THE ROLE OF FERTILISERS IN CONSERVING SOIL FERTILITY

ULOGA ĐUBRENJA U OČUVANJU PLODNOSTI ZEMLJIŠTA

Gorica CVIJANOVIĆ[*], Ivica ĐALOVIC[**]., Miladin VESKOVIĆ[*], Drago CVIJANOVIĆ[***]

[*]*Maize Research Institute, Zemun Polje,–Zemun, Serbia,*
[**]*Faculty of Agronomy–Serbia*
[***]*Institute of Agricultural Economics–Belgrade, Serbia*
Corresponding author: Gorica CVIJANOVIĆ, *E–mail: cgorica@mrizp.co.yu*

Abstract: In order to maintain the existing level of the soil fertility, nutrients taken out are necessary to be returned to the soil by the yield. It is allowed to use all available sources in the course of returning of nutrients taken out. This paper presents results gained on the effects of fertilisation methods on the yield of the maize hybrid ZP SC 704, then on the dynamics of organic matter in the soil and the abundance of important systemic and physiological groups of microorganisms that provide soil biogeny. The following fertilisers were applied in the maize crop: mineral fertilisers in the rates of 332 and 664 kg ha^{-1}, ploughed down stover, as an organic matter (each year in the amount of 8,000 kg ha^{-1}), combinations of mineral nitrogen and stover ploughed down, manure in the amount of two-three animal units per hectare. It was determined that observed parameters (amount of organic matter, degree of organic matter transformation into soil organic matter, the abundance of certain systemic and physiological groups of microorganisms), as well as, the nitrogen content, were significantly increased in variants with ploughed down organic matter and mineral fertilisers. According to obtained results it was determined that a long term application of mineral fertilisers did not significantly affect the changes of the organic matter content in the soil nor it decreased the soil productivity. A long term application of organic fertilisers in the form of stover and manure very significantly increased the content of organic mater and elements of biogeny in the soil, whereby a positive effect of the combination of organic mater and mineral fertilisers was particularly pronounced. Such a method of fertilising in the crop production undoubtedly satisfies the fundamental principles of organic agriculture (organic food production with the ecological and economical effect).

Rezime: Za održavanje postojećeg nivoa plodnosti zemljišta neophodno je da se u zemljište vrate iznete hranljive materije prinosom. Prilikom vraćanja iznetih hranljivih materija dozvoljeno je koristiti sve raspoložive izvore. U radu su izneti rezultati uticaja načina đubrenja na prinos kukuruza hibrida ZP SC 704, na dinamiku organske materije u zemljištu i brojnost važnih sistematskih i fizioloških grupa mikroorganizama koji određuju biogenost zemljišta. U usevu kukuruza primenjeno je đubrenje mineralnim đubrivom u količinama 332 i 664 kg.ha^{-1} NPK hraniva, zaoravanjem kukuruzovine svake godine u jesen (u količini od 8 000 kg.ha^{-1}) kao organske materije, kombinacije mineralnog azota i zaorane kukuruzovine, stajnjaka u količini dva–tri uslovna grla po hektaru. Utvrđeno je da su ispitivani parametri (količina organske materije, stepen transformacije organske materije u organsku materiju zemljišta, brojnost pojedinih sistematskih i fizioloških grupa mikroorganizama), kao i sadržaj azota, bili su značajno povećani u varijantama sa zaornom organskom materijom i mineralnim đubrivima. Na osnovu dobijenih rezultata utvrđeno je da dugotrajna primena mineralnih đubriva nije značajno uticala na promenu sadržaja organske materije u zemljištu niti je došlo do opadanja produktivnosti zemljišta. Dugotrajno unošenje organskih đubriva u vidu kukuruzovine i stajnjaka, vrlo značajno je uticalo na povećanje sadržaja organske materije i elemenata biogenosti u zemljištu, pri čemu je posebno ispoljen pozitivan uticaj kombinacije sa organske materije sa mineralnim đubrivom. Ovakav način đubrenja u ratarskoj proizvodnji svakako zadovoljava osnavna načela organske poljoprivrede (proizvodnja zdrave hrane uz ekološki i ekonomski efekat).

