SOIL RELATION

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ADJUSTMENT OF COMMON RAGWEED (*AMBROSIA ARTEMISIIFOLIA*) TO SOIL TYPE AND NUTRIENT SUPPLY

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Abstract: Common ragweed is one of the most dangerous weed species in Europe and especially in Hungary. The reason of wide spreading is very good adaptability to environmental factors.
Ambrosia artemisiifolia can be found on all soil types, but it multitudinous on brown forest soil and loose sandy soil. Biomass production and seed yield of plants are influenced by nutrient supply, first of all by the nitrogen nutrition. Common ragweed is known as a nitrofil weed. We had no data's about growth and biomass production of common ragweed influenced by nitrogen forms.
The aim of our pot experiment was to study the effect of soil type and different nitrogen fertilizers - péti-salt, ammonium-nitrate and carbamide - on early growth of *Ambrosia artemisiifolia.* The experiment was set up on meadow soil, sandy soil with acidic pH and Ramann type brown forest soil. We also had control pots without fertilization on all three soil types.
Plants grew poorly on settled meadow soil, fresh mass of ten plants was 5,06 g without fertilizers, while on sandy soil was 13,17 g, and on Ramann-brown forest soil was 10,39 g. Height, leaf area and dry mass of plants also staid behind plants grown on other soil types. Nitrogen treatments increased fresh mass, it was significant in ammonium-nitrate (15,36 g) and carbamide (16,6 g) treatments on sandy soil. Nitrogen forms influenced the examined parameters differently on all three soil types.

Keywords: *Ambrosia artemisiifolia*, soil type, nitrogen fertilizer, leaf area, fresh mass, dry mass

Introduction

Ambrosia artemisiifolia is multitudinous on brown forest soils and on loose sandy soils. Nutrient supply of the soil influences the biomass production of common ragweed and hereby the seed production, but plants able to live and generates seeds between wide limit of nutrient supply (Lehoczky, 2004; Kőmíves et al., 2006).
Several examinations studied the effect of nitrate and ammonium nitrogen forms on plant development. Different plant species react contrary to two nitrogen forms (Kirkby, 1981). The most of the plants species prefer nitrate and growth better on soil supply with nitrate that ammonium.
Researches established that the plants love acidic soil fitted to ammonium nutrition. Ammonium has an advantage over nitrate in a lot of species of young plants.
On the base of former results the dry matter production less with ammonium nutrition that nitrate, lose of dry mass may be 15-60%. Plants supply with booth nitrogen forms increase nitrogen uptake, the growth will be quicker and more crop will develops, dry mass and protein content will be rise. This effect was proved a lot of cultures as winter wheat, maize, soya bean, flex or lettuce (Mengel-Kirkby 1982; Nádasyné 1999).
Béres and Sárdi (1994) examined the effect of nitrogen fertilizers on germination of wheat and its weeds. They established that péti-salt did not influenced germination of wheat at 100 mg N kg^{-1} doses in soil, but decreased the germination of catchweed bedstraw (*Galium aparine*) and increased of *Matricaria inodora*. The same doses of ammonium-nitrate increased germination of wheat with 2%, decreased of *Galium aparine* with 54%, but increased of *Matricaria inodora* with 34%. Carbamide decreased

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germination of wheat also with 2%, contrary rose of catchweed bedstraw with 54 and *Matricaria inodora* with 6%.

Materials and methods

We made a pot experiment in the greenhouse of the Plant Protection Institute in May of 2009 to study how can influence the soil type and different nitrogen fertilizers the early development of common ragweed.
Experiment was set up on meadow soil (Bonyhád), sandy soil with acidic pH (Tarany) and Ramann type brown forest soil (Keszthely). Pots contained 2 kg air dried soil (Table 1.).

Table 1. Parameters of experimental soils

Soil type	Place	K_A	Humus %	pH $_{H2O}$	P_2O_5 mg kg^{-1}	K_2O mg kg^{-1}
meadow soil	Bonyhád	52	2,11	6,2	128	122
sandy soil	Tarany	31	1,46	5,87	134	266
Ramann type brown forest soil	Keszthely	39	2,28	7,26	210	334

Applied fertilizers were nitrochalk (27% N), ammonium-nitrate (34% N) and carbamide (46% N) with 100 mg N kg^{-1} soil in each treatment, except of unfertilized control pots on every three soils. We worked with four replications so we had 48 pots altogether.
In every pot were planted 20 pieces common ragweed plants with 1-2 leaves. Plants were collected from the edge of corn field in Keszthely. After three weeks we took samples moving out 10-10 plant from all pots. Leaf areas, length of shoots, fresh mass and after air drying the dry mass were measured. Results were statistically analyzed with SPSS program.

