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Orientation of nitrogen transformation processes in the soil with corn growing under the different fertilization practices

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Aim. To explore the peculiarities of nitrogen transformation in sod-podzolic soils with corn growing under different fertilizer types and the effect of bacterization. **Methods**. Agrochemical, field and lyzimetric, chromatographic determination of nitrogen fixation activity and emission of N_2O. **Results**. The highest losses of nitrogen from the soil occurred in the variants with manure application and use of mineral fertilizers $N_{90}P_{90}K_{90}$. The processes of nitrogen transformation in soil and corn yield were optimized using the combination of mineral fertilizers with green manure and microbial agent. **Conclusions**. The application of fertilizers for corn growing on sod-podzolic soils of Polissya region should be accompanied with the use of green manures. The use of microbial preparations is recommended.

Keywords: corn, nitrogen fixation, N_2O emission, fertilizers, green manure, microbial preparation.

INTRODUCTION

The intensity of the nitrogen transformation processes in the soil may serve as an indicator of favorable or threatening situation in agrocenoses under the action of various biotic and abiotic technological factors. At this, the characteristics of two opposing processes of nitrogen cycle, run by soil microorganisms, – nitrogen fixation and N_2O emissions – are of great importance. Besides, a significant role is attributed to the intensity of nitrogen leaching outside the soil root layer, which depends not only on soil and climatic conditions but also on the fertilization practices and organic matter in soil.

Our current research was aimed at the determination of the direction of the nitrogen transformation processes in the soil with corn growing under different fertilization practices and the use of microbial preparation.

MATERIALS AND METHODS

The present study was conducted in stationary and lysimetric experiments in the Institute for Agricultural Microbiology and Agricultural Production NAAS on sod-podzolic sandy loam soils (pH_{salt} – 4.9, humus content – 1.1 %, mobile P_2O_5 – 179.0 mg/kg, exchangeable potassium – 80 mg/kg soil).

The experiments were performed on corn of Kyshkun variety.

The scheme of the experiment (same for field and lyzimeters) was as follows:

Treatment I. Without bacterization

1. Control (without fertilizers)
2. Green manure
3. $N_{90}P_{90}K_{90}$
4. $N_{90}P_{90}K_{90}$ + green manure
5. Manure, 40 t/ha

Treatment II. With bacterization
(microbial preparation Biogran)

6. Control (without fertilizers)
7. Green manure
8. $N_{90}P_{90}K_{90}$
9. $N_{90}P_{90}K_{90}$ + green manure
10. Manure, 40 t/ha

The experiments were conducted in the field on the testing plots of 102 sq.m (total) and 60 sq.m. (accountable), the repetition of the experiment – 4-fold, randomized design.

Corn sowing rate – 75 thousand seeds/ha. Farming practices – standard for Polissya region conditions. Planting dates – early May.

The fodder lupine crops, sowed in early August as the intermediate culture after rye, were used as the green manure. The green fodder lupine was disked in the second week of November. Sowing rates – 1.5 million seeds per 1 ha (160 – 180 kg/ha).

The technology included stubble shelling, plowing, disking of green manure, pre-sowing cultivation combined with the application of fertilizers, herbicides, and seeding.

Nitrogen fertilizers were applied in the form of ammonium nitrate (34.5 % dv), granulated simple superphosphate (19.5 % dv) and potassium chloride (60 % dv). Phosphate and potash were applied under major soil treatment, nitrogen – at pre-sowing cultivation.

The bedding manure containing 0.50 % of N, 0.25 % of P_2O_5 and 0.60 % of K_2O was used as organic fertilizer.

Granular microbial preparation Biogran was applied at the rate of 2 granules per seed. Taking into the account the sowing rate of 75 thousands seeds per hectare, the number of granules of taken biological preparations was approximately 150 thousand per hectare (6 kg/ga). The local application of Biogran was performed with the planter at corn seeding. Biogran contains the active cells of nitrogen fixing bacteria *Azospirillum brasilense* 4014 immobilized on vermicompost (TU U 24.1-00497360-006:2008).

The study in the stationary field experiment was conducted during 2010–2013, followed by lyzimetric experiment in 2013.

In their design lyzimeters are concrete, of filled soil type. Lyzimetric cells were filled with soil step-by-step starting from bedrock considering the capacity of genetic horizon. Single cell layer of soil – 155 cm, weight – 10.5 tons.

