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SOIL BIOLOGY

The Influence of Liming on the Microflora and Microbiological Characteristics of Belarussian Soddy-podzolic Soils

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Abstract—The influence of liming on some biological characteristics of soddy-podzolic soil was studied in a field experiment with different rates of organic and mineral fertilizers. A decrease in soil acidity resulted in a reduced amount of $C0_2$ production and lower invertase activity, while nitrogen fixation and hydrolysis of nitrogen-containing organic substances were activated.

INTRODUCTION

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A number of studies have shown that liming reduces the acidity of soddy-podzolic soils and improves their chemical, physical, and biological properties. A consulerable improvement in the properties of the adsorption complex in response to liming is well documented. However, biological properties of plowed soils with different acidity have not been thoroughly investigated. According to Mishustin [8], many biological processes in soil are activated by liming. Karyagina *et al,* who studied this problem in Belarus [3, 4], demonstrated an increase in nitrification, nitrogen fixation, and activity of urease, invertase, and nitrogenase, and a decrease in $C0_2$ production in the soils subjected to liming.

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The main purpose of our investigation was to reveal the changes in microbiological characteristics of Belarussian soddy-podzolic soils under the impact of liming.

MATERIALS AND METHODS

The soils were treated with different rates of organic and mineral fertilizers. The field experiment was conducted from 1988 to 1996 on soddy-podzolic sandy loamy soil underlain by moraine loam at a depth of 0.5 m. The soil has a moderate nutrient supply, the original pH_{KC1}5.0, total acidity 4.3 cmol/kg of soil, and the sum of exchangeable cations 5.4 cmol/kg of soil. The layout of the experiment included three different modes of lime application: (1) Cao—without lime; (2) Caj—the amount of lime added was calculated so that the total acidity could be neutralized (6.5 t/ha); (3) Ca_2—lime was added in an amount sufficient for reaching the optimal pH_{KC1} 6.2 (12.4 t/ha). Each of these modes included nine different treatments with organic and mineral fertilizers in four replicates: 0, 12, and 24 t/ha of peat-manure compost (PMC) in combinations wijth different rates of mineral fertilizers (zero rate, the rate calculated so that the yield (in forage units) could reach 5 t/ha, and the rate increased by 30-50% depending upon the crop)/. Lime and organic fertilizers were applied once – at the beginning of experiment. Mineral fertilizers were applied annually, simultaneoously with soil cultivation.

The rate of $C0_2$ production was determined using the LXM-8 gas chromatograph [5]; the potential activhy of nitrogen fixation was determined by the acetylene reduction technique; the amount of ethylene formed was measured by the Chrom-4 gas chromatograph [9]; invertase and urease activities were determined by the Shcherbakova-Romeiko and Malinskaya methods, respectively [101.

RESULTS AND DISCUSSION

CO_2 Emission

The study of soil biology was started in 1989 one year after liming. The results obtained (Table 1) attest to a decrease in $C0_2$ production in response to liming, An active emission of $C0_2$ was observed on the plots with acid soil (Cao, pH 5.0). A decrease in soil acidity was accompanied by the reduction of $C0_2$ emission from soils. Thus, an increase in pH up to 5.5 (Caj) resulted in the reduction of $C0_2$ emission by 19-32%; the further rise in pH up to 5.9 led to an additional decrease in $C0_2$ emission by 2-15%. A somewhat increased production of $C0_2$ in the acid soil under clover is attributable to the specific influence of leguminous plants on the soil. A decrease in $C0_2$ emission in response to liming can be explained by the lower rate of mineralization of organic matter and the intensified accumulation of humic substances. The application of organic and mineral fertilizers resulted in the increase of $C0_2$ production across all the plots, except for the plots under clover.

Table 1. The influence of lime and fertilizers on the intensity of CO_2 production, nitrogen fixation, enzyme activity, and agrochemical properties of soddy-podzolic sandy loamy soil

