Increasing the Nitrification Capacity of Chestnut Soil under the Influence of Lanthanum-Containing Microfertilizers

NADEZHDA E. ABASHEEVA[1], NINA M. KOZHEVNIKOVA[2], MARIA G. MERKUSHEVA[1], LYUDMILA N. BOLONEVA[1] and ZOYA A. SOLDATOVA[1]

[1]Institute of General and Experimental Biology, Siberian Branch of the Russian Academy of Sciences, Ul. Sakhyanovoy 6, Ulan-Ude 670047 (Russia)

E-mail: ioeb@bsc.buryatia.ru

[2]Baikal Institute of Nature Management, Siberian Branch of the Russian Academy of Sciences, Ul. Sakhyanovoy 8, Ulan-Ude 670047 (Russia)

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Abstract

New efficient lanthanum-containing microfertilizers rendering biopositive prolonged action to nitrification capacity of chestnut soil are obtained by sorption technology. Lanthanum-containing microfertilizers increase the productivity of peas green mass, pepper and tomato fruitage improving their feed and nutritional qualities due to increase in the content of general and protein nitrogen, saccharides, ascorbic acid.

INTRODUCTION

Chestnut soils which make up 37 % of the Transbaikalian cropland are in significant degree subject to degradation because of deflationary processes of natural and man-caused character [1]. To increase chestnut soil fertility it is of great importance, along with the application of organic fertilizers, to search for new ones with high biological activity which can provide optimal circulation of biophilic elements in soil, promote intensification of physicochemical, microbiological and enzymatic transformations, and also significant dynamism of soil parameters.

It is known [2, 3] that lanthanum sulphate and nitrate applied as microfertilizers manifest high biological activity. It is shown that lanthanum sulphate catalyzes atmospheric nitrogen fixation by azotobacter in the sowed legumes; lanthanum nitrate is an effective microfertilizer increasing the germination of wheat, peas, corn, beet seeds and raising the fertility of cultures by 22–40 %, accretion of dry matter by 11–13 %; at the same time a period of maturing decreases by 6–10 days.

High biological activity of rare earths was marked in the works of D. N. Pryanishnikov [4] who pointed out to necessity of application of rare earth compounds to increasing the soil fertility. The content of rare earth compounds in phosphoric fertilizers makes up from 0.5 to 2.5 %, therefore, bringing phosphoric fertilizers into the soil we also bring rare earth elements. Hence it is necessary to study their influence on the processes in the fertilizer – soil – plant system.

It is established that rare earths take part in the process of humus accumulation and intensify the nitrogen exchange [5]. The studies carried out by us on the ecologo-agrochemical estimation of lanthanum compounds showed that lanthanum-containing microfertilizers promote the activation of microbiological activity in chestnut soil increasing the total number of microorganisms as well as Actinomycetes, fungi and yeast during the shorter time in comparison with the control. An increase in soil enzymatic activity is also shown for the example of catalase, dehydrogenase, protease and urease [6].

Biological activity of lanthanum compounds can be increased with the help of sorption technology, using natural zeolites as a sorbent. At present, sorption technology is the most rational approach to the creation of efficient microfertilizers, which makes it possible to prolong their action and to decrease possible migration, which is the most important for chestnut soils of light granulometric composition with the low biological activity [7].

According to available data [8–11], lanthanum sorption was carried out only on synthetic zeolites. It was found out that as a consequence of ion-sieve effect it was impossible to conduct the complete exchange of lanthanum ions on the zeolites X and Y at 250 °C, and also to obtain the lanthanum form of the zeolite A [9]. It is necessary to note that the exchange for lanthanum ions in all cases was carried out from chloride solutions. The values of effective diffusion coefficients determined during the study of lanthanum sorption kinetics on the NaY zeolite were 10^{-8}–10^{-9} cm^2/s [10].

Earlier we have studied the kinetics and equilibrium of lanthanum ion sorption by mordenite-containing tuff from sulphate and nitrate solutions [12]. It is established that mordenite-containing tuff has the capacity for extracting lanthanum ions from water solutions. In the region of low concentrations (<0.002 M) lanthanum ions are quantitatively extracted independently of the size of sorbent grains and the ratio of the mass of solid to liquid phases. With an increase in the concentration of solutions, a decrease in sorption capacity of mordenite-containing tuff with respect to lanthanum ions is observed. The process rate depends on the size of tuff grains and on the concentration of solution.

