZWIĘKSZENIA ŻYZNOŚCI GLEBY

Abstract: Modern agriculture faces to new challenges and problems. Application of organic waste compost (C_p) and *Jatropha* seed cake (JSC) represents new possibilities to improve soil organic matter (SOM) and thus reduce the risk of soil degradation. Our paper presents results of laboratory experiment. Based on these results, we conclude that the application of organic substances has positive effect on soil fertility but the impact of individual substances is different. JSC has higher influence on soil properties (microbial activity and plant production) in the short term. Conversely, C_p affects soil properties in the long term. These properties are due to their chemical composition.

Keywords: soil fertility, *Jatropha* seed cake, compost, microbial activity, mineral nitrogen

Introduction

In many countries of the world soils are being degraded at an alarming rate by wind and water erosion, desertification, and salinization resulting from misuse and improper farming practices [1]. Soil health is a term which is widely used within discussions on sustainable agriculture to describe the general condition or quality of the soil resource. Soil is undeniably a very complex structure. It may be described as a multicomponent and

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multifunctional structure with definable operating limits and a characteristic spatial configuration. Within a continuum of possibilities, there are recognizable soil types that originate depending on variations in factors, such as parent material, climate and topography, which largely determine the dominant physical and chemical properties [2]. The term soil organic matter (SOM) is generally used to represent the organic constituents in soils including un-decayed plant and animal tissues, their partial decomposition products, and the soil biomass [3]. Retain and increasing the content of SOM in agricultural land (arable soil) is essential for achieving sustainable agriculture.

Soil organisms, including micro-organisms, use soil organic matter as source of energy. Factors affecting the activity of micro-organisms in soil and their quality and quantity include content of organic substances, nitrogen compounds, macro- and micro-elements, water, and oxygen, as well as soil pH and temperature [4-6]. Soil organisms mobilize many main and trace nutrients (particularly N) for the plant through their conversion processes alone, and are involved in particular in the nutrient cycles of carbon, nitrogen, phosphorus, and sulfur [6]. The waste products produced by micro-organisms are also soil organic matter. This waste material is less decomposable than the original plant and animal material but it can be used by a large number of organisms. By breaking down carbon structures and rebuilding new ones or storing the C into their own biomass, soil biota plays the most important role in nutrient cycling processes and, thus, in the ability of a soil to provide the crop with sufficient nutrients to harvest a healthy product [7]. There are many options to increase content of SOM in soil and thus reduce the risk of loss soil fertility. The most accessible method is the application of organic waste, which may be of different origin but it should be produced near the farmland where it will be applied. Application of organic waste must be carried out in accordance with relevant standards (Regulation of the European Parliament no. 1774/2002; Decree of the Czech Ministry of Agriculture no. 382/2001 Sb.; ČSN EN - Czech Technical Standard European Standard 46 5735), which specifies the procedure for the waste utilization in agriculture. This factor is very important for profitability of SOM application, especially in developing countries where farmers have limited financial resources [8-11]. Therefore, we focused on the utilization of organic waste compost (C_p) and *Jatropha* seed cake (JSC). Industrial countries in Central Europe use the composting process primarily for disposal of municipal organic waste and organic waste from agriculture. Conversely, developing countries in South Africa do not have such resources and must search for new possibilities in agriculture. Such an opportunity is cultivation of new species of crops that have important economics and environmental properties [12].

The resulting organic waste compost contains a quality organic matter with high potential. In Central Europe, the composting process is especially used for treatment of municipal organic waste and organic waste from agriculture.