Year; crop	Without fertilizers			N90P70K150			N90P70K150 + PMC, 12 t/ha			LSD_{05}
	Ca_0	Ca_1	Ca_2	Ca_0	Ca_1	Ca_2	Ca_0	Ca_1	Ca_2	
CO_2 emission, mg/kg of soil per 96 h										
1989. Barley	470	387	369	513	429	365	554	419	410	76
1991. Winter rye	275	257	257	311	311	243	338	239	225	47
1992. Potatoes	351	338	270	381	367	297	437	383	315	9
1992. Clover	392	405	468	360	423	437	315	338	356	31
Activity of nitrogen fixation, mg N_2/kg soil per 24 h										
1989. Barley	23	65	72	31	45	53	19	54	61	17
1990. Barley	12		37	14		38	19		49	24
1991. Winter rye	60	73	79	60	76	76	67	78	76	9
1992. Potatoes	33	50	59	36	50	55	40	44	52	8
1992. Clover	74	110	116	90	98	108	93	93	98	4
1996	81	86	92	86	87	89	89	92	87	13
Invertase activity, mg glucose/kg soil per 4 h										
1989. Barley	1088	984	880	1246	1175	1070	1676	1220	1130	356
1991. Winter rye	1220	1295	1267	1498	1387	1370	2080	1436	1689	70
1992. Potatoes	1094	890	800	1235	989	893	1267	1096	1034	98
1992. Clover	1436	1451	1295	1579	1622	1460	1691	1776	1525	62
1996. Before sowing	1164	1693	1286	1592	1816	1166	2113	1667	1086	163
Urease activity, mg NH_4^+ /kg soil per 4 h										
1989. Barley	250	314	356	279	361	378	306	342	486	45
1990. Barley	183		221	200		234	218		271	26
1992. Potatoes	148	207	217	175	176	178	195	176	248	27
1992. Clover	192	249	256	213	238	214	242	220	241	28
pH_{KCl}										
1989	5.1	5.4	5.9	5.0	5.3	5.8	5.0	5.6	5.9	0.23
1992	5.1	5.5	6.0	4.9	5.5	6.0	4.8	5.5	6.1	0.19
1996	4.8	5.4	5.9	4.6	5.2	5.9	4.6	5.4	6.0	0.24
Exchangeable Ca, mg/kg soil										
1989	920	820	945	905	835	965	925	840	1070	183
1992	830	810	925	790	810	905	870	835	1050	151
1996	835	825	940	735	780	930	870	895	1025	149
Exchangeable Mg, mg/kg soil										
1989	176	231	297	150	224	282	165	270	286	42
1992	173	215	259	158	206	272	133	220	261	42
1996	147	204	290	106	184	293	114	212	288	47

In 1990, we studied biological properties of the soils under the plots without liming and with lime added in an amount sufficient to optimize soil pH (Table 2). The plots without lime were characterized by an increased rate of CO_2 production. The application of both organic and mineral fertilizers led to a distinct augmentation of CO_2 production, which supports the conclusion that the mineralization of organic matter increases in response to fertilization.

Nitrogen Fixation

During every year of the experiment, nitrogen fixation was more intensive in the soils with lower acidity,

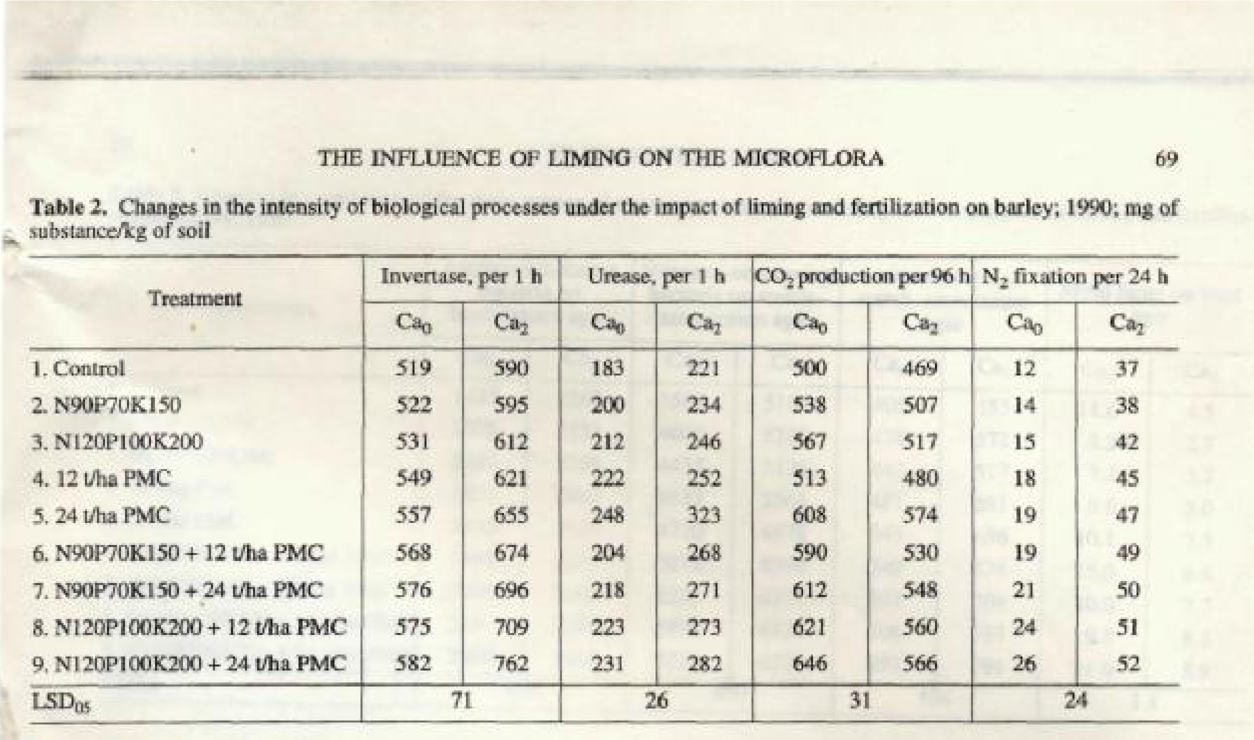

Table 2. Changes in the intensity of biological processes under the impact of liming and fertilization on barley; 1990; mg of substance/kg of soil