The sown area of lyzimetric cell – 3.8 sq.m., repetition of the experiment – 4 fold.

During stationary experiments the dynamics of potential nitrogen fixation activity [1], potential nitrous oxide emissions [2] in rhizosphere soil of corn plants, as well as yield calculations were measured. The content of nitrates, ammonia nitrogen and soluble humus compounds was determined in lyzimetric waters [3]. The experiments and statistical analysis were carried out in accordance with the existing methods [4].

RESULTS AND DISCUSSION

The research conducted revealed the stimulating effect of intermediate green manure on the process of nitrogen fixation in the root zone of corn plants. The combination of bean green manure with Biogran was shown to be favorable. The highest rates of nitrogenase activity in the experiment were revealed under these conditions (Table 1).

The increased activity of nitrogen fixation in the rhizosphere of corn plants was also observed in the variants with manure application. Nevertheless, its combination with bacterial preparation had no cumulative effect, which can be explained by the competition interaction between the bacteria introduced into the agrocenosis and microorganisms in manure, since its application is followed by the soil enrichment with bacteria and micromycetes. The possibility of the soil bacterization with manure was indicated at the end of the nineteenth century by Dokuchaev V. V.: "*Undoubt-*

Table 1. Potential nitrogen fixation activity in rhizosphere soil of corn plants under the influence of different types of fertilizers and Biogran, nmol C_2H_4/g soil/h

Variants	Corn development stages		
	6–8 leaves	flowering	ripening
Treatment I – without bacterization			
Without fertilizers	33.5	28.0	23.7
Green manure	49.9	44.4	39.0
$N_{90}P_{90}K_{90}$	11.4	19.0	29.3
$N_{90}P_{90}K_{90}$ + green manure	20.5	31.9	34.8
Manure	37.0	39.5	31.3
Treatment II – bacterization with microbial preparation Biogran			
Without fertilizers	35.0	33.5	26.5
Green manure	59.7	55.0	40.5
$N_{90}P_{90}K_{90}$	18.5	22.1	32.0
$N_{90}P_{90}K_{90}$ + green manure	32.7	39.2	42.5
Manure	38.3	40.3	35.0
LSD_{05} experiment	6.2	5.6	5.5
fertilizer	3.3	2.8	2.7
inoculation and interaction	3.2	2.8	2.8

edly, together with manure we introduce into the soil bacteria, which role, probably, is not less than the one of applied materials” [5].

Mineral fertilizers suppressed the progress of the process for a lasting period. The combination of fertilizers and green manure restored nitrogen fixation activity, thus indicating the improvement of the environmental conditions. It should be noted that the significant activation of nitrogen fixing microorganisms was observed in the variants with microbial preparation, applied on given backgrounds.

The described characteristics were similar for all the years of research.

Another, opposite to the biological nitrogen fixation, process is denitrification, whose potential activity was measured by the intensity of the nitrous oxide emissions (Table 2).

Performed in the dynamics, our studies revealed the significant loss of nitrogen in the form of N_2O in variants with fertilizers and manure.

The bacterization on the early stages of plant development slightly stimulated the activity of biological denitrification in all the variants. This may indicate that juvenile corn plants have sufficient nitrogen supply from the soil, and under these conditions nitrogen fixing bacteria introduced in agrocenoses temporarily “switch” to the better substrate – mineral nitrogen, which results in biological denitrification [6].

Table 2. Potential N_2O emissions in rhizosphere soil of corn plants under the influence of different types of fertilizers and Biogran, nmol N_2O/g soil/h

Variants	Corn development stages		
	6–8 leaves	flowering	ripening
Treatment I – without bacterization			
Without fertilizers	7.5	6.6	4.5
Green manure	5.2	3.9	4.1
$N_{90}P_{90}K_{90}$	17.4	15.0	11.8
$N_{90}P_{90}K_{90}$ + green manure	12.8	10.2	6.2
Manure	20.2	19.1	13.5
Treatment II – bacterization with microbial preparation Biogran			
Without fertilizers	8.9	4.1	3.9
Green manure	6.5	3.2	2.8
$N_{90}P_{90}K_{90}$	19.0	11.3	6.5
$N_{90}P_{90}K_{90}$ + green manure	13.6	6.0	5.4
Manure	21.0	18.8	12.9
LSD_{05} experiment	6.0	7.8	5.2
fertilizer	3.3	3.9	2.8
inoculation and interaction	3.0	4.0	2.6

Later in the season, microbial preparation started to contribute to the reduction of gaseous nitrogen losses from the soil. This effect is explained by the positive impact of introduced bacteria on the growth of corn, as they utilize much larger amounts of nitrogen for constructive metabolism and, thus, limit the amount of substrate (nitrate) for denitrifying microorganisms.

