Agronomy Research **7**(Special issue I), 300–304, 2009

Long-term manuring and liming effect on moraine loam soil fertility

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Abstract. Soil fertility is influenced by different forms of land use. In a field trial (Western Lithuania, Vezaiciai branch of the Lithuanian Agriculture Institute) two manure rates (40 t ha^{-1} and 60 t ha^{-1}) were introduced in acid and limed soil. The mineral fertilization in both acid and limed soil was the same: $N_{60}P_{60}K_{60}$ for cereals, $N_{120}P_{90}K_{150}$ for forage beet, $N_{40}P_{60}K_{60}$ for barley with undercrop, $P_{60}K_{90}$ for perennial grasses in the 1st usage year, $N_{60}P_{60}K_{90}$ for perennial grasses in the 2nd usage year. It was revealed that the long-term manuring and liming combination had a positive effect on moraine loam *Dystric Albeluvisol* fertility. Application of manure in acid and limed soil increases the nutrient stocks in the rooting zone of crops, increases pH value, amount of organic carbon and thus improves the topsoil structure. Long term manuring at rate 60 tha^{-1} resulted in the highest amount of mobile phosphorus (329 mg kg^{-1}) in limed topsoil. The amount of mobile aluminium was reduced from 112.9 to 16.6 mg kg^{-1} if manure at a rate of 60 t ha^{-1} was applied. The combination of liming and fertilization ensure soil chemical indicators at the optimal level for more plant growth.

Key words: acid and limed soil, manure, chemical and physical soil properties

INTRODUCTION

Lime and fertilizers are common amendments routinely applied to agricultural soils. The effect of lime and manure applications on soil organic matter status and soil physical properties is of importance to agricultural sustainability and soil fertility. The scientific researches of Haynes (1998) and Kristaponyte (2005) have already shown that manured and limed soil had a higher content of organic matter, the largest number of microfauna and was more enriched in P, K, Ca, Mg in topsoil than unlimed and unfertilized soil. Other research finds that the soil amended with 40 g manure kg^{-1} had three or four times more plant-available P and K than unamended soil (Whalen et al., 2000); manured soils also had lower bulk density and higher aggregate stability relative to non-fertilized soil (Douglas, 2003). According to most authors, soil aggregate stability showed a clear response to soil organic fertilizing. Soil aggregate stability increased in the following order: non –N < green manure < peat < farmyard manure. Increasing C_{org} contents generally enhanced aggregation (Gerzabek et al., 2006; Fortun et al., 2006). Manure–amended soil had significantly higher pH than unamended soil (Whalen et al., 2000). Research in the Baltic region indicates that the efficiency of various management practices on soil properties and fertility depends on the geochemical environment (soil texture and climate) in that the human activity is direct.

The paper provides the data of long-term manuring and liming effect on moraine loam soil chemical properties and structure in the humid littoral climatic region of Western Lithuania.

MATERIALS AND METHODS

The investigations were carried out in Western Lithuania, on the eastern part of sea-coast lowland with a moderately warm, humid agroclimate. The soil was *Dystric-Epihypogleyic Albeluvisol* (texture – morain loam (clay 13–15%). The aim of the investigation was to evaluate the effect of two manure rates: 40 t $ha^{-1}$and 60 t ha^{-1} on chemical properties and structure of acid and limed soil. Investigations were conducted in a 7-field crop rotation: 1) winter wheat (*Triticum aestivum* L.), 2) spring barley (*Hordeum vulgare*), 3) oats (*Avena sativa* L.), 4) forage beets (*Beta vulgaris* L.), 5) spring barley (*Hordeum vulgare* L.) with under crop, 6) perennial grasses, 1st usage year red clover (*Trifolium pratense* L.) + timothy (*Phleum pratense* L.), 7) perennial grasses, 2nd usage year. There were two soil backgrounds: acid and limed was used for incorporating the manure rates. Every year after harvesting the soil was limed at 1.0 rate by existing hydrolytic soil acidity. The amount of manure (Table 1) was applied on an equal portion (40 and 60 t ha^{-1}) two times in the crop rotation for winter wheat and forage beets. The type of organic fertilizer – litter cattle manure. The manure chemical composition was the following: dry matter 21.3–36.4%, total nitrogen 0.20–0.41%, P_2O_5 0.18–0.23%, K_2O 1.10–1.22%. The mineral fertilization in both acid and limed soil was the same: $N_{60}P_{60}K_{60}$ for cereals, $N_{120}P_{90}K_{150}$ for forage beet, $N_{40}P_{60}K_{60}$ for barley with undercrop, $P_{60}K_{90}$ for perennial grasses in the1st usage year, $N_{60}P_{60}K_{90}$ for perennial grasses, 2nd usage year. The soil samples for chemical analyses and structure were taken from the topsoil after harvesting. Samples for soil structure analyses were taken in topsoil layer 0–20 cm depth by 3 replicates.