Treatment	Invertase, per 1 h		Urease, per 1 h		CO_2 production per 96 h		N_2 fixation per 24 h	
	Ca_0	Ca_2	Ca_0	Ca_2	Ca_0	Ca_2	Ca_0	Ca_2
1. Control	519	590	183	221	500	469	12	37
2. N90P70K150	522	595	200	234	538	507	14	38
3. N120P100K200	531	612	212	246	567	517	15	42
4. 12 t/ha PMC	549	621	222	252	513	480	18	45
5. 24 t/ha PMC	557	655	248	323	608	574	19	47
6. N90P70K150 + 12 t/ha PMC	568	674	204	268	590	530	19	49
7. N90P70K150 + 24 t/ha PMC	576	696	218	271	612	548	21	50
8. N120P100K200 + 12 t/ha PMC	575	709	223	273	621	560	24	51
9. N120P100K200 + 24 t/ha PMC	582	762	231	282	646	566	26	52
LSD_{05}	71		26		31		24	

particularly under barley (Tables 1 and 2). The activity of nitrogen fixation was considerably greater in the variant with a high (Ca_2) rate of liming. Thus, for the plots without fertilizers it increased by three times as compared to the control without liming. In 1989, the nitrogen-fixing capacity of limed soils increased by 2.8 times in the control (without fertilizers), by 1.4 times in the soils treated with mineral fertilizers, and by 2.8 times in the soils treated with NPK and peat-manure compost, as compared to the background without liming (Table 1). Similar results were obtained for the plots that had been treated with increased doses of lime. Data obtained by Aristovskaya [1], Kalininskaya [2], and Karyagina ***et al.*** [3, 4, 6] allow us to regard nitrogen fixation and humification as conjugated processes. As a rule, a combination of such factors as augmentation of nitrogen fixation, reduction of $C0_2$ production, and saturation of soils with C^{2+} and Mg^{2+} results in a rise in coefficients of humification (when pH values change from 4.0-4.2 to 6.0-6.2, a 1.5-2-fold increase in coefficients of humification is observed). This allows the conclusion that when the optimum soil reaction is achieved, humification becomes more intensive than mineralization.

The application of fertilizers did not render a definite impact on nitrogen fixation. A distinct intensification of nitrogen fixation was only observed in 1990 under the plots with barley that were treated with increased rates of organic and mineral fertilizers (Table 2).

Enzyme Activity

Within a year after liming we determined a distinct difference between the plots with respect to the activity of hydrolytic enzymes urease and invertase (Table 1). Judging by the activity of invertase, the intensity of the decomposition of carbohydrates decreased under trie impact of liming, indicating a better preservation of carbon-containing substances in the soil and the possibility of a reduction of organic matter losses. A decrease in soil acidity accelerated the decomposition of nitrogen-containing substances in soil. For example, urease that catalyzes the hydrolysis of urea was more active in the soil to which lime was applied (Tables 1 and 2), regardless of the amount of fertilizers added.

Usually, organic fertilizers increase the activity of urease. The activity of invertase increased significantly in response to an increase in the rate of fertilizers during each year of the experiment (by up to 90% in the plots without liming). Nitrogenase activity usually did not correspond to the amount of fertilizers applied. At the same time, it considerably increased in the plots treated with lime, as compared to those without lime (Table 1).

Changes in Microbial Cenosis

Neutralization of soil acidity was always accompanied by the regrouping of the microbial cenosis; the population of mold fungi decreased (Table 3), and bacterial microflora, such as, for example, ammonium-fixing and nitrogen-consuming bacteria, actively developed. The population of the aforementioned bacteria increased even more intensely when mineral and, especially, organic nitrogen fertilizers were applied. The application of lime caused a growth in the population of Actinomycetes, particularly in the plots without fertilizers. The application of fertilizers on the plots without lime caused the same effect on the population of Actinomycetes. The impact rendered by organic fertilizers on fungi was insignificant in nonlimed soil, though considerable in the variants with liming (pH 6).