It is of interest to study the influence of lanthanum-containing microfertilizer on nitrification processes in chestnut soil, since the content of nitrate nitrogen in soil can be an index of ecological safety in the soil medium and reflects the level of its fertility. In the number of works [1, 13] it is demonstrated that growing on nitrate, plants have a higher level of organic acids in cells and a larger store of saccharides, *i. e.*, less depend on the intensity of photosynthesis. An important circumstance is the fact that assimilation of nitrates is strictly coordinated and regulated by carbon metabolism. Nitrates can be accumulated in different organs of a plant, since they are considerably less toxic for it than ammonium nitrogen [13].

EXPERIMENTAL

Mordenite-containing tuff of the Mukhor-Talinsk perlite-zeolite deposit (Buryatia) was used as a sorbent, of the following content, %: SiO_2 70.96, Al_2O_3 11.97, MgO 0.18, CaO 0.92, Na_2O 2.38, K_2O 5.22. Saturation of natural zeolite by lanthanum ions was carried out from 0.001–0.0015 M $La_2(SO_4)_3$ solutions; lanthanum was completely extracted from solutions till the exchange capacity of 0.001–0.085 mg-eq/g. It was established that during the lanthanum ion sorption from sulphate solutions the equilibrium state was achieved in 37–40 h of the contact of zeolite with solution [12].

The study of the efficiency of the action of lanthanum-containing microfertilizer on the nitrification activity of chestnut soil, fertility and quality of agricultural crops was carried out in vegetative and field-vegetative experiments. In the fist one, in the vessels with a volume of 6 l, chestnut soil was used with humus content 2.40 %, pH 6.8, well fed with mobile phosphorus (21 mg P_2O_5) and mean content of exchange potassium 11 mg K_2O per 1 kg of soil. Lanthanum content of the soil was 0.003 %. In each vessel 15 peas seeds of "Nonshowered" grade were sown. By harvesting, 5 plants were kept in the phase of mass blooming. Humidity of soil in the vessels was sustained at the level of 60 % from complete water capacity. The sowing was carried out in June 8, harvesting – in July 29. Repetition of the experiment was fourfold.

In vegetative experiment, ammonium nitrate, monosubstituted calcium phosphate $Ca(H_2PO_4)_2$, potassium chloride counting on 0.15 g N, 0.15 g P_2O_5, 0.15 g K_2O per 1 kg of soil were brought into the soil as a background. Lanthanum was introduced into the soil in the form of $La_2(SO_4)_3$ counting on 3 and 6 mg per 1 kg of soil. Microfertilizer on the basis of natural zeolite and lanthanum was introduced by 3 and 6 mg dozes counting for lanthanum. Thus, microfertilizer was introduced by 6 and 12 g dozes per vessel, respectively.

Field-vegetative experiment was carried out in vessels without bottom, per 7 kg of soil with humus content of 2.66 %, high content of mobile phosphorus and exchange potassium. Repetition of the experiment was ninefold. In each vessel, a yield of one plant in technical maturity of peppers "Gold medal" and tomatoes "Miracle of a market" was taking into account. Mineral fertilizers were not brought into the soil.

Chemical analysis of soils was executed according to the standard procedures: humus – according to Tyurin (in Nikitin's modification), mobile phosphorus and exchange potassium from one extract – according to Machigin [14]. Chemical analysis of plants was carried out according to [15]. Lanthanum content of plants was determined after dry combustion photometrically with arsenazo III [16]. Mathematical treatment of experimental data was carried out by the standard methods of variance and correlation analysis [17, 18].

RESULTS AND DISCUSSION

Soils of Buryatiya are characterized by high potential nitrification capacity, but under natural conditions nitrification in them is suppressed in contrast to ammonification because of climate dryness, cold late spring and early summer periods. The latter circumstance causes higher content of ammonium nitrogen in soil in comparison with its nitrate form. The introduction of trace elements (molybdenum, manganese, copper, cobalt, zinc) into the soil intensifies its microbiological activity, increases the amount of nitrifying bacteria and the content of nitrate nitrogen in it [19].

The influence of rare earths on nitrate-accumulation in soils was not practically studied. When determining potential nitrifying activity of chestnut soils in laboratory experiment, we obtained the data on the dynamics of nitrate and ammonium nitrogen depending on duration of incubation and under the influence of lanthanum-containing microfertilizers (Fig. 1).