***Key words*:** soil, fertilisers, organic mater, nitrogen, microorganisms.
***Ključne reči*:** zemljište, đubriva, organska materija, azot, mikroorganizmi.

INTRODUCTION

The degradation and disappearance of soil is one of the most important ecological threats. Globally, 10% of the total areas are cultivated, and only 3% out of these 10% are highly productive. However, arable areas per capita have been declining and amount to 0.88 ha, while in Asia and Europe, as the most endangered continents, they amount to only 0.60 ha. Although, the soil is a renewable resource, anthropogenetic activities have been compromising the land resources, whereby besides pollution, great areas of arable lands are permanently lost by erosion or changes of their purpose. Renewability can be provided only in the case of a proper and rational system of utilisation, whereby the accumulated energy is maintained or increased. The quantity and quality of humus, microflora that characterise the soil biogeny, are the elements of renewability and regeneration of the soil potential. Chemisation in agriculture, affecting a chemical composition of the soil and furthermore microbiological activities, has been contributing to the deterioration of the state of soil during the last several decades.

The developmental strategy implying the idea of a sustainable system was adopted at great world ecological meetings, Conference on the Human Environment held in Stockholm in 1972, Earth Summit, held in Rio de Janeiro in 1992, and Johannesburg Summit 2002. The term sustainable agriculture is differently defined in the world and our country, but sustainable agriculture should maximise well-being in the present, without compromising the ability of future generations to meet their needs. The ecological starting points are related to safeguarding of non-renewable resources and conservation of the biological diversity. It can be economically comprehended through the need of a more qualitative development with a limitation of a more quantitative increase (Milojić, 1991, Bertlin, 1992 Kovačević, 2004). In the European Union, this is defined by the adopted Agenda 21 and it means a technically feasible, ecologically acceptable and economically effective development that will ensure food requirements with conservation of natural resources and protection of biological diversity. Namely, it is quite clear that natural resources have their own limits and that there is a need to synchronise relations between the food production and relational utilisation of fundamental agricultural resources in a way that pollution of the environment and agroecosystem is minimised (*Lang, 1994*).

Great amounts of mineral fertilisers, especially of nitrogen ones, used to be applied in the conventional agricultural production. The application of high rates of nitrogen fertilisers in a longer period of time has adverse effects from the aspects of ecology and the disturbance of the soil fertility, i.e. of biogeny. The number of microorganisms that oxidise ammonium nitrogen is decreasing, as well as, the number of those groups that fix atmospheric nitrogen. Such changes of the microbial world affect changes of organic matter and also of humus as the most stable form of soil organic matter that determines its fertility.

The conservation and improvement of organic matter is one of aims of the EU policy on the sustainable development that can be achieved by fertilisation with organic and mineral fertilisers by the incorporation of harvest residues, nitrogen-fixing microorganisms, etc. In such a way, organic matters are directly returned to the soil (Vesković, 1988, Molnar, 1999). The type and amounts of applied fertilisers mostly affect the content of organic matter in the soil in the course of the plant production. According to principles of sustainable agriculture, a breeding of one animal unit per hectare is necessary to provide 30-40 tons of manure each fourth year. This is very significant as manure is important in conservation of organic matter and renewal of microflora. There are different notions in the world and our country on effects of certain types of fertilisers on the soil fertility: there are beliefs that effects of mineral fertilisers on the plant growth, yields and the soil fertility are the same and even higher than manure, and vice versa, there are beliefs that mineral fertilisers cannot maintain soil fertility so well as ploughed sown organic fertilisers (manure, green manure, stover).

Information gained within the filed of biological nitrogen fixation has been increasingly applied in the production, because nitrogen fixers do not only fix atmospheric nitrogen, but also produce biologically active substances, antibiotics, hence they are included into biological control of phytoparasites. An idea that certain amounts of nitrogen fertilisers are decreased by the amount of nitrogen fixed by selected strains of nitrogen fixers - diazotrophs and their combinations has been existing for a long time. Saving of expensive mineral fertilisers can be achieved by the application of inoculates with certain groups of diazotrophs. In this way, soil chemisation, as a mode of fertilisation, is reduced, soil biogeny is conserved, and, at the same time, financial inputs into the food production are lower.