Soil sample chemical analyses were made using the following methods: potentiometric for pH_{KCl}, Kappeno for hydrolytic soil acidity, Sokolov for mobile aluminium, mobile P_2O_5 et K_2O using method by Egnerio–Rimo–Domingo (A–L) and Kjeldalio for total nitrogen, mobile Ca by spectrofotometric method, organic and inorganic carbon by analyser VARIO EL III (Derzavin, 1975; Sokolova, 1975). Soil structure and aggregate stability in water analyses were done using the Savinov method (Vadiunina & Korchagina, 1986). The experimental data were processed using software package “SELEKCIJA” (Tarakanovas & Raudonius, 2003).

RESULTS AND DISCUSSION

Soil chemical properties. The main soil chemical properties influencing crop productivity are hydrolytic soil acidity, exchangeable soil acidity and the amount of mobile aluminium. The effect of manure to change these acidity indicators depends on the manure amount, its incorporation periodicity and soil texture.

Long term periodical liming (factor A) had a significant ($P < 0.01$) positive effect on soil acidity indexes: pH increase by 1.81 units, hydrolytic and exchangeable soil acidity decrease by 40.0 and 5.453 meq. kg^{-1} (meq = milliequivalents kg^{-1} of soil), respectively, remove mobile aluminium and the exchangeable Ca increase by 1348 mg kg^{-1} in comparison with unlimed soil (Table 1).

Table 1. Effect of manuring and liming combination on topsoil chemical properties.

Treatments	pH_{KCl}	Hydrolytic soil acidity meq. kg^{-1}	Exchangeable soil acidity meq. kg^{-1}	Mobile Al mg kg^{-1}	Exchangeable Ca mg kg^{-1}
Liming – factor A					
Unlimed	4.39	62.47	5.809	52.23	1176.22
Limed	6.20**	22.47**	0.356**	0.00**	2524.22**
Manuring – factor B					
Manure 0 t ha^{-1}	5.12	51.01	6.637	56.43	1423.83
Manure 40 t ha^{-1}	5.33**	40.89**	1.438**	13.61**	1903.83**
Manure 60 t ha^{-1}	5.43**	35.76**	1.174**	8.30**	2223.0**
Interaction of factor A x B					
Unlimed x 0 t ha^{-1} manure	4.17	77.67	12.828	112.87	758.00
Unlimed x 40 t ha^{-1} manure	4.40*	61.55**	2.569**	12.20**	1242.00**
Unlimed x 60 t ha^{-1} manure	4.46**	48.69**	2.031**	16.61**	1528.67**
Limed x 0 t ha^{-1} manure	6.07**	24.35**	0.445**	0.00**	2089.67**
Limed x 40 t ha^{-1} manure	6.27**	20.22**	0.307**	0.00**	2565.67**
Limed x 60 t ha^{-1} manure	6.27**	22.84**	0.316**	0.00**	2917.33**

* – 95% probability level, ** – 99% probability level

Farmyard manure (factor B) neutralizes soil acidity. Manuring with 40 t ha^{-1} and 60 t ha^{-1} significantly (P < 0,01) improves the soil chemical status: it increases the soil pH, decreases hydrolytic and exchangeable soil acidity, decreases the amount of mobile aluminium and increases the amount of exchangeable Ca as compared with unfertilized soil. The amount of mobile aluminium was reduced from 112.9 to 16.6 mg kg^{-1} if manure at a rate 60 t ha^{-1} was applied. The largest soil acidity neutralizing effect results from the combination of manuring and liming.

Manure enriches the soil with nutrition, depending on the crop type and productivity, soil texture and agro-climatic conditions. The soil is the buffer system so the changes of nutrition show up over a long time period (Tripolskaja, 2005). Significant (P < 0.01) increase of the amount of mobile P_2O_5 and total N in limed soil was determined (Table 2). The lime has no effect on the amount of mobile K_2O and organic carbon. Manuring increased the amounts of mobile P_2O_5, K_2O, total nitrogen and organic carbon. A significant increase of the amount of mobile P_2O_5, K_2O, total nitrogen and the tendency of organic carbon in limed and manured soil to increase was determined. The largest increase of mobile P_2O_5 to 329 mg kg^{-1} was obtained in the soil manured with 60 t $ha^{-1.}$ The largest amount (1.32%) of organic carbon in acid, manured with 60 t ha^{-1} soil was fixed. The combination of liming and fertilization ensure soil chemical indicators at the optimal level for more plant growth.