Results and discussion

Growth of plants and length of shoots were influenced first of all by soil type (Table 2.). Shoot length differed from each other significantly grown on all three soils. Plants developed the most slender on meadow soil. Much smaller differences were found between shoot length of plants grown on sandy soil and Ramann type brown forest soil, benefit of sandy soil. This result are similar to those of Kőmíves et al. (2006), that *Ambrosia artemisiifolia* likes brown forest soils and sandy soils too. Though common ragweed does not choosy considering the soil type but doesn't like the strongly fixed, bad water permeable, cracking soils.
Nitrogen fertilization promoted growth of shoots, except of carbamide treatment on meadow soil, where length of plants decreased not significantly. It can possible explain with ammonium accumulation in badly breathing soil, which is toxic for sensitive young plants. Since carbamide during decomposition converts into ammonium the first, this suddenly increases the pH, and after converts into nitrate during processes of nitrification, when the pH considerable decreases.

Table 2. Length of shoots, leaf area, fresh and dry mass of common ragweed on different soils influenced by nitrogen treatments

Soil	Treatment	Length of shoots (mm plant^{-1})	Leaf area (cm^2 plant^{-1})	Fresh mass (g 10 plant^{-1})	Dry mass (g 10 plant^{-1})
meadow soil (Bonyhád)	Control	70,73	14,91	5,06	0,94
	Nitrochalk	91,87	18,68	5,86	1,24
	Ammonium-nitrate	81,07	16,19	5,34	1,05
	Carbamide	65,7	11,69	4,06	0,73
sandy soil (Tarany)	Control	159,88	42,51	13,17	2,24
	Nitrochalk	166,48	44,13	12,98	1,78
	Ammonium-nitrate	170,38	52,92	15,36	1,89
	Carbamide	175,25	56,87	16,6	2,1
Ramann typebrown forest soil (Keszthely)	Control	128,08	32,32	10,39	1,55
	Nitrochalk	128,45	34,08	10,63	1,31
	Ammonium-nitrate	127,25	33,38	9,86	1,36
	Carbamide	131,9	38,83	10,74	1,34
	$LSD_{5\%}$	15,39	6,86	1,91	0,38

The highest plants were developed on sandy soil fallowed by Ramann type brown forest soil. We measured significant increase of shoot length by the effect of fertilization treated with nitrochalk on soil from Bonyhád, and in carbamide treatment on sandy soil from Tarany.

We established that the leaf area of plants differed significantly on every three soils. The leaf area on meadow soil was almost half of plants' growth on Ramann type brown forest soil. The biggest area was measured on sandy soil.

Nitrogen fertilization increased the leaf area except on meadow soil treated with carbamide, but this stimulating effect was significant only on sandy soil with carbamide and ammonium- nitrate.

Fresh mass of ten plants showed strong differences on three soils. Fresh mass of common ragweed was threefold on sandy soil, and twofold on brown forest soil than on meadow soil.

The fresh mass of plants on meadow soil also decreased similarly to shoot length and leaf area treated with carbamide compared to unfertilized control. Nitrogen treatments usually increased the fresh mass in small extent; it was significantly justified on sandy soil in ammonium-nitrate and carbamide treatments.

The tendency of dry mass changing looks like the fresh mass. Dry mass of plants differed significantly growing on different soils; it was maximal on sandy soil and minimal on meadow soil. Nitrogen treatments slightly decreased the dry mass on sandy soil and brown forest soil.

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Conclusions

Studying the development of *Ambrosia artemisiifolia* we found strong differences among plants growth on three experimental soils. Common ragweed grew conspicuously poorly on meadow soil, the length of shoot, leaf area and biomass production were behind compared to plants grew on Ramann type brown forest soil and on sandy soil. *Ambrosia* liked sandy soil the best, examined parameters of plants were the biggest on this soil.