Therefore, the aim of the present study was to observe effects of different systems and methods of fertilising on some parameters that define soil fertility and biogeny in the course of maize cultivation. Furthermore, their effect on maize grain yield was established.

MATERIAL AND METHODS

The trial with a maize hybrid ZP SC 704 in the density of 56,818 plants ha^{-1} was set up according to the randomised block design on chernozem type of soil in the experimental field of the Maize Research Institute, Zemun Polje. The experimental plot size was 44.64 m^2.

All cropping practices were performed in due time. The following fertilisation combinations were used in the trial: control, mineral fertiliser (NPK nutrients) in the rates of 332 and 664 kg N ha^{-1}, organic fertiliser (the amount of 8 t stover ha^{-1} was ploughed down), combinations of organic and mineral fertilisers and manure applied in the amount of 60 tons every third years, i.e. two animal units annually. Stover is chopped by a "tarup–chopper" and ploughed down in autumn when primary tillage was carried out to the depth of 25-30 cm.

When the trial was completed, the content of soil organic matter was established and the percentage of the transformation of organic matter incorporated into soil organic matter was calculated, and the content of total nitrogen in the soil was determined by Kjeldahl method (Bremner and Mulvamney, 1982).

Then, the number of important groups of microorganisms in the microbial association of the rhizospheric soil was established by standard microbiological methods (Pochon and Tardieux, 1962).

RESULTS AND DISCUSSION

In order to maintain the existing level of the soil fertility, nutrients taken out are necessary to be returned to the soil by the yield. In the course of returning of nutrients taken out it is necessary to use all available sources with which the level of organic matter in the soil can be increased or maintained. Humus is a complex factor of the soil fertility in anthropic soils.

According to data on the incorporated amounts of organic matter, different results on the alternation of organic matter in the soil were obtained and they depended, first of all, on the type of a fertiliser (Table 1).

Many researches concluded that the content of organic matter can be maintained or even enhanced by the application of mineral fertilisers (Wisniewski 1984, Marković et al., 1985). Just of a few authors established the decrease of the organic matter content in the soil when only mineral fertilisers had been applied (Andreyuk et al., 1985). According to obtained results this decrease amounted to 103.20 kg ha^{-1}. These results can be explained by the humus decrease that occurred as organic matter was not returned to the soil when only mineral fertilisers had been applied and when there had been no returning of harvest residues to the soil. A strong tendency of the organic matter increase in the soil was established when stover had been ploughed down with and without the application of different rates of mineral fertilisers (332 and 664 kg NPK ha^{-1}). The highest changes in the organic matter content were established in the variant with manure and the combination with a mineral fertiliser in which the content increased by 3.93%, i.e. 6,295.2 kg ha^{-1} and by 2.32 %, i.e. 3,776.8 kg ha^{-1}, respectively. Obtained results are in agreement with results gained by Starčević and Marinković, 1988, who pointed out that the application of manure under different soil and climatic conditions significantly increased the organic matter content.

Table 1.

Changes of the soil organic matter content in dependence on the fertilisation method

Fertilising	Changes of the soil organic matter content in %	Changes of the soil organic matter content in relation to the weight of the 0-40–cm layer in %	Changes of organic matter content in kg ha^{-1}
Control	–0.77	–0.21	–1083.6
Mineral fertiliser (average)	–0.07	–0.002	–103.2
Organic matter	+ 1.70	+ 0.051	+ 2631.6
Organic matter + mineral fertilisers	+ 1.23	+ 0.037	+ 1909.2
Manure	+ 3.93	+ 0.122	+ 6295.2
Manure+ mineral fertilisers	+ 2.32	+ 0.73	+ 3776.8

Based on the data presented in the above Table 1 and on the mathematical relation between the amount of organic matter accumulated in the soil and the amount of incorporated organic matter, the percentage of transformation of organic matter incorporated into the soil was established (Table 2). There is a lack of this transformation in the variant in which only mineral fertilisers had been applied. In the remaining variants, the degree of transformation of organic matter into soil organic matter was recorded. This degree in the variant with ploughed down stover was higher by 2.91% than in the variant with ploughed down organic matter and mineral nitrogen.