The green manure was shown to be the powerful limiting factor influencing the biological denitrification process, especially in the combination with microbial preparation. The combination of green manure with mineral fertilizers and Biogran application reduced the emissions of gaseous nitrogen starting from the second phase of given study. This effect might be caused by the intensive growth of microorganisms stimulated both by the introduction of agronomically beneficial microorganisms into the soil and stimulation of their development (as well as other soil microorganisms) with fresh organic matter. The rapid growth of microorganisms also resulted in binding a significant amount of nitrogen for the specific time, thus eliminating the substrate for denitrifying bacteria for nitrate respiration and limiting their function.

As it was noted above, the manure stimulates biological denitrification process. Thus, the combination of manure and corn seeds bacterization did not cause any significant changes in the activity of biological denitrification process.

The described characteristics were clearly traceable during all research years.

Thus, green manure and microbial preparation used both separately and (especially!) in combination significantly limited the gaseous loss of nitrogen from the agrocenoses soil and can be used as a powerful practice for the optimization of nitrogen nutrition of crops. The combination of given practices with the use of mineral fertilizers is necessary, taking into the account the conservation of nitrogen pool in the soil and improvement of environmental conditions. The application of manure stimulated the process of nitrogen fixation, but also caused the activation of nitrous oxide emissions.

The determination of nitrogen content of humic compounds in wash waters demonstrated that a large

Table 3. Losses of nitrogen and soluble humus under different corn fertilization practices, kg/ha

Variants	$N\text{-}NO_3$		$N\text{-}NH_4$		Water soluble humus	
	I	II	I	II	I	II
Control	40.0	27.0	5.6	5.0	24.8	14.0
Green manure	36.1	30.0	4.0	3.0	16.0	15.0
$N_{90}P_{90}K_{90}$	56.0	50.0	6.8	6.0	26.0	18.0
$N_{90}P_{90}K_{90}$ + green manure	52.0	44.0	6.0	5.4	19.0	18.0
Manure, 40 t/ha	64.0	62.0	8.8	8.8	31.4	31.0
LSD_{05} experiment	4.5		0.4		2.1	
fertilizer	2.3		0.2		1.1	
inoculation and interaction	2.2		0.2		1.1	

Note: Treatment I – without bacterization; treatment II – use of Biogran.

amount of their losses was observed in the variants with mineral fertilizers and manure (Table 3).

Thus, compared to the control the nitrate losses increased 1.4 and 1.6 times, respectively. Ammonium leaching was relatively small, but still had noticeable differences between the options. The highest losses were observed in variants with manure and mineral fertilizers. Green manure on the contrary had limited leaching of ammonia nitrogen.

Similar dependences were observed for soluble humus.

The application of biological preparation proved to limit significantly the intensity of nutrients leaching. Thus, the loss of nitrate in the variants without fertilizers on the Biogran background decreased by 48 %, ammonia nitrogen – by 12 %, water soluble humus – by 77 %.

The microbial preparation used in the variants with $N_{90}P_{90}K_{90}$ limited the losses of nitrates, ammonium and soluble humus by 12, 13 and 44 %, respectively.

Table 4. Corn yield influenced by biological preparations, types and fertilizer combinations, t/ha