We established that effect of 100 mg kg^{-1} nitrogen fertilization promoted the growth of plants in a little extent. Lehoczky (2004) experienced that the optimal nitrogen dose for growth of common ragweed was the 200 mg nitrogen kg^{-1} soil. So the nitrogen dose we used in present experiment proved to be limited to good development of this nitrophil weed species.

Nitrogen fertilizer forms influenced leaf area, shoot length and biomass production differently on three examined soils. On meadow soil the nitrochalk, but on sandy soil and on brown forest soil the carbamide helped the development of ragweed, contrary hindered on meadow soil. This effect resulted probably ammonium storage in soil, in consequence of bad water regime.

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AMELIORATIVE PK-FERTILIZATION AND LIMING IMPACTS ON SOIL STATUS

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Abstract: Five steps of PK-fertilization were applied in spring of 2004 on Pavlovac acid (pH_{KCl} = 3.99) soil (Bjelovar-Bilogora County) moderately supplied with phosphorus (available P_2O_5 according AL-method: 9.40 mg $100g^{-1}$) in amounts as follows: a = ordinary fertilization (kg ha^{-1}: 125 P_2O_5 + 82 K_2O), b = a + NPK-1, c = a + NPK-2, d = a + NPK-3 and e = a + NPK-4. The fertilizer NPK 10:30:20 was source of P and K (using in amounts 416, 1249, 2082, 2916 and 3748 kg ha^{-1}, for the treatments a, b, c, d and e, respectively). Nitrogen amount (375 kg N ha^{-1}) was equilized for all five treatments by addition of correspondingle quantities of CAN (calcium ammonium nitrate: 27% N). The experiment was conducted in four replicates (basic plot 77 m^2). Subsequent intervention in the experiment was liming (10 tones ha^{-1}) of half of the area with granulated fertdolomite containing 24.0% Ca + 16.0% MgO + 3.0% N + 2.5% P_2O_5 + 3.0% K_2O. Remaining two replicates have been used as control. At third soil sampling two soil samples were taken from each basic plot. Soil sampling (0-30 cm) were made in three terms as follows: at start of the trial (April 3, 2004), November 15, 2005 and September 3, 2009. According to the results of AL-method, the five steps of PK fertilization significantly increased the average content of soluble phosphorus and potassium in soil. The liming had a similar significant effect on the available phosphorus but liming caused insignificant decrease in available potassium. Hence, mineral fertilization and liming simultaneously increased available phosphorus, but effects on the potassium were opposite. Also, mineral fertilization and liming had a different impact on soil pH since mineral fertilization significantly decreased and liming significantly increased soil pH.

Keywords: fertilization, liming, pH, phosphorus, potassium

Introduction

Low levels of plant available phosphorus alone or in combination with potassium are limiting factors of some field crops yields (Kovacevic and Vukadinovic, 1992). Also, there are examples where low levels of these two nutrient were in combination with low soil pH reaction (acidic soils) and these soils are not common for efficient crop production. Ameliorative fertilization and application of lime could be solution for normalization of plant nutrition under that conditions (Kovacevic et al., 2007). The influence of fertilization and liming on soil properties were investigated by numerous authors (Bowszys et al., 2005; Hughes et al., 2004; Jovanovic et al., 2006; Loncaric et al., 2007; Rastija et al., 2008). The aim of this paper was to determine the effects of different rates of mineral fertilizer and liming as subsequent intervention on the changes in the soil chemical properties.

Materials and methods

The field experiment
Five steps of PK-fertilization were applied in April of 2004 on Pavlovac acid (pH in KCl = 3.99) soil (Bjelovar-Bilogora County) moderately supplied with phosphorus (available P_2O_5 according AL-method: 9.40 mg $100g^{-1}$) in amounts as follows: a = ordinary fertilization (kg ha^{-1}: 125 P_2O_5 + 82 K_2O), b = a + NPK-1, c = a + NPK-2, d =