Table 2.

Degree of transformation of organic matter as fertilisers incorporated into soil organic matter

Fertilising	Changes of the soil organic matter content in %	Amount of organic matter incorporated into the sol in kg ha^{-1}	Transformation of organic matter incorporated into soil organic matter in %
Control	–1.083.6	–	–
Mineral fertiliser (average)	–103.2	–	–
Organic matter	+ 2.631.6	24.844	10.59
Organic matter + mineral fertilisers	+1.909.2	24.844	7.68
Manure	+ 6.295.2	11.673	53.93
Manure+ mineral fertilisers	+3.776.8	11.673	32,35

Namely, the average degree of transformation of organic matter incorporated into soil organic matter was the highest in the variant with manure and amounted to 53.90%, while it amounted to 10.59% in the variant with stover. The analysis of these results points out to a somewhat greater degree of transformation of incorporated manure organic matter than of stover organic matter. This can be explained by the properties of organic matter in manure and stover, i.e. by the degree of decomposition, i.e. their susceptibility to decomposition by the soil micropopulations. Namely, the C:N ratio in stover is broader, hence stover is more susceptible to decomposition in the soil. Similar results were obtained by many researchers, while Allison, 1973, Cavazza et al., 1974, stated that the coefficient of humification of plant residues was very changeable and that it was lower for the matter with less nitrogen than for the matter with more nitrogen.

According to obtained results, a general conclusion can be drawn: a degree of transformation of incorporated manure organic matter is far higher than the degree of transformation of stover organic matter.

Table 3 presents results on the abundance of elementary systemic and physiological groups of microorganisms within the microbial association in the soil. The total number of microorganisms and the number of azotobacters can be used as principal parameters of the soil fertility (Milošević et al., 1997). The distribution and biomass of microorganisms are usually in a direct correlation with the amount of plant residues and a proportion of organic matter in the soil (Alexander, 1977). The total abundance of microorganisms increases with the application of microbiological inoculates and organic fertilisers (Cvijanović, 2002). Gained results point out that the highest total number of microorganisms (7.84 log numbers of cells) was in the variant with manure and mineral fertilisers, making an increase of 3.3%, while the highest percentage of the increase of the total number of 6.9% was recorded in the variant with stover and both rates of mineral nitrogen. *Azotobacter* is a bacterium that can fix elementary nitrogen from the atmosphere, hence with the increase of its number and activity, the soil nitrogen balance is increased (Govedarica et al., 1997).

Table 3.

Effects of fertilisation methods on the number of various systemic and physiological groups of microorganisms

Type of microorganisms		K	MM1	MM2	OM	O+MM	S	S+MM
Total number of microorganisms	Log number of cell	7.59	7.79	7.67	7.59	7.79	7.75	7.84
	Index level	100	102.6	102.3	100	106.9	102.1	103.3
Number of azotobacters	Log number of cell	2.98	2.72	2.86	2.55	3.25	3.18	3.78
	Index level	100	91.3	95.9	95.9	109.1	106.7	126.8
Number of ammonifiers	Log number of cell	5.49	5.69	5.57	6.41	6.05	5.72	6.28
	Index level	100	103.6	101.4	117.6	110.2	104.9	114.4
Number of actinomycetes	Log number of cell	3.85	3.79	3.56	4.03	7.74	4.56	4.44
	Index level	100	98.4	92.4	104.6	201.0	118.4	115.3
Number of fungi	Log number of cell	3.85	4.23	4.35	4.31	4.03	4.27	4.34
	Index level	100	109.8	112.9	111.9	104.7	110.9	112.7
Average	Log number of cell	4.75	4.84	420	4.98	5.51	5.09	4.84
	Index level	100	101.9	88.9	104.8	116.0	107.4	101.9

This group of bacteria is very susceptible to all changes occurring in the soil and it responds by its number and activities and is a good indicator of all changes and degradation of the soil. As in the case of any other microorganism, the number of azotobacters can be affected by various cropping practices. The highest increase in the number (26.8%) was recorded in the variant with manure and mineral fertilisers. The greatest log number of cells (3.78) was also recorded in this variant. Furthermore, ploughed down stover and mineral fertilisers also resulted in a fairly high number of this group of bacteria (3.25 log number of cells).