Soil structure. Aeration and moisture conditions in the plant–soil system are highly dependent on the soil structure. According **to** Levin (1972), the most favourable air and moisture regime in *Dystric Albeluvisol* was obtained when the agronomically valuable mezoaggregate fraction (5–0.25 mm) was predominant and the water-stable aggregates (> 0,25 mm) reached more than 70%. The investigations in Lithuania showed that it is impossible to reach optimal soil conditions for plant growth by using intensive liming only. It is necessary to ordinate proper liming and organic fertilizer (Ozeraitiene, 2001).

Table 2. Effect of manuring and liming combination on the amount of nutrition and carbon.

Treatment	P_2O_5 mg kg^{-1}	K_2O mg kg^{-1}	Total N %	Total C %	Organic C %
Liming – factor A					
Unlimed	207.44	268.22	0.138	1.492	1.169
Limed	258.67**	253.67	0.160**	1.594	1.067
Manuring – factor B					
Manure 0 t ha^{-1}	170.00	202.50	0.131	1.315	0.920
Manure 40 t ha^{-1}	247.33**	288.00**	0.152**	1.621*	1.114
Manure 60 t ha^{-1}	281.83**	292.33**	0.163**	1.693**	1.321**
Interaction of factor A x B					
Unlimed x 0 t ha^{-1} manure	175.33	226.00	0.125	1.238	0.936
Unlimed x 40 t ha^{-1} manure	212.67*	281.67*	0.140*	1.598*	1.152
Unlimed x 60 t ha^{-1} manure	234.33**	297.00*	0.148**	1.640*	1.420**
Limed x 0 t ha^{-1} manure	164.67	179.00	0.137	1.392	0.903
Limed x 40 t ha^{-1} manure	282.00**	294.33*	0.164**	1.645*	1.076
Limed x 60 t ha^{-1} manure	329.33**	287.67*	0.177**	1.746**	1.223

* – 95% probability level, ** – 99 % probability level

Table 3. Effect of manuring and liming combination on topsoil aggregate composition and on the amount of water-stable aggregates (%).

Treatment	Size of aggregates mm			Size of water-stable aggregates mm	
	macro aggregates >5	mezo aggregates 5–0,25	micro aggregates <0,25	>0,25	>1,0
Liming – factor A					
Unlimed	11.30	65.15	23.55	60.23	18.32
Limed	13.21*	66.93	19.85*	62.31	15.54
Manuring – factor B					
Manure 0 t ha^{-1}	11.88	65.17	22.95	55.63	13.17
Manure 40t ha^{-1}	12.61	66.52	20.87	65.92**	16.79*
Manure 60t ha^{-1}	12.46	66.42	21.12	62.26**	20.83**
Interaction of factor A x B					
Unlimed x 0 t ha^{-1} manure	9.75	65.64	24.61	56.14	14.03
Unlimed x 40 t ha^{-1} manure	10.82	64.30	24.84	64.46	16.76
Unlimed x 60 t ha^{-1} manure	11.62	63.52	24.86	60.10*	24.17**
Limed x 0 t ha^{-1} manure	13.96*	64.76	21.28	55.13	12.31
Limed x 40 t ha^{-1} manure	14.40**	68.73*	16.87**	67.39**	16.82
Limed x 60 t ha^{-1} manure	11.29	67.32	21.39	64.41**	17.49

* – 95 % probability level, ** – 99 % probability level

The data of our investigations substantiate this affirmation. The long-term manuring had a positive effect on both acid and limed moraine loam soil structure (Table 3).

From an agronomic point of view valuable structural mezoaggregates (0.25–5 mm) prevail (65–67%) and fractions of little value (>5 and <0.25 mm) were from 11–13% and 20–24% both in acid and limed soil. The tendency of increase of agronomically valuable mezoaggregates has already been seen in the limed soil when the largest manure rates – 40 and 60 t ha^{-1} has been used. The largest (67–69%) amount of valuable mezoaggregates (0.25–5 mm) was obtained in the limed and fertilized soil. After estimating these soil structure qualities, it can be affirmed that manuring is a good management method for improving stability of soil aggregates. In the soil manured with 40 t ha^{-1} the amount of water-stable aggregates reached 66% or was 11% units higher in comparison with unfertilized soil.

CONCLUSIONS

The long-term manuring and liming combination had a positive effect on moraine loam *Dystric Albeluvisol* fertility. The application of manure in acid soil increases nutrient stocks in the rooting zone of crops, increases pH value and the amount of organic carbon. The largest soil acidity neutralizing effect results from the manuring and liming combination. The largest increase of P_2O_5 (to 329 mg kg^{-1}) was obtained in the soil which was limed and manured - with 60 t ha^{-1} soil. A liming and manuring (40 t ha^{-1}) combination is the best way to improve the structure of moraine loam soil. The largest (67%) amount of water-stable aggregates > 0.25 mm was obtained in this soil.

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