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a + NPK-3 and e = a + NPK-4. The fertilizer NPK 10:30:20 was source of P and K (using in amounts 416, 1249, 2082, 2916 and 3748 kg ha^{-1}, for the treatments a, b, c, d and e, respectively. Nitrogen amount (375 kg N ha^{-1}) was equilized for all treatments by addition of adequate quantities of CAN (calcium ammonium nitrate: 27% N) were used. Both fertilizers are products of Petrokemija Fertilizer Factory in Kutina, Croatia. The experiment was conducted in four replicates. The experimental plot measured 77 m^2. Soil sampling (taking by auger to 0-30 cm of depth) were made in three terms as follows: at starting of the trial (April 3, 2004), November 15, 2005 and September 3, 2009. Crop sequence since 2004 has been as follows: maize (2004), soybean (2005), maize (2006), wheat (2007), maize (2008), and maize (2009). Subsequent intervention in the experiment was liming (10 tones ha^{-1}) of half of the area (the third and fourth replicates) with granulated fertdolomite (product of Petrokemija Fertilizer Factory in Kutina, Croatia) containing 24.0% Ca + 16.0% MgO + 3.0% N + 2.5% P_2O_5 + 3.0% K_2O. Remaining two replicates have been used as control. At third soil sampling two soil samples were taken from each basic plot.

Soil characteristics

Nutritional status of soil was controlled by phosphorus and potassium extractions using AL-method (Egner et al., 1960), which is the most frequently used method in Croatia. Soil pH reaction was analyzed according to standard methods (ISO, 1994) in water and M KCl solution. Soil organic matter was determined by sulfochromic oxidation (ISO, 1998). Also, hydrolytic acidity was determined by extraction of soil samples using Na-acetate solution.

Results and discussion

Investigated soils were very acid (pH_{KCl} 3,99) and according to AL method showed very low phosphorus and moderate potassium content. Organic matter was 1.93 % and hidrolitycal acidity 6.92 cmol kg^{-1} (Table 1). The five steps of PK fertilization significantly increased average of available phosphorus and potassium in soil. Compare to control, phosphorus availability increased from 9.40 to 21.43 mg $100g^{-1}$ and potassium from 17.8 to 25.55 mg $100g^{-1}$ (highest NPK treatments).

The soil pH (pH_{KCl}) was slightly decreased by mineral fertilization from 3.99 to 3.38. At the same time mineral fertilization had no significant influence on soil organic matter and hydrolytic acidity (Table 1). The resembling results were confirmed by Rastija et al. (2006).

The liming had a similar significant effect on the available phosphorus and the content of available phosphorus were higher under liming conditions (16.00 mg $100g^{-1}$) than on control plots (9.40 mg $100g^{-1}$). Similar effects regarding available phosphorus were observed by Loncaric et al. (2007) and Rastija et al. (2008). However, insignificant decreased of available potassium was found under liming conditions (Table 1). Liming is known to affect the availability of several plant nutrients but the extent of the lime effect is usually difficult to quantify (Curtin and Smille, 1986). The major role of liming was to overcome soil acidity and application of lime in this trial increased soil pH from pH_{KCl} 3.9 to pH_{KCl} 4.55. As it was expected, the hydrolytic acidity was lower after liming and decreased from 6.92 to 4.88 cmol kg^{-1}. Mineral fertilization and liming simultaneously increased available phosphorus up to 18.70 mg $100g^{-1}$, but effects on the potassium were opposite. In fact, slightly decreasing of available potassium was found after liming and fertilization (15.6 mg $100g^{-1}$) comparing to control treatment without liming and fertilization (17.08 mg $100g^{-1}$). The decrease of soluble AL-K content might be the result of Ca – K cationantagonism in soil. Also, mineral fertilization in combination with liming had a positive impact on soil pH and pH_{KCl} increased up to 4,67. Organic matter content was independent on the fertilization and liming treatments.