Jatropha curcas L. (JCL) is a deciduous shrub that grows up to a height of 3-5 meters and has productive life of 50 years. It belongs to the family of *Euporbiaceae*. JCL is believed to have been spread by Portuguese seafarers from its center of origin in Central America and Mexico via Cape Verde and Guinea Bissau to other countries in Africa and Asia. It is now widespread throughout the tropics and sub-tropics. The possibility of growing JCL for the purpose of producing biofuel is really attractive and gets attention of investors and policy-makers worldwide. The seeds of JCL contain non-edible oil with properties that are well suited for the production of biodiesel. Although optimum ecological conditions for JCL production are in the warm subhumid tropics and subtropics, JCL's ability to grow in dry areas on degraded soils, that are marginally suited for agriculture, makes it especially attractive. In addition, JCL can be used as a living fence to keep out livestock, control soil erosion and improve water infiltration. The waste products from JCL biodiesel production, JSC, can be used as fertilizer or livestock feed and for producing biogas [13].

This study evaluates the potential of using C_p and JSC as a source of organic nutrient to further nurture the growth of crops. More than a decade ago, it had been reported that there was a usage of JSC as fertilizer for growing potatoes [14]. There were shown that crops of pearl millet, cabbage, and rice had high percent of yield increases after an application of JSC as fertilizer comparing to none application [15].

The aims of the present study were therefore as follows: (1) to investigate the influence of C_p and JSC application on soil fertility (2) to investigate the different impact of JSC on soil fertility in comparison with C_p (3) the possibility of using of organically treated waste (C_p and JSC) to improve soil fertility and thus soil resiliency to negative phenomena.

Materials and methods

Design of experiment

Presented hypotheses were tested by pot experiment which was carried out in a grow box. The experiment was conducted in the period from 1st February to 20th March 2014 (48 days). During the whole experiment, plants were kept in a climate chamber at 22.5°C with a day length of 12 hours and light intensity of 350 μmol/m·s. Twenty-one experimental pots of a diameter 115 mm and height 110 mm were prepared. Lettuce (*Lactuca sativa*) was used as an indicator plant to determine the influence of C_p and JSC application on plant production. Each experimental pot was filed with 1100 g of arable soil with or without addition of C_p, JSC or with mixed C_p and JSC. Soil sampling was carried out on 25^{th} November 2013 in accordance with the Czech National Standard ČSN ISO 10 381-6. C_p was obtained from the Central Composting Plant in Brno which is registered for agriculture use in the Czech Republic. Information about the chemical composition of used C_p are listed in Table 1. Used C_p was prepared by outdoor composting process in piles with mechanical aeration. The C_p used corresponded to three-month-old mature compost, which was provided by a full-scale aerobic composting plant located in Brno - Černovice (Czech Republic). Samples of C_p were taken on 27^{th} November 2013 in accordance with the Czech National Standard ČSN EN 46 5735. Soil and C_p samples used for the experiment were sieved through a sieve (grid size of 2 mm). Before storage, the samples of soil were pre-incubated at 18.5°C in laboratory for 30 days. Prepared samples of C_p and soil were stored in a thermostat at a temperature of 3.5°C. JSC was purchased from Zambian farmer on 18th November 2012 and transported to the Czech Republic on 22^{th} November. Before storage, this material was sieved through a sieve (grid size of 2 mm) and then stored in thermostat at 3.5°C.

To demonstrate effect of C_p and JSC application, seven variants of experiment (identified as V1-V7 on Figures) with different doses of these fertilizers were prepared (Fig. 1). Each one was prepared in three repetitions. Individual doses were recalculated according to the dry matter content (density of used arable soil = 1 571 kg/m^3):

- V1: variant without addition of fertilizers - 1100 g of arable soil (identified as control in text; 180).
- V2: dose of 23.4 g of JSC (representing 50 Mg/ha) identified as S+J 50 Mg

- V3: dose of 46.8 g of JSC (representing 100 Mg/ha) identified as S+J 100 Mg
- V4: dose of 33.2 g of C_p (representing 50 Mg/ha) identified as S+C_p 50 Mg
- V5: dose of 66.4 g of C_p (representing 100 Mg/ha) identified as S+C_p 100 Mg
- V6: combined dose of 16.6 g of C_p and 11.7 g of JSC (this combined dose representing 25 Mg/ha of C_p and 25 Mg/ha of JSC) identified as S+C_p+J 25 Mg
- V7: combined dose of 33.2 g of C_p and 23,4 g of JSC (this combined dose representing 50 Mg/ha of C_p and 50 Mg/ha of JSC) identified as S+C_p+J 50 Mg