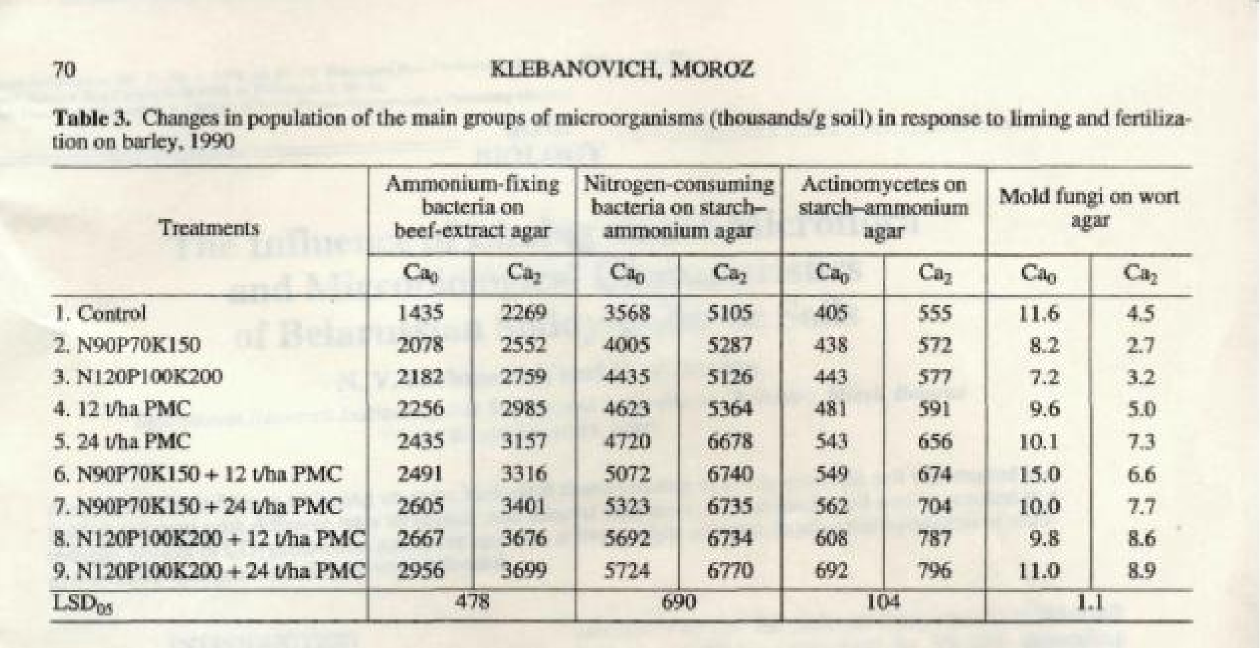

Table 3. Changes in population of the main groups of microorganisms (thousands/g soil) in response to liming and fertilization on barley, 1990

Treatments	Ammonium-fixing bacteria on beef-extract agar		Nitrogen-consuming bacteria on starch–ammonium agar		Actinomycetes on starch–ammonium agar		Mold fungi on wort agar	
	Ca_0	Ca_2	Ca_0	Ca_2	Ca_0	Ca_2	Ca_0	Ca_2
1. Control	1435	2269	3568	5105	405	555	11.6	4.5
2. N90P70K150	2078	2552	4005	5287	438	572	8.2	2.7
3. N120P100K200	2182	2759	4435	5126	443	577	7.2	3.2
4. 12 t/ha PMC	2256	2985	4623	5364	481	591	9.6	5.0
5. 24 t/ha PMC	2435	3157	4720	6678	543	656	10.1	7.3
6. N90P70K150 + 12 t/ha PMC	2491	3316	5072	6740	549	674	15.0	6.6
7. N90P70K150 + 24 t/ha PMC	2605	3401	5323	6735	562	704	10.0	7.7
8. N120P100K200 + 12 t/ha PMC	2667	3676	5692	6734	608	787	9.8	8.6
9. N120P100K200 + 24 t/ha PMC	2956	3699	5724	6770	692	796	11.0	8.9
LSD_{05}	478		690		104		1.1	

A general conclusion can be made that liming activates the development of bacteria and Actinomycetes and depresses the development of fungi in the soil.

CONCLUSION

The changes in the soil adsorption complex under the impact of lime cause a significant alteration in the biological state of soils. The intensive transformation of organic matter accompanied by the production of C0$_2$ and the intensive breakdown of carbohydrates (under the impact of invertase) are typical of acid soils. A decrease in soil acidity results in decreasing C0$_2$ emission and invertase activity. Liming activates the fixation of air nitrogen and the hydrolysis of nitrogen-containing organic substances. It leads to a regrouping of the soil microflora: the populations of bacteria and Actinomycetes increase, while the population of fungi is reduced.

In general, the optimization of the acidity of soddy-podzolic soil helps to optimize its biological state.

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