Table 1. Soil chemical characteristics before and after trial

	Soil property (0-30 cm)											
	pH				AL-method (mg 100 g^{-1})				%		Hydrolytic acidity*	
	H_2O		KCl		P_2O_5		K_2O		Humus		cmol kg^{-1}	
	The first soil sampling (before starting of the experiment: April 3, 2004)											
Control	5.44		3.99		9.40		17.8		1.93		6.92	
	The second soil sampling (November 15, 2005) – Rastija et al., (2006)											
Control	4.86		3.77		11.57		17.31		2.33		6.02	
NPK-1	4.90		3.43		11.70		19.57		2.22		5.86	
NPK-2	4.68		3.43		12.30		18.37		2.05		5.61	
NPK-3	4.35		3.38		18.60		24.24		2.16		5.97	
NPK-4	4.47		3.42		21.43		25.55		2.29		5.48	
LSD 0.05	n.s.		0.23		0.69		0.58		n.s.		n.s.	
LSD 0.01			n.s.		n.s.		n.s.					
	Subsequent intervention on the NPK-fertilization treatments: liming of half of the experiment area (Noveber 13, 2007) with granulated Fertdolomite (10 tons ha^{-1}) containing 24.0% Ca + 16.0% MgO + 3.0% N + 2.5% P_2O_5 + 3.0% K_2O											
	The third soil sampling (Sept. 3, 2009): effects of liming (A1= control; A2 = Fertdolomite 10 tons ha^{-1}), NPK-fertilization (five steps of B) and their interactions											
	Effects of liming (the factor A)											
Control (A1)	4.94		3.81		14.47		19.00		1.98		6.92	
Lime (A2)	5.61		4.55		16.00		17.80		1.98		4.88	
	Effects of NPK-fertilization (the factor B)											
Control (B1)	5.30		4.12		11.93		15.73		1.94		5.84	
NPK-1 (B2)	5.17		4.10		12.33		17.13		2.00		5.87	
NPK-2 (B3)	5.34		4.28		16.13		18.73		1.98		5.60	
NPK-3 (B4)	5.28		4.18		16.67		20.10		1.98		6.02	
NPK-4 (B5)	5.30		4.21		19.10		20.30		2.01		6.16	
	Effects of the AB interaction											
	A1	A2	A1	A2	A1	A2	A1	A2	A1	A2	A1	A2
Control (B1)	4.92	5.67	3.80	4.44	11.1	12.7	15.6	15.7	1.89	2.00	6.82	4.85
NPK-1 (B2)	4.97	5.36	3.87	4.32	11.5	13.2	17.7	16.6	2.09	1.91	6.54	5.20
NPK-2 (B3)	4.94	5.76	3.80	4.77	14.4	17.8	19.7	17.8	1.95	2.00	6.56	4.64
NPK-3 (B4)	4.98	5.58	3.81	4.55	16.6	16.719.5	21.4	18.8	1.95	2.01	7.12	4.92
NPK-4 (B5)	4.90	5.69	3.75	4.67	18.7		20.5	20.1	2.03	1.99	7.57	4.78
	The third soil sampling (Sept. 3, 2009): Statistical analyses (ns = non-significant)											
LSD -test	0.05	0.01	0.05	0.01	0.05	0.01	0.05	0.01	0.05	0.01	0.05	0.01
A	0.11	0.24	0.10	0.23	1.78	ns	ns		ns		0.52	1.20
B	ns		ns		1.72	2.37	1.61	2.22	ns		0.23	0.31
AB	ns				ns		ns		ns		0.32	0.44

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Conclusions

Resulted showed that five steps of PK fertilization significantly increased average content of available phosphorus and potassium in soil. The liming had a similar significant effect on the available phosphorus but at the same time insignificant decreased available potassium. Hence, mineral fertilization and liming simultaneously increased available phosphorus, but effects on the potassium were opposite. Also, mineral fertilization and liming had a different impact on soil pH since mineral fertilization significantly decreased and liming significantly increased soil pH. Liming and mineral fertilization had no influence on soil organic matter.

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APPLICATION OF ROCK WOOL INTO SOIL AS A MEANS FOR ITS INCREASED RESILIENCE AGAINST SOIL FERTILITY DEPRESSION

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Abstract: Effect of rock (basalt) wool on increase and strengthening of soil resilience threshold against decrease of its fertility was investigated in pot experiment with spring barley. The experiment was carried out in a vegetation cage located within the area of the Slovak Agricultural University in Nitra. The experimental pots were fulfilled with 24 kg of soil (16 kg of Haplic Luvisol + 8 kg of siliceous sand) and rock wool called Nobasyp was added. Nobasyp is a commercial name for loose, not used thermo-insulating material sold as Nobasil. It is produced by milling (recycling) of Nobasil which has not met the requirements of the consumer. Results achieved at the experiment showed, that application of Nobasyp at the rate of 20 $t.ha^{-1}$ improved those soil characteristics which improve soil stability. There was increased content of total carbon, carbon of humic substances, humic acids as well as fulvic ones in the soil. At the same time pH_{KCl}, S (sum of basic cations), V (base saturation), T (sorption capacity) values were increased and bulk density (BD) of soil decreased. Application of NPK fertilizers worsened all above mentioned parameters.
Solo Nobasyp application as well as in combination with NPK fertilizers improved those parameters of the soil which increase its productivity and resilience against depression of fertility (caused particularly by one-sided mineral nutrition of plants) and also strengthened the threshold of the resilience.