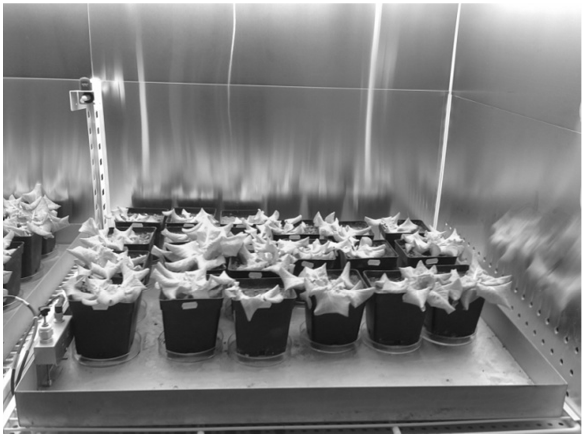

Fig. 1. Location of experimental containers in a growth box

Analysis of the arable soil and fertilizers chemical properties (organic substances)

The basic properties (available nutrients, soil reaction, C_{tot} and N_{tot}) were determined in homogenized sample of arable soil, C_p and JSC. Available nutrients: P, K, Ca and Mg were extracted by Mehlich III according to Mehlich [16]. Subsequently the content of these nutrients in the extract was measured by Manasek et al [17]: available phosphorus (P) in the extract was determined colorimetrically and the content of available potassium (K), magnesium (Mg) and calcium (Ca) by atomic absorption spectrometry (AAS). The ion-selective electrode (ISE) method was used to determine the pH value after extraction in 0.01 M $CaCl_2$. C_{tot} and N_{tot} were measured according to Nelson and Sommers [18] and Bremmer [19].

Determination of substrate induced respiration

Substrate induced respiration (SIR) was determined by measuring the CO_2 production from soils incubated in serum bottles for 4 hours after the addition of glucose. Field-moist soil (5 g) was added to three replicate serum bottles and 2 cm^3 of a glucose solution was added to each bottle (4 mg C/g of dry soil). Bottles were sealed with butyl rubber stoppers, and soils were incubated at 25°C. After 2 and 4 hours, a 0.5 cm^3 sample of the internal atmosphere was analyzed by gas chromatography (see previous section). SIR was calculated from the CO_2 increase during the 4 h incubation period according Simek et al [20].

Measurement of the leaching of mineral nitrogen

The leaching of N_{min} was measured according Elbl et al [10]: N_{min} (consisting of ammonium nitrogen NH_4^+-N and nitrate nitrogen NO_3^--N), which leached out of the experimental containers, was captured by resin grain. These grains were placed into special plastic (PVC) discs that were located under all containers. Each disc was composed of a plastic ring that was 75 mm wide and 5 mm thick. From both side of each disc, nylon mesh (special type UHELON) was glued (grid size of 0.1 mm). Resin grains for capture of N_{min} are called ion exchange resin (IER). Mixed IER was used for this experiment. This IER consists of cation exchange resin (CER for capturing NH_4^+-N) and anion exchange resin (AER - for capturing NO_3^--N) in ratio 1:1. IER used for experiment were made by Purolite Company (France). These types were applied: (1) AER Macroporous Strong Base Anion Exchange Resin - A520E (total capacity 0.9 eq/ dm^3) and (2) CER Gel Strong Acid Cation Resin - C100E (total capacity 1.9 eq/dm^3).