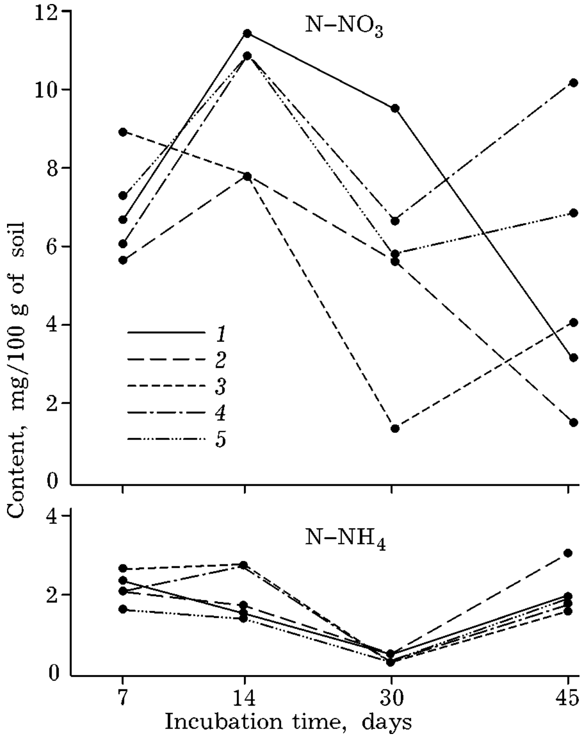

Fig. 1. Influence of lanthanum-containing microfertilizers on nitrification capacity of soil: *1* – control (without fertilizers); *2, 3* – La, 3 and 6 mg, respectively; *4, 5* – La in zeolite, 3 and 6 mg, respectively.

In soil with the initial content of $N{-}NO_3$ – 1.97 mg, $N{-}NH_4$ – 2.71 mg per 1 kg of soil during incubation for 7 days the amount of nitrate nitrogen increases substantially when lanthanum is introduced in the doze of 6 mg/kg of soil and the same doze of the trace element microfertilizer. With smaller doze, the amount of nitrate nitrogen decreases in comparison with the control. The maximum activity of nitrification is observed under 14-day composting. The content of $N{-}NO_3$ during this period is the highest for the whole experiment time excluding a variant with the 6 mg lanthanum doze, where the amount of $N{-}NO_3$ in this and the following periods decreases in comparison with the previous 7-day composting. (Unfortunately, we can not explain such a regularity). In the soil with the microfertilizer, the maximum content of $N{-}NO_3$ is also observed under 14-day incubation. However, nitrification activity was lower than in the control soil. Against this background, the variants with the introduction of lanthanum in 3 mg/kg doze and

TABLE 1

Influence of microfertilizers with lanthanum on productivity of peas dry mass

No.	Variant of experiment	Productivity, g/vessel	Increase with respect to background	
			g/vessel	%
1	$N_{0.15}P_{0.15}K_{0.15}$ (background)	7.9	–	–
2	Background + La (3 mg/kg)	8.8	0.9	11.4
3	Background + La in zeolite (3 mg/kg)	10.8	2.9	36.7
4	Background + La (6 mg/kgr)	12.4	4.5	57.0
5	Background + La in zeolite (6 mg/kg)	11.4	3.5	44.3

microfertilizer in 6 mg/kg doze stand out, in which the level of nitrate-accumulation in soil is comparable with the control. With the increase in experiment duration up to 30 days the content of nitrate nitrogen in all variants is lower than that in the control. More sharp decrease is registered with the 6 mg/kg lanthanum doze. When introducing lanthanum in the form of microfertilizer, the amount of nitrate nitrogen is although lower than in the control, but substantially higher than that in lanthanum application in the form of salt. Under 45-day incubation, the intensity of nitrification remains high in the variants with microfertilizers, especially with 3 mg/kg doze. Thus, a deceleration of nitrification processes in the soil of the control variant by the end of experiment is connected with exhaustion of power resources. An increase in nitrification capacity when lanthanum is introduced by the 45-day period of composting is likely to be caused by the adaptation of microbocenosis to new conditions of functioning.

The content of ammonium nitrogen in soil during its incubation is at a lower level in comparison with nitrate nitrogen, which is caused by the activity of ammonium nitrogen nitrification. The amount of $N-NH_4$ in all variants remains practically at the same level somewhat exceeding the control under 14-day incubation. Its dynamics in the control soil depends on the activity of nitrification of $N-NH_4$. In the variants with fertilized soils such a dependence is weakly expressed.

The results of vegetative and field-vegetative experiments confirm the biological activity of lanthanum-containing microfertilizers (Table 1).