Keywords: basalt wool, rock wool, soil remediate substance, resilience, threshold

Introduction

Increasingly rising pressure on plant production effectiveness and often worsening soil fertility at the same time creates new challenges for growers to utilize traditional as well as new sources of nutrients and soil improvers (Macák, 2006; Hanáčková et al., 2008, Berzsenyi, 2009).
Information about the application of rock wools in the field plant production are very rare (Gilewska, 2005; Kováčik, 2006) in spite of the fact that they have typically high porosity – more than 90 %, good water capacity which never decreases below 80 %, elasticity of 95 % as minimum and absorbability of 200 % and more.
Their use has been connected mainly with the hydroponics plant growing (Bougoul et al., 2005). In plant production they are applied particularly as soil remediate substances increasing soil sorption capacity (Baran et al., 2008) or as a part in the mixture of other substrates, for example peat, bark, composts etc. (Bussell and McKennie, 2004). Kováčik and Wiśniowska-Kielian (2009) introduce their application as components of substrate for green roofs, sports and recreation areas or for growing the carpet grass.

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The aim of evaluated experiment was to find out the effect of milled rock wool (Nobasyp) on those soil parameters which increase its productivity and resilience against yield depression caused by one-sided mineral plant nutrition.

Materials and methods

The experiment was carried out in a vegetation cage located within the area of the Slovak Agricultural University in Nitra (48˚ 18´ N, 18˚ 05´ E). The experimental pots were fulfilled with 24 kg of anthropogenic soil with addition of rock wool called Nobasyp. Nobasyp is a commercial name for loose, not used thermo-insulating material sold as Nobasil. It is produced by milling (recycling) of Nobasil which has not met the requirements of the consumer (shape, thickness, colour, etc.)

Twenty-four kilograms of anthropogenic soil was prepared by mixing 16 kg of Haplic Luvisol and 8 kg of siliceous sand. Basic parameters of applied soil are stated in table 1 and methods of their determination can be found below this table. There was sowed up 100 seeds of spring barley (variety Expres) in each container. After emerging of barley the number of plants was thinned for 75 per pot. Moisture of soil was maintained on the level of 60 % of full water capacity by regular irrigation.

The experiment consisted of 5 treatments which were four times repeated (0 – control, NS_1- Nobasyp at the rate of 20 $t.ha^{-1}$, NPK – mineral NPK fertilizers at the rate 140 kg N ha^{-1}, 50 kg P ha^{-1}, 40 kg K ha^{-1}, NPK+NS_1 – mineral fertilizers + Nobasyp at basic rate of 20 $t.ha^{-1}$, NPK+$NS_{1/2}$ – mineral fertilizers + 10 $t.ha^{-1}$ of Nobasyp). The rates of NPK nutrients were calculated according to N_{in} and available P and K content in soil and the need of nutrients for planned yield of barley. Nitrogen was applied in DAM 390 fertilizer, P in the form of simple superphosphate and K in the form of 60 % KCl. The rates of Nobasyp were derived according to knowledge of Kováčik (2006).

The harvest of spring barley was carried out at the growth stage of DC 91. After harvest the soil sample of the whole profile of the each pot was taken and the following parameters were determined in it: C_{ox} - total carbon, C_{HS} - carbon of humic substances, HA - humic acids, FA- fulvic acids, soil reaction - pH_{KCl}, BD - bulk density. Parameters C_{HS}, HA and FA were determined by the method of Konovova and Beľčiková (1962). Methods for the determination of the other parameters are mentioned below the table 1. Achieved results were evaluated by analysis of variance using computer program Statgraphics, version 5.