Trapped ions of ammonium-N and nitrate-N were quantified according Novosadova et al [21]: the IER were dried at room temperature. Absorbed NH_4^+-N and NO_3^--N were evaluated from IER using 100 cm^3 1.7 M NaCl and determined by distillation and titration method according Peoples et al [22]. The results obtained from the discs with IER were expressed in mg of N_{min} (NH_4^+-N / NO_3^--N) per m^2 of soil surface/surface of experimental containers [mg/m^2].

Results and discussion

Properties of compost, *Jatropha* seed cake and soil

Brittaine and Lutaladio [13] state that *Jatropha curcas* L. can be used for production of wood, oil, green manure and for erosion control and to improve water infiltration. Especially production of oil from the seeds is very interesting for farmers in developing countries because of its high economical profit. After the production process, farmers receive high-quality fertilizer in the form of "biological-waste" that is generated by pressing the seeds. This "biological-waste" is known as the JSC and it represents an excellent organic matter with high nitrogen content.

Table 1

Arable soil and fertilizers chemical properties supplemented with trace elements

Sample	Methods							
	Mehlich [16] and Manasek et al [17]; available nutrients content					Nelson and Sommers [18]	Bremmer [19]	
	pH ($CaCl_2$)	P [$mg \cdot kg^{-1}$]	K [$mg \cdot kg^{-1}$]	Ca [$mg \cdot kg^{-1}$]	Mg [$mg \cdot kg^{-1}$]	C_{tot} [$g \cdot kg^{-1}$]	N_{tot} [$g \cdot kg^{-1}$]	C/N
Arable soil	6.32	180.61	167.80	1449.00	52.50	13	1.41	9.19
C_p	8.06	565.23	6422.00	11235.00	1255.00	166.53	1 593	10.45
JSC	6.81	353.73	9818.00	829.00	3301.00	464.27	20.87	22.25

The Table 1 shows the complete overview of arable soil, C_p and JSC properties. The above information indicates that there can be differences between C_p and JSC in effects on soil properties. JSC is a fertilizer with high nitrogen and carbon content than C_p. Moreover, Selanon et al [24] reported that JSC containing high protein has served as a source of protein hydrolysate applied for plant growth stimulation. In addition, soil reaction (pH) and content of essential nutrients (P, K, Ca and Mg) are very important indicators which directly affect the soil microbial activities and subsequently soil fertility. Data in Table 1 show differences in content of plant available nutrients and soil reaction between C_p (higher content of P and Ca) and JSC (lower soil reaction; higher content of K and Mg). Based on these data, authors conclude that properties of C_p and JSC directly affected the main objectives of experiment.

Effect of organic material addition on substrate induced respiration - on potential microbial activity in soil

The soil respiration is an important indicator the soil state. The substrate-induced respiration (SIR) consists in the measurement of microbial respiration of samples after amending them with an excess of a readily nutrient source, usually glucose, to trigger microbial activity. Thus, the initial maximum respiratory response, which has to be optimized for every new kind of sample, is related with the current size of living microbial biomass [25, 26]. SIR serves as a means of quantifying microbial activities in soils. Results of substrate induced respiration are shown in Figure 2. The results of SIR were expressed in microgram of carbon dioxide per gram of soil and one hour.

The Figure 2 shows significant differences in production of CO_2 between variants with and without addition of JSC. The significant (ANOVA; $P < 0.05$) highest microbial activity was measured in variants with application of JSC (S+J 50 Mg) and a mixture of JSC and C_p (S+C_p+J 25 Mg) in comparison with control variant and variant where C_p was applied. This is due to the fact that JSC contains high amounts of simple sugars supporting microbial activity.