It is marked that in all variants of experiments with soils fertilized by trace elements, the yield of green peas mass is higher than that in the NPK background soil. The maximum increase in the yield with the 3 mg lanthanum doze was obtained when the element was introduced in the form of microfertilizer. With the 6 mg lanthanum doze, the maximum increase by 57 % was obtained; introducrion of the same element in the same doze in the form of microfertilizer caused the crop decrease by 12.7 % in comparison with the pre-

TABLE 2

Influence of lanthanum-containing microfertilizer on composition of nitrogen compounds in peas, % to dry matter

Variant of experiment	Nitrogen		
	total	protein	nonprotein
$N_{0.15}P_{0.15}K_{0.15}$ (background)	2.88 ± 0.03	1.84 ± 0.02	1.04 ± 0.006
Background + La (3 mg/kg)	3.35 ± 0.04	1.81 ± 0.02*	1.54 ± 0.01
Background + La in zeolite (3 mg/kg)	3.13 ± 0.03	1.99 ± 0.02	1.14 ± 0.01
Background + La (6 mg/kg)	3.36 ± 0.04	1.81 ± 0.01*	1.55 ± 0.009
Background + La in zeolite (6 mg/kg)	3.39 ± 0.05	2.07 ± 0.02	1.32 ± 0.01

*Uncertain to background ($t_{theor} > t_{actual}$).

TABLE 3

Mineral composition of peas green mass when importing lanthanum-containing microfertilizer, % to dry matter

Variant of experiment	Ashes	P_2O_5	K_2O	CaO	MgO
$N_{0.15}P_{0.15}K_{0.15}$ (background)	9.52	0.11	1.27	2.82	1.03
Background + La (3 mg/kg)	11.34	0.09*	0.80	3.43	0.76
Background + La in zeolite (3 mg/kg)	11.35	0.09*	0.98	2.61	1.33
Background + La (6 mg/kg)	10.30	0.09*	0.82	3.46	0.68
Background + La La in zeolite (6mg/kg)	10.48	0.11*	1.07	3.67	1.32

*Uncertain to background ($t_{theor} > t_{actual}$).

vious variant; the increase regarding the background was 44.3 %. It is probably caused by the fact that with an increase in lanthanum doze up to 6 mg the mass of mordenite tuff also grows, with which the sorption of feed elements by zeolite increases.

The data of analysis of peas chemical content show that the amount of total nitrogen noticeably grows under the influence of lanthanum and the microfertilizer. The content of protein nitrogen increases substantially when microfertilizer is introduced (Table 2). In this case, the influence of microfertilizer on an increase in protein nitrogen in peas green mass is clearly observed, which is in consistence with literature data [1, 7]. At the same time, the amount of nonprotein nitrogen decreases in comparison with the variants where lanthanum was used. In all variants of experiments with fertilizers, the content of nonprotein nitrogen is higher than in the control. Despite a steady increase in the content of protein nitrogen in plants, the protein content of green mass practically doesn't increase with respect to the background. It is noticeable from the fact that in plants on the NPK background the amount of protein nitrogen in the structure of its total content makes up 63.9 %, while lanthanum introduction in 3 and 6 mg dozes a substantial decrease in the relative amount of protein nitrogen (till ~54 %) is registered. In the variants with the introduction of microfertilizer, the relative amount of protein nitrogen increases almost up to the background level and makes up 63.9 and 61.0 %, respectively. Hence, protein yield in crops will substantially exceed the background amount which is due to a sharp increase in the productivity of peas green mass in the variants with soils fertilized by lanthanum. Studying mineral composition it is necessary to pay attention to an increased content of calcium when introducing microfertilizer in 6 mg doze. Besides, with the microfertilizer, the amount of magnesium increases in peas biomass (Table 3).

Thus, the introduction of microfertilizer based on lanthanum and mordenite tuff increases the content of total and protein nitrogen, magnesium in peas green mass; the amount of calcium grows under the influence of lanthanum and microfertilizer in 6 mg doze.

In field-vegetative experiment carried out with sweet pepper, a significant increase in the yield with microfertilizer containing 6 mg/kg of lanthanum is shown. High efficiency of microfertilizer was exhibited on soil without mineral fertilizers. At the same time, the content of dry substance increased, the food qualities of peppers improved due to an increase in the amount of caccharides and ascorbic acid (Table 4).