Table 1. The basic parameters of soil used in the experiment

Year	pH_{KCl}	N_{in}	P	K	N_t	C_{ox}	S	T	V	EC
		mg.kg^{-1}				%	mmol.kg^{-1}		%	mS.cm^{-1}
2004	5.66	8.8	31.9	339	1190	1.880	145.48	165.50	87.90	0.030
2005	5.75	12.7	41.3	242	1064	0.974	87.76	101.48	86.48	0.040
2006	5.07	12.8	18.9	181	1064	0.992	90.55	106.36	85.13	0.025

pH_{KCL} – 1,0 M KCl; N_{min} – counted as a sum N-NH_4^+ + N-NO_3^-; N-NH_4^+ - colorimetric method, Nessler agent; N-NO_3^- - colorimetric method, phenol - 2,4 disulphonic acid; P - colorimetric method, Mehlich II;, K - flame photometry, Mehlich II; N_t – Kjeldahl; C_{ox} – as total (oxidizable) carbon, Tjurin; S - sum of basic cations and V - base of saturation and T - sorption capacity as Kappen method, EC – electric conductivity

Results and discussion

Application of loose rock wool (Nobasyp) at the rate of 20 $t.ha^{-1}$ caused increase of content of total carbon, carbon of humic substances, humic acids, fulvic acids, inorganic nitrogen, available potassium, calcium and magnesium, respectively (treat. NS_1 versus treat. 0). In addition, sorption capacity, sum of basic cations, base of saturation and value of pH were increased, too (Table 2 and Table 3). The above stated increases were statistically significant in the case of C_{ox}, T, S, pH_{KCl}, available K, Ca, Mg and represent the findings which point to the convenience of Nobasyp utilization as soil improver (soil remediate substance). The similar results were found out by Baran et al., (2008).
Nobasyp, although insignificantly, decreased soil volume weight which is considered to be one of the key parameters influencing utilization of nutrients by plants (Marschner, 2005). Positive effect of Nobasyp on soil was also maintained when it was applied together with NPK fertilizers. However, better ratio of humic acids : fulvic acids, lower bulk density, higher sorption capacity and especially higher content of available K and Mg were achieved when together with NPK fertilizers was not applied 10 $t.ha^{-1}$, but 20 $t.ha^{-1}$ of Nobasyp.

Table 2. The effect of Nobasyp on some pedological parameters at the end of the trial

Treatment	C_{ox}	C_{HS}	C_{HA}	C_{FA}	C:N	HA:FA	T	S	V
	%						$mmol.kg^{-1}$		%
0	0.954*ab*	0.369*bc*	0.164*bc*	0.205*ab*	12.4*a*	0.800	120.3*a*	109.6*a*	91.2
NS_1	1.135*c*	0.405*c*	0.172*c*	0.233*b*	15.6*b*	0.738	182.2*d*	173.0*d*	94.9
NPK	0.893*a*	0.333*ab*	0.137*a*	0.196*ab*	11.4*a*	0.699	119.8*a*	107.1*a*	89.4
NPK +NS_1	1.021 *abc*	0.324*a*	0.145*ab*	0.179*a*	11.9*a*	0.810	159.5*c*	147.9*c*	92.7
NPK+$NS_{1/2}$	1.063*bc*	0.337*ab*	0.143*ab*	0.194*ab*	12.4*a*	0.737	150.0*b*	137.8*b*	91.9
$LSD_{0,05}$	0.1492	0.0447	0.0218	0.0460	1.400		4.157	4.644	
$LSD_{0,01}$	0.2028	0.0607	0.0297	0.0625	2.037		6.049	6.757	

Table 3. The effect of Nobasyp on some agrochemical parameters in the soil at the end of the trial

Treatment	pH_{KCl}	EC	BD	N_{in}	P	K	Ca	Mg
		$mS.cm^{-1}$	$g.cm^{-3}$	$mg.kg^{-1}$				
0	5.63 *a*	0.06 *a*	1.28 *ab*	13.30 *ab*	37.9 *a*	235.3 *a*	1 132.8 *a*	270.7 *a*
NS_1	5.95 *b*	0.09 *a*	1.21 *ab*	14.92 *b*	37.0 *a*	270.1 *b*	1 533.8 *c*	429.5 *c*
NPK	5.60 *a*	0.14 *b*	1.34 *b*	11.19 *a*	46.2 *a*	264.4 *ab*	1 333.0 *b*	266.7 *a*
NPK +NS_1	5.93 *b*	0.14 *b*	1.14 *a*	10.37 *a*	43.5 *a*	320.0 *c*	1 419.5 *bc*	423.5 *c*
NPK+$NS_{1/2}$	5.92 *b*	0.18 *c*	1.24 *ab*	11.07 *a*	45.3 *a*	298.3 *bc*	1419.5 *bc*	336.7 *b*
$LSD_{0,05}$	0.1360	0.0321	0.168	3.146	15.41	33.90	157.68	34.08
$LSD_{0,01}$	0.1849	0.0437	0.244	4.276	20.95	46.07	214.31	46.32

Applied rock wool besides already above stated positive effect on total carbon in soil probably also supported mineralization process of N-compounds resulting in widening of C : N ratio (treat. NS_1 versus treat. 0). At the same time the HA : FA ratio was reduced, what confirmed the findings of Tobiášová and Šimanský (2009) who claims that incorporation of soil conditioners usually increases mainly content of non-stabile humic acids.