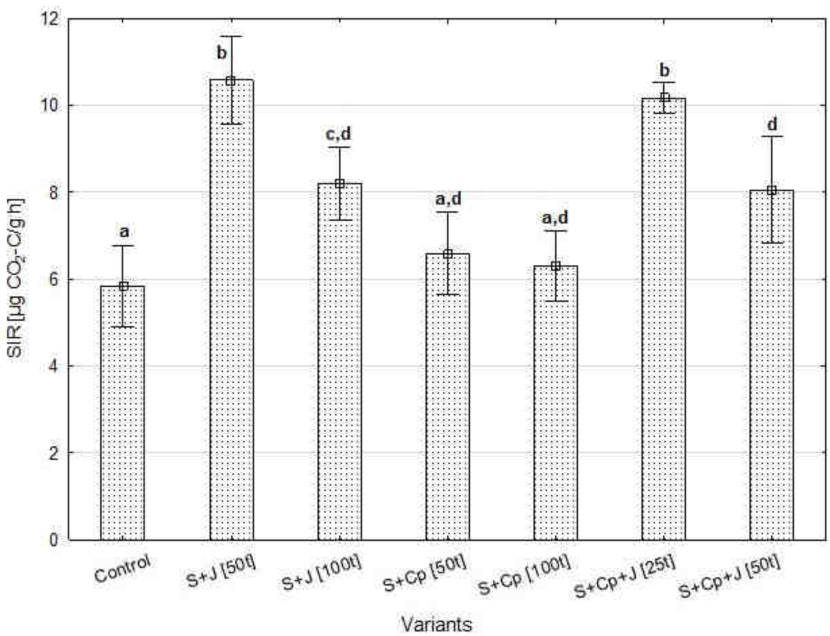

Fig. 2. Substrate induced respiration (mean values ± standard error, $n = 3$, different letters indicate a significant differences in SIR at the level 0.05 - ANOVA, $p < 0.05$)

Bloem and Hopkins [27] state: Soil respiration is a key process for carbon flux to the atmosphere. Soil water content, oxygen concentration and the bioavailability of carbon are the main factors that regulate soil respiration. Consider data which are presented in the Table 1. These data show differences in chemical composition between C_p and JSC. According Brittaine and Lutaladio [13] JSC contains organic and nitrogen compounds which are easily degradable by soil organisms. Therefore, the JSC is useful as a source of energy for soil microorganisms. The application of JSC contributes to the development of microbial activity and subsequently to an increase in production of carbon dioxide and utilization of glucose/carbon compounds.

Positive effect of JSC addition on microbial activity in soil was confirmed by Brittaine and Lutaladio [13]. Moreover, Wolf and Snyder [8]; Donn et al [23] and Ouni et al [28] state that the applications of organic substances are fundamental to improve soil fertility. The size of the applied dose of organic materials (C_p and JSC) must be determined on the basis of their composition and saturation of the soil sorption complex. The authors draws particular attention to the possibility of increasing the content of organic compounds (eutrophication), salts and heavy metals in the soil. Disposable high doses of C_p or JSC in can lead to formation of toxicity of arable land for soil microbes. Compare the amount of SIR in variant S+J (50 Mg) with measured value of SIR in S+J (100 Mg). These data indicate that the dose 50 Mg/ha was more optimal than 100 Mg/ha. Moreover the same decrease in value of SIR is between variants S+C_p+J (25 Mg) and S+C_p+J (50 Mg). Based on these values, we conclude that increased dose of JSC (50 Mg) had a negative effect on microbial communities and this effect is caused by JSC composition (see Table 2; the deoiled seed cake was used). The potential risk of high doses of JSC application on soil health and quality was studied and reported by Brittaine and Lutaladio [13], Hidayat et al [30] and Srinophakun et al [31].

Table 2

Composition of de-oiled JCL samples [wt.% on dry basis], Hidayat et al [30]