Variants	Years				Average, t/ha	Increase			
						to control		from inoculation	
	2010	2011	2012	2013		t/ha	%	t/ha	%
Treatment I – without bacterization									
Without fertilizers, control	4.00	3.80	4.40	3.40	3.90	–	–	–	–
Green manure	4.40	4.24	4.70	5.60	4.74	0.84	22	–	–
$N_{90}P_{90}K_{90}$	6.50	7.02	7.50	6.61	6.91	3.01	77	–	–
$N_{90}P_{90}K_{90}$ + green manure	7.80	7.68	7.92	8.20	7.90	4.00	103	–	–
Manure, 40 t/ha	4.52	4.60	4.70	5.01	4.71	0.81	21	–	–
Treatment II – bacterization with microbial preparation Biogran									
Without fertilizers, control	4.40	3.92	4.56	3.52	4.10	0.20	5	0.20	5
Green manure	4.86	4.58	5.16	6.04	5.16	1.26	32	0.42	9
$N_{90}P_{90}K_{90}$	6.78	7.42	7.82	6.94	7.24	3.34	85	0.33	5
$N_{90}P_{90}K_{90}$ + green manure	8.30	7.90	8.14	8.68	8.27	4.37	112	0.37	5
Manure, 40 t/ha	4.60	4.60	5.00	5.24	4.86	0.96	25	0.15	3
LSD_{095} experiment	0.26	0.30	0.29	0.22					
backgrounds	0.13	0.16	0.15	0.12					
inoculation and interaction	0.13	0.15	0.17	0.12					

A significant decrease in the intensity of studied substances leaching occurred in the variants with the combination of green manure and microbial preparations (Table 3). Considering aforesaid this combination can be recommended for introduction in order to optimize the environmental conditions in agrocenosis.

The investigated factors of corn fertilization influenced the yield formation in different ways. The data, shown in Table 4, indicates that organic fertilizers ensured almost the same level of productivity and yield increase comparing to the control – 0.8 t/ha (averaged for four years).

The fertilizers significantly increased the yield of corn with the mean increment of 3 t/ha. However, the highest corn productivity was observed in the variants with the combination of green manure and fertilizers – the gain to control was 103 %.

The application of Biogran increased crop productivity, but comparing to manure background the increment was within the statistical error. The significant yield increase was observed on the background of green manure, fertilizers and their combinations (Table 4). The yield increase caused by the bacterization was relatively low – within 0.3–0.4 t/ha, but considering the low cost of preparation and a significant environmental impact, the feasibility of its application is not in doubt.

CONCLUSIONS

The application of mineral fertilizers in the corn growing practices on sod-podzolic soils in Polissya region of Ukraine should be accompanied by the use of green manures. It ensures optimization of the nitrogen transformation processes in the soil and promotes yield increase. The use of microbial preparation Biogran improves ecological conditions of agrocenosis.

Направленість процесів трансформації азоту в ґрунті під кукурудзою за різного удобрення культури

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Мета. Дослідити особливості трансформації азоту в дерново-підзолистому ґрунті при вирощуванні кукурудзи за внесення різних видів добрив і бактеризації. **Методи.** Агрохімічні, польовий і лізиметричний, газохроматографічне визначення активності азотфіксації та емісії N_2O. **Результати.** Найбільші втрати азоту з ґрунту відбуваються за внесення гною та $N_{90}P_{90}K_{90}$. Процеси трансформації азоту в ґрунті і врожайність кукурудзи оптимізуються за поєднання мінеральних добрив з люпиновим сидератом і мікробним препаратом. **Висновки.** У технологіях вирощування кукурудзи на дерново-підзолистих ґрунтах Полісся внесення мінеральних добрив слід доповнювати використанням сидератів. Бажано застосовувати при цьому мікробні препарати.

Ключові слова: кукурудза, азотфіксація, емісія N_2O, добрива, сидерати, мікробний препарат.

Направленность процессов трансформации азота в почве под кукурузой при различном удобрении культуры

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Цель. Изучить особенности трансформации азота в дерново-подзолистой почве при выращивании кукурузы под влиянием различных удобрений и бактеризации. **Методы.** Агрохимические, полевой и лизиметрический, газохроматографическое определение активности азотфиксации и эмиссии N_2O. **Результаты.** Наиболее высокие потери азота из почвы отмечены при внесении навоза и $N_{90}P_{90}K_{90}$. Процессы трансформации азота в почве и урожайность кукурузы оптимизируются при дополнении минеральных удобрений люпиновым сидератом и микробным препаратом. **Выводы.** В технологиях выращивания кукурузы на дерново-подзолистых почвах Полесья внесение минеральных удобрений следует дополнять использованием сидератов. Желательно применение микробных препаратов.

Ключевые слова: кукуруза, азотфиксация, эмиссия N_2O, удобрения, сидераты, микробный препарат.

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