TABLE 4

Productivity and quality of sweet pepper with lanthanum-containing microfertilizer introduced

Variant of experiment	Productivity, g/vessel	Increase		Dry matter	Saccharides	Ascorbic acid, mg/100 g
		g/vessel	%			
Control without fertilizers	344.9 ± 10.3	–	–	10.5	58.78	505.99
La in zeolite (6 mg/kg)	445.6 ± 9.8	100.7	29.1	12.2	73.83	533.59

TABLE 5

Productivity of tomatoes, content of saccharides and ascorbic acid in fruits when using lanthanum-containing microfertilizer

Variant of experiment	Productivity, g/vessel	Increase		Content with respect to raw matter	
				Saccharides	Ascorbic acid mg/100 g
		g/vessel	%		
Control without fertilizers	1400 ± 32			4.27	12.88
La in zeolite (6 mg/kg)	1834 ± 55	434	31	6.87	20.24

In field-vegetative experiment, the data were also obtained witnessing an increase in fertility of tomatoes, in the content of saccharides and ascorbic acid in them (Table 5).

It is necessary to note that when using lanthanum-containing microfertilizer, the time of crop maturing decreased by 10–12 days; no accumulation of lanthanum in plants (180–230 μg/kg) was observed in comparison with the control (160–210 μg/kg).

CONCLUSION

The studies carried out showed that lanthanum-containing microfertilizer renders biopositive influence on nitrification capacity of chestnut soil, and also intensifies nitrogen exchange in peas increasing the content of nitrogen in plants. Microfertilizer increases the productivity of peas green mass by 37–57 %, sweet pepper and tomato fruitage by 29–31 %, improves food qualities of the latter due to an increase in the content of saccharides and ascorbic acid.

The use of lanthanum-containing microfertilizers opens a perspective to increasing soil fertility, productivity and quality of agricultural crops.

REFERENCE

1 N. E. Abasheeva, Agrokhimiya pochv Zabaikalya, Nauka, Novosibirsk, 1992.
2 A. A. Drobkov, Dokl. AN SSSR, 32 (1941) 668.
3 B. I. Kogan, Ekonomicheskiye ocherki po redkim zemlyam, Izd-vo AN SSSR, Moscow, 1961, vol. 1.
4 D. N. Pryanishnikov, Rol' otdel'nykh elementov v pitanii rasteniy, Izd-vo AN SSSR, Moscow, 1952, vol. 1.
5 O. A. Samonova, *Pochvovedeniye*, 6 (1992) 45.
6 N. E. Abasheeva, M. G. Merkusheva, L. L. Ubugunova *et al.*, Kompleksnye udobreniya iz prirodnogo i tekhnogennogo syrya Zabaikalya, Izd-vo BNTs SO RAN, Ulan-Ude, 2002.
7 N. E. Abasheeva, N. M. Kozhevnikova, M. G. Merkusheva *et al.*, Polucheniye i primeneniye udobreniy prolongiruyushchego deyctviya na osnove sorbtsionnoy tekhnologii, Izd-vo Buryatskogo gos. un-ta, Ulan-Ude, 1999.
8 H. S. Sherry, *J. Colloid Interface Sci*, 28 (1968) 288.
9 D. W. Breck, W. O. Eversole, R. M. Milton *et al.*, *J. Amer. Chem. Soc.*, 78 (1965) 596.
10 T. Y. Lee, T. S. Lu, S. H. Chen, K. J. Chao, *Indian Eng. Chem. Res.*, 29 (1990) 2024.
11 R. W. Hartford, M. Kojima, C. R. Connor, *Ibid.*, 28 (1989) 1748.
12 N. M. Kozhevnikova, N. E. Abasheeva, E. L. Zonkhoeva *et al.*, *Khimiya v interesakh ustoichivogo razvitiya,* 7 (1999) 675.
13 N. P. L'vov, Molibden v assimilyatsii azota u rasteniy i mikroorganizmov, Nauka, Moscow, 1989.
14 Agrokhimicheskiye metody issledovaniya pochv, Nauka, Moscow, 1975.
15 A. I. Ermakov, V. V. Arasimovich, M. I. Smirnova-Ikonnikova, I. I. Murri, Metody biokhimicheskogo issledovaniya rasteniy, Nauka, Leningrad, 1952.
16 П. Джеффери, Химические методы анализа горных пород, Мир, Москва, 1973.
17 E. A. Dmitriev, Matematicheskaya statistika v pochvovedenii, Izd-vo MGU, Moscow, 1972.
18 B. A. Dospekhov, Metodika polevogo opyta (s osnovami statisticheskoy obrabotki rezul'tatov issledovaniy), Kolos, Moscow, 1979.
19 S. Sh. Nimaeva, Mikrobiologicheskaya aktivnost' kholodnykh pochv, Nauka, Novosibirsk, 1992.