<table>
<tr><th colspan="2">Component</th><th>Deoiled seed shell (DSS)</th><th>Deoiled seed cake (DSC)</th></tr>
<tr><td rowspan="6">Total saccharides [%]
DSS = 44.21
DSC = 33.4</td><td>Arabinose</td><td>0.66</td><td>1.27</td></tr>
<tr><td>Xylose</td><td>12.11</td><td>7.34</td></tr>
<tr><td>Mannose</td><td>1.30</td><td>0.96</td></tr>
<tr><td>Galactose</td><td>0.97</td><td>1.01</td></tr>
<tr><td>Glucose</td><td>28.85</td><td>22.60</td></tr>
<tr><td>Rhamnose</td><td>0.31</td><td>0.23</td></tr>
<tr><td rowspan="2">Total lignin [%]
DSS = 44.04
DSC = 28.84</td><td>Acid insoluble lignin</td><td>43.71</td><td>28.25</td></tr>
<tr><td>Acid soluble lignin</td><td>0.33</td><td>0.59</td></tr>
</table>

Effect of organic fertilizers addition on mineral nitrogen loss from arable soil

Leaching of mineral nitrogen (N_{min}) from arable soil is a major threat to the drinking water quality of underground reservoirs in the Czech Republic [10]. The Figure 3 presents results of leaching of mineral nitrogen from experimental containers. The greatest loss of N_{min} was detected in variants with application of JSC (S+J 100 Mg; S+J 50 Mg) and a mixture of JSC and C_p (S+C_p+J 50 Mg). In addition, dose 50 Mg of JSC per ha contains 1 043 kg of N_{tot} and dose 50 Mg of C_p per ha 796.5 kg of N_{tot}. This difference is significant in comparison with control variant and variant where C_p was applied. JSC contains a large number of simple carbon compounds and nitrogen compounds; they can be easily used by plants and soil microorganisms. But if the soil is not ready for it, a loss of nutrients occurs (N_{min}) through leaching. In contrast, if the compost is stabilized, so that nutrients will be released slowly. Plant and soil microorganisms receive them slowly. Therefore, significant lowest loss of N_{min} was found in variant S+C_p (50 Mg) in comparison with S+J (50 Mg) and S+C_p+J (25 Mg).

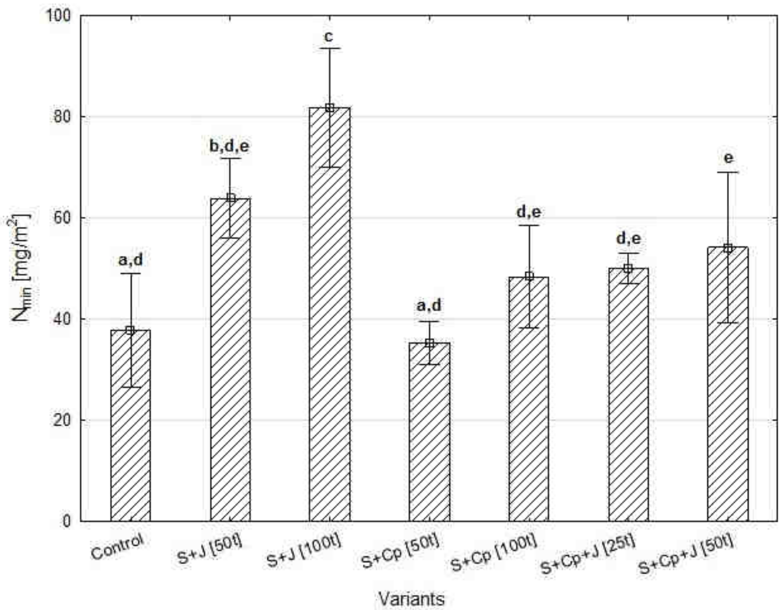

Fig. 3. Loss of mineral nitrogen from experimental containers (mean values ± standard error, n = 3, different letters indicate a significant differences in SIR at the level 0.05 - ANOVA, $p < 0.05$)

