Mini Review
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Zea mays L. in monoculture and northernity, microbocenosis of its rososphere

Abstract

The regularities of the action of various species, doses and combinations of mineral fertilizers with their long use in monoculture for more than 50years and ten-field crop rotation (5 rotations) on the productivity of maize, the content and stocks of carbon, and the microbocenosis of the rhizosphere of plants were studied. It is shown that, in the conditions of the Central Chernozem Region, maize is able to withstand prolonged cultivation in monoculture. The high efficiency of fertilizers was achieved in the variant N60P60K60, where the average annual productivity of green mass and corn grain exceeded the control in the crop rotation, respectively33.6 and 37.7%, in monoculture - by 45.7 and 47.0%, and the content of organic carbon in the soil was maintained during the time of the experiment at the initial level. The adaptive potential of the microbocenosis formed under the monoculture of maize is quite high, which allows one to assert about its counteraction to soil fatigue.

Keywords: corn, crop rotation, monoculture, fertilizers, long-term application, carbon, microbocenosis

Volume 8 Issue 6 - 2018

Alexander Fedorovich Stulin,[1] Nadezhda Vladimirovna Verkhovtseva[2]

[1]Department of Agricultural Sciences, All-Russian Research Institute of Corn, Russia

[2]Moscow State University, Russia

Correspondence: Alexander Fedorovich Stulin, Voronezh Branch of the All-Russian Research Institute of Corn, All-Russian Research Institute of Corn, 396835, Voronezh Region, Khokholsky District, Experimental Station, Chayanov St., 13, Russia, Email opyfnoe@vmail.ru

Received: February 16, 2018 | **Published:** November 16, 2018

Introduction

According to its biological characteristics, corn belongs to crops that are resistant to permanent cultivation and, therefore, in many countries and, primarily in the USA, it is believed that permanent corn crops are economically more profitable than the crop rotation system and suggest that in the future the permanent cultivation of this culture will increase.[1]Already in the United States about 15% of the acreage is corn, grown more than 5years in a row in permanent planting.[2] The results of studies obtained in long field experiments on different backgrounds in monoculture of maize and crop rotation with varying degrees of their saturation with corn do not allow one to draw unequivocal conclusions about the size of output from 1 hectare of arable land for certain soil-climatic conditions.[3–5] Economists provide statistically comparable yield data for this crop on a fertilized background, both in monoculture and in crop rotation. In their opinion, monoculture of corn is economically expedient, since it does not require significant labor input.[2]

Long-term experiments with maize monoculture are the only basis for studying the dynamics of C3 and C4 vegetation due to a significant difference in discrimination of the heavy 13C isotope depending on the type of photosynthesis, which allows to determine the necessary characteristics of the carbon cycle in agrocenoses, since even small changes in carbon stocks in the soil can have a significant influence on the composition of the atmosphere. Experiments with corn monoculture are widely represented in the USA, Canada, Germany, Denmark, Hungary and other countries. The longest in the world experiments with corn monoculture continue at the University of Illinois, the experimental fields of Morrow since 1876 and Sanborn since 1888.

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The study of various mechanisms in the functioning of permanent corn crops was not widely used in Russia due to the predominance of C3-type vegetation on its territory and the lack of long-term experiments with this culture. The investigations were carried out in stationary field experiments (51o36'28.8 N and 38o58'9.54 E). The crop rotation is deployed in three fields and one field with a corn monoculture with an area of each field of 1.1 hectares. The ten-field crop rotation with alternating crops: legumes, winter wheat, sugar beet, maize for silage, winter wheat, corn for grain, legumes, winter wheat, sunflower, barley. Corn in monoculture since 1960 and spatially placed at a distance of 12m from the crop rotation.