This is in accordance with previous studies that show that great amounts of mineral nitrogen adversely affect the number and activity of this group, as greater amounts of mineral nitrogen inhibit enzyme nitrogenase. The lowest number was detected in the variant with stover ploughed down. This can be explained by the competitive relation with other microbial populations, because a greater amount of fresh organic matter was incorporated. Ammonifiers are a very important group of microorganisms that are directly included into in the decomposition of fresh organic matter in the processes of ammonifaction. The number of ammonifiers was the highest (6.41 log number of cells) in the variant with stover ploughed down, which led to a highest percentage of the increase (17.6%), which is in the correlation with the amount of fresh organic matter ploughed down. Fungi and actinomycetes represent a group of microorganisms with a very developed enzymic system and they are very capable of decomposition of both, organic and inorganic matters.

Based on the obtained results it is observable that the number of actinomycetes increased in the variants with ploughed down stover by 4.6 %, while this increase was 101 % in the variants with mineral fertilisers. The differences in the number of actinomycetes (18.4 and 15.3%) in variants with ploughed down manure and mineral fertilisers were small. Fungi were stimulated in their number to approximately the same intensity in all variants of fertilising. The lowest number and the lowest percentage of the increase were established in variants with ploughed down stover and mineral fertilisers. On the average, all groups of microorganisms were mostly stimulated by fertilisation with the combination of ploughed down stover and mineral nitrogen, hence it can be concluded that the incorporation of fresh organic mater increased soil biogeny, which certainly affected the increase of the soil fertility. The results on the number increase of soil microbes are positively correlated with the degree of transformation of organic matter into soil organic matter.

According to the analysis of the nitrogen content in the soil in the variants with different fertilising with various rates of mineral fertilisers, it was established that the content of total nitrogen in the soil was changed (Table 4).

Table 4.

Effects of different fertilisation methods on changes of the nitrogen content in the soil

Fertilising	Transformation of organic matter incorporated into soil organic matter in %	Changes in nitrogen content %
Control	–	98.31
Mineral fertiliser 332 kg.ha^{-1}	–	100.00
Mineral fertiliser 664 kg.ha^{-1}	–	101.61
Organic matter	10.59	98.90
Organic matter+mineral fertilisers	7.68	101.57
Manure	53.93	101.03
Manure+ mineral fertilisers	32.35	101.93

If the fertiliser rate of 332 kg ha^{-1} is considered 100%, then the nitrogen content in control and the variant with ploughed down stover was decreased. Fertilising with a higher rate of mineral fertilisers (664 kg ha^{-1}) resulted in the increase of the nitrogen content of 1.61%. Ploughing down of organic matter (stover and manure) resulted in higher nitrogen content in the soil, and it amounted to 1.91% and 1.57% in the variants with manure and mineral fertilisers, i.e. stover and mineral fertilisers, respectively.

CONCLUSION

Fertilising with nothing more but mineral fertilisers led to a slight decrease of organic matter in the soil (103.2 kg ha^{-1}). Changes in the content of organic matter in the soil of 6,295.2 kg ha^{-1} were established in the variant with ploughed down manure in the soil layer a to the depth of 40 cm. Analogically, the highest degree of transformed fresh organic matter into soil organic matter (53.93 %) was established in the variant with ploughed down manure, while it was a somewhat lower in the combination with mineral fertilisers.

Different fertilisation methods resulted in changes of the nitrogen content in the soil and the highest increase was determined in the variant with manure and mineral fertilisers. The dynamics of the abundance of microbes is correlated with the increase in organic matter and obtained yield. The abundance of both, azotobacters and actinomycetes, was inhibited in the variant in which only the mineral fertiliser was applied. The remaining groups of microorganisms were stimulated in all variants of fertilising of different intensity depending on the fertilisation method and the type of microorganisms.