Influence of type of fertilization and kind of fertilizers on loss of N_{min} from arable soil was studied and confirmed by Wolf and Snyder [8]; Simek et al [20] and Donn et al [23]. Conversely positive effect of C_p application on the content and store of nitrogen in arable soil was published in Diaz et al [9]; Nevens and Reheul [11] and Mylavarapu and Zinati [29]. The positive effect of the C_p addition on leaching of N_{min} is based on its chemical composition. The chemical compounds of C_p are interesting. Among the most important substances in C_p: carbon, two forms of nitrogen (organic and inorganic) and phosphorus are available. More than 85-90% of the total nitrogen content in C_p is organic, while the remaining 10-15% is inorganic and immediately available to the plants. Moreover, available carbon (from C_p) is source of energy for microorganisms, thus this energy can be subsequently used for the processing of nitrogen. Increasing microbial activity results in increased capacity for N_{min} retention (additionally supplied from compost and another mineral fertilizer). N_{min} is captured in SOM [9, 10].

Effect of organic material's addition on plant production

Production of lettuce (*Lactuca sativa*) was chosen as the main indicator of the influence of the above organic substrates application. Results of production of plant biomass are shown in Figure 4. The significant greatest production of plant biomass was found in the variant with application of JSC (S+J 50 Mg). This is due to the JSC's content of large number of available carbon and nitrogen compounds while production of plant biomass in the variant with application a mixture of C_p and JSC (S+C_p+J 25 Mg) was only slightly higher than in control variant.

Brittaine and Lutaladio [13] state that JSC contains a large number of nutrients in different forms which are useful as a source of nutrients for soil microorganisms and subsequently also for plants. Consider production of plant biomass in variants S+J (50 Mg) and S+C_p (50 Mg) with loss of N_{min}. These values indicate that the application of organic matter contributes to the development of microbial activity and thus to the development of soil organic - mineral complex, which is essential for uptake and utilization of nutrient in soil and for plant production.

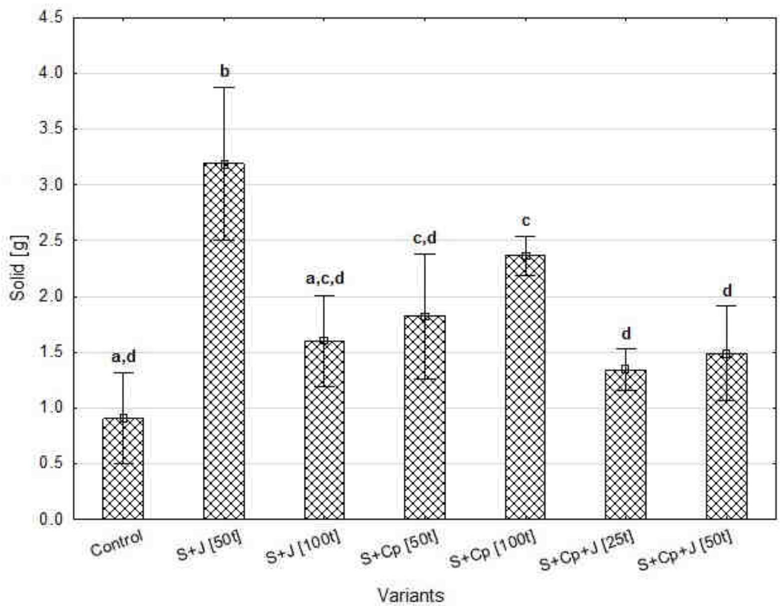

Fig. 4. Production of plant biomass (mean values ± standard error, n = 3, different letters indicate a significant differences in production of plant biomass at the level 0.05 - ANOVA, $p < 0.05$)

Conclusion

Modern agriculture faces to new challenges and problems. One of the greatest threats is depletion in soil fertility. Therefore, we must search for news biotechnology to maintain soil fertility and renewal of its natural properties. Application of C_p and JSC represents new possibilities to improve SOM and thus reduce the risk of soil degradation. Our paper presents results of laboratory experiment. Based on these results, we conclude that the application of above organic substances has positive effect on soil fertility but the impact of individual substances is different. JSC has higher influence on soil properties (microbial activity and plant production) in the short term. Conversely, C_p affects soil properties in the long term. These properties are due to their chemical composition.

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