This is the longest ongoing experience with corn monoculture not only in Russia, but also in the near abroad. The area between the crop rotation and corn monoculture is "eternal" pure steam (since 1960). The vapor is maintained in a clean state, the weed vegetation is destroyed by mechanical shoots. Annually autumn plowing is carried out in the area with pure steam, in corn monoculture and in crop rotation. Soil is chernozem leached chernozems (Chernozems Luvic Pachic) with the content in the arable layer at the time of the experiment: humus 5.65%, total nitrogen 0.24%, phosphorus 0.15%, potassium 2.0%, pH5.5, the sum of the absorbed bases is 38.4mmol/100 g of soil, the degree of saturation with bases above 90%. Mineral fertilizers (Na, Pcr, Kx) were introduced annually from 1965 in the fall according to the scheme given in the table. The area under cultivation is 269.5m^2, accounting - 192.5m^2. Repeatability is 3-fold. The yield of green mass of corn on an unfertilized background on average for 5 rotations of crop rotation was 26.2 t/ha (with fluctuations in years from 17.4 to 40.7t/ha), in monoculture - 22.1t/ha (from 16, 2 to 30.3t/ha) (Table 1).

The crop yield by rotation of rotation on a natural background was: I - 28.4t/ha, II - 25.8t/ha, III - 20.5t/ha, IV - 31.5t/ha and V - 25, 0t/ha, which is higher than in monoculture: in I-III rotations - by 14%, IV - by 24% and V - by 26%. The reaction of maize to the introduction of nitrogen, phosphorus and potassium fertilizers was the same and did not depend on the place of its cultivation. The introduction of N60 increased the yield of green mass of corn on average over the years of research in crop rotation by 4.0tons/ha.

Table 1 Productivity of maize in crop rotation and monoculture with long-term application of fertilizers, t / ha (average for 5 rotations)

Option	Crop rotation		Monoculture		Prirost due to sevos	
	green mass	grain	green mass	grain	green mass	grain
Without fertilizers	26.2	3.42	22.1	2.81	4.1	0.6
M60	4	0.73	5.2	0.73	2.9	0.61
P60	0.4	0.02	-0.9	-0.04	5.4	0.67
K60	0.8	0.04	1.1	0.01	3.8	0.64
M60P60	7.4	1.11	7.7	1.1	3.8	0.62
M60K60	4.9	0.84	6.7	0.97	2.3	0.48
P60K60	1.3	0.13	1.2	0.1	4.2	0.64
M60P60K6	8.8	1.29	10.1	1.32	2.8	0.58
M60P30K6	8.1	1.21	9	1.28	3.2	0.54
M60R120K1	8.7	1.24	9.5	1.29	3.3	0.56
M60P60K12	8.6	1.21	9.6	1.35	3.1	0.47
M120R60K1	11.5	1.65	13.2	1.79	2.4	0.47
HCP05	2.9	0.35	2.4	0.32		

In monoculture, the average increment from application of N60 was higher than in crop rotation by 30%. Long-term studies show that nitrogen fertilizers must be added together with phosphorus and potassium fertilizers at 60 kg/ha, while the yield increment is doubled in comparison with N60. Synthesis of data from 140 field experiments with maize grown in the European part of Russia confirmed the indisputable advantage of complete mineral fertilization before pair wise combinations in the formation of yield of corn. Yield of the green mass of maize increased from the application of N60P60K60 in crop rotation by 34%, in monoculture by 46%. Reducing the phosphorus dose to 30 kg/ha, as well as increasing it and potassium to 120 kg/ha in full fertilizer, does not change the yield. With an increase in the nitrogen dose in full fertilizer to 120 kg/ha, the increase in green mass of corn in the crop rotation was 11.5tons per hectare, in monoculture 13.2tons/ha, which is 14.8 percent more.