On the average, fertilising with ploughed down stover and mineral fertilisers affected, to greatest extent, the number of microorganisms (16%), while the application of greater rates of mineral fertilisers reduced the number, which is in correlation with the content of organic matter. Moreover, the highest abundance was established in the variants with manure, except for ammonifiers and actinomycetes that had a higher number in the variant with ploughed down stover and mineral fertilisers. A high productivity of this soil was pronounced in the variant with mineral fertilisers, although the decrease in the content of organic matter in the soil was established. If organic matter (ploughed down stover, manure) is applied, the soil productivity is certainly increased, which is very important for soils of a lower productivity.

LITERATURE

1.ALEXANDER M. (1977): *Introduction to soil microbiology*. John Willey and Sons Inc. New York, London.

2.ALLISON F.E. (1973): Soil organic matter and its role in crop production. Washington.

3.BERTLIN, J. (1992): Sustainable agriculture and natural resources development. Annali. Fac. Agr. Univ. Perugia, Vol. XLVI:1344

4.BREMNER, J. M., MULVAMNEY,C. S. (1982): *Total nitrogen* In: Page A.L., Miller R.H.. Keeney R.D. (eds). Methods of Soil Analysis Part 2. Chemical and microbiological properties, 2 end. Agronomy series No. 9. ASA, SSSA, Medison, Wis., pp 595–6284.

5.CAVAZZA, I., BALDONI, R., MARZI, V., PATRUNO, A. (1974): *The influence of the fertilization on soil fertility and crop yield with different rotations in a Mediterranean area.* 10th Int. Congress Soil Sci. Moscow.

6.CVIJANOVIĆ, G. (2002): *Uticaj diazotrofa na prinos i mikrobiološku aktivnost u zemljištu pod usevom kukuruza, pšenice i soje*. Doktorska disertacija, Poljoprivredni fakultet u Novom Sadu.

7.GOVEDARCA M., MILOŠEVIĆ N., JARAK M., (1997): *Biološka azotofiksacija u poljoprivredi: mogućnosti primene i perspektive*. XXXI Seminar agronoma, Novi Sad 35–43.

8.KOVAČEVIĆ, D. (2004): Sistem zemljoradnje u konceptu održive poljoprivrede. Međunarodna konferencija o održivoj poljoprivredi i evrposki integracioni procesi. Uvodni referat. Knjiga abstrakata: 34, 19–24 septembar, Novi Sad.
9.MILOJIĆ, B. (1991): Sistem biološke poljoprivredeu svetu i kod nas. Ekonomika poljoprivrede, Vol 38. No. (6–7–8) Beograd :263–275.
10.MILOŠEVIĆ N., GOVEDARICA M., JARAK M.(1997): *Mikrobi zemljišta: značaj i mogućnosti* « Uređenje, korišćenje i očuvanje zemljišta», JPDZ, Novi Sad, 389–398.
11.MOLNAR I., (1999): *Proučavanje uticaja organskog i mineralnog đubrenja na prinos ratarskoh kultura i hemijske osobine zemljišta*. Zbornik radova naučnog skupa «Čovek i biljka», Novi Sad 121–129.
12.POCHON J., TARDIEUX., (1962): Tehnickues d analise en microbiologique du Soil edit de la tourele, Paris.
13.STARČEVIĆ, LJ., MARINKOVIĆ, B. (1988): Prinos kukuruza i neke agrohemijske osobine zemljišta u zavisnosti od dugogodišnje upotrebe organskih i mineralnih đubriva Simpozijum: Savremeni sistemi kontrole plodnosti zemljišta i upotrebe đubriva u funkciji optimalnih prinosa danas i sutra, Novi Sad.
14.VESKOVIĆ M. (1988): *Bilans organske materije u zemljištu i prinos kukuruza na černozemu Zemun Polja pri različitim sistemima đubrenja*, Doktorska disertacija, Poljoprivredni fakultet, Beograd–Zemun.
15.WISNIEWSKI, W., GONET, S. S., MURAWSKA, B. (1984): *The influence of nitrogen fertilization on the transformation of soil organic matter*. 9th World fert. Congres, Budapest.