The yield of corn grain on an unfertilized background on an average for years of research in the crop rotation was 3.42 t/ha with a span of variation in years from 1.84 t/ha in 1983 to 5.08 t/ha in 2015. In monoculture, the average grain yield was 2.81 t/ha with fluctuations from 1.63 t/ha in 1986 to 4.42 t/ha in 2015. When applying a full mineral fertilizer in a dose of 60 kg/ha ai. The yield of grain in the crop rotation increased by 38%, in monoculture the increase was somewhat larger - 47%. The same scheme of fertilization and agrotechnics in the cultivation of the same maize hybrid in crop rotation and monoculture makes it possible to clarify the role of the rotation factor in the productivity of maize. The increase in the yield of corn due to the rotation factor by the variants of the experiment was in the range of 2.3-5.4 t/ha of green mass and 0.47-0.67 t/ha of grain. The highest content of organic carbon in agrochernozem was in the plow layer. The archived soil sample, selected before the experiment, contained 3.19%, in the "eternal" pure pair 3.12%, in the monoculture of corn on an unfertilized background and with the annual application of N60P60K60 - 3.37 and 3.42%, respectively, with further its decrease along the soil profile. In the soil layer of 60-80 cm, there were no significant differences in the carbon content of the variants studied. The carbon stocks in the chernozem indicate a high stability of the organic matter of this soil to changes in agricultural practices, the carbon stocks in the soil layer 0-80 cm remained at a very high level, from 270 to 287 t/ha and not reliably differed among themselves. After 50years of growing corn, the carbon from plants C4 was 5% of the total soil organic matter in the 0-20cm layer and less than 0.4% in the 60-80cm layer. This low rate of carbon renewal is associated with high reserves carbon in the black earth soil. The composition of the microbial community was reconstructed using chemical markers of microorganisms by gas chromatography-mass spectrometry (GC-MS) at HP-5973 Agilent Technologies, USA. Studies have found, that the number of microorganisms determined by the GC-MS method for all the experiment variants, including the 1966 archival sample, was quite high-107-108 cells/g for bacteria, up to 76μg/g of soil for saprotrophic fungi and up to 195μg/g of soil for arbuscular mycorrhizal fungi. 48 bacterial species reconstructed in microbial communities belonging to 35 genera, which belong to the five phylums-Proteobacteria, Actinobacteria, Firmicutus, Bacteroidetes, Chlamydiae. In the corn rhizosphere, regardless of the place of its growth, representatives of the phylum Actinobacteria - active hydrolytics (about 60%) prevail.

When considering the contribution of the "new" carbon coming from corn to the biomass of soil microorganisms, in our experience it has been established that saprotrophic fungi do not play a leading role in the transformation of the organic matter of the soil. The incoming carbon of the root extracts and plant remains of maize actively transforms bacteria and mycorrhizal fungi. When considering the contribution of the "new" carbon coming from corn to the biomass of soil microorganisms, in our experience it has been established that saprotrophic fungi do not play a leading role in the transformation of the organic matter of the soil. The incoming carbon of the root extracts and plant remains of maize actively transforms bacteria and mycorrhizal fungi.

Citation: Stulin AF, Verkhovtseva NV. *Zea mays* L. in monoculture and northernity, microbocenosis of its rososphere. *Adv Plants Agric Res.* 2018;8(6):379–381. DOI: 10.15406/apar.2018.08.00354

Obligations and changes in the qualitative composition of the microbial community in the soil under permanent corn crops were not detected. However, during the 50year-old corn monoculture (judging from the archival pattern), microbiocenosis was reconstructed. The decrease in subdominant groups in the community was noted, while the dominant ones increased their number 3-4 times. According to the ecological indicator - the Berger-Parker leveling index - there was an increase in monodomination. From an environmental perspective, this situation can be considered an unfavorable trend. At the same time, the prolonged use of various agronomic methods did not affect the number of microbial communities of agrochernozem The biodiversity index (Shannon) is high in all variants of the experiment, which indicates the leveling and stability of microbial communities, which allows us to assert that a specific multi-species microbial community was formed under maize monoculture, in which a large aerobic-anaerobic regulating association (*Micobacterium* spp., *Propionibacterium* spp .) with a high adaptive potential, capable of resisting soil fatigue.

Conclusion

In agroecological conditions of the Central Chernozem Region of Russia, maize is able to withstand prolonged cultivation on the same field. On an average for five rotations of ten-field crop rotation, the annual application of N60P60K60 increased the yield of green mass and corn grain in crop rotation by 8.8 and 1.29 tons/ha, respectively, and by 10.1 and 1.32tons/ha in monoculture. The increase in the yield of green mass and grain of corn due to the rotation factor on the variants of the experiment was in the range of 2.3-5.4 and 0.5-0.7 t/ha. The reserves of organic carbon in agrochernozem from the 0-80cm soil samples have been preserved at a very high level, from 270 to 287 tons Corg/ha, which indicates the high stability of the organic matter of this soil. The adaptive potential of the microbocenosis formed under the monoculture of maize is quite high, which makes it possible to speak of its counteraction to soil fatigue.

Acknowledgements

None.

Conflict of interest

Author declares that there is no conflict of interest.

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