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Application of NPK fertilizers, besides positive effect on available nutrients content worsened all above mentioned parameters (treat. NPK versus treat. 0). However, statistically significantly decreased only content of humic acids and increased content of salts.
Achieved results show that application of Nobasyp, solo or in combination with NPK fertilizers, improved those parameters of soil which increase its productivity and resilience against decrease of fertility often caused by one-sided mineral plant nutrition.

Conclusions

Loose rock wool produced by milling of unutilized products determined for thermal insulation (sold under commercial name Nobasyp) showed during 3 – year experiment positive to highly positive effect on those soil parameters which contribute to increase of soil fertility and increase of resilience threshold against soil fertility decline.

Acknowledgements

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CRITICAL KEY BUFFER CAPACITY POINTS IN THE SOIL PESTICIDE TOLERANCE

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Abstract: The bioavailability and mobility of a compound is not only influenced by concentration and quantity, but also by the ability of soil to recharge the compounds that plants have taken up from soil solution or removed by the moving ground water. The effective diffusion and mass flow of the compounds depends on the soil's buffer capacity for that compound. The buffer capacity in function of equilibrium concentration (EBC) can be calculated as the first derivative of sorption isotherms. Using the measured and modelled multi-step isotherms for this calculation we could get wave-shaping functions where the maximums are bigger even ten times than the minimums in the 5-10 % interval of the whole soluble pesticide concentration. This result is highlighting some problems what we have never been taken into account before: Very small difference in the measured concentration can cover even ten times more or less amount of pesticide in the soil and the capacity of the soil to tolerate disturbance may also change even a magnitude in the aforementioned interval.

Keywords: pesticide, adsorption, buffering capacity

Introduction

As the importance of pesticide and toxic organic chemical soil sorption for environmental fate has became apparent, it has been studied intensely for the last 22 years (R Don Wauchope et al., 2002). The soil science and agricultural chemistry literature describe that the buffer capacity mainly used the phosphorus availability and pollution problems as a solution. The buffer capacity is measured from either adsorption or desorption isotherms and the equilibrium buffer capacity - function B - can be written as:

$$B = \frac{\partial q}{\partial c}.$$

Specifically at the Langmuir isotherms the following formula can describe the equilibrium buffering capacity as a function of equilibrium concentration:

$$B = \frac{A}{(1 + kc)^2},$$

(Rattan, 2006). The buffer capacity of the soil's P system may be described by the phosphorus adsorption isotherm. As a result of differentiating the adsorption equation, the equilibrium buffer capacity at any concentration (EBC) can be calculated as:

$$EBC = \frac{dP_{ads.}}{dc} = \frac{1}{3} \cdot \frac{k}{\sqrt[3]{c^2}},$$

assuming that the adsorption reduces exponentially according to the Freundlich isotherm with a 1/3 exponent (Tolner and Füleky, 1995). The advantage of using Q/I relationships is that they allow the prediction of both P retention and release in soils (Kpomblekou and Tabatabai, 1997). The P-buffering capacity of a soil is its ability to

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resist a change in the P concentration of the solution phase. Phosphorus-buffering capacities of soils can be related to both plant nutrition and environmental pollution. The Q/I model can be applied to either adsorption or desorption experiments (Yaobing et al., 2000). Results showed that Q/I parameters (the intercept labile P, a; the equilibrium buffering capacity, EBC; and the equilibrium P concentration, EPC) varied significantly between and within sites for the studied cropping systems.

Materials and methods

The herbicides as solutes resulted in two- or more step isotherms on soils and quartz. This phenomenon has not been observed yet concerning on the trace compounds in the environment. In this case the so-called Distributed Reactivity Model (DRM) is used to suggest the total sorption is given as the sum of the local adsorption isotherms (Czinkota et al., 2002; Konda et al., 2002).

$$q = \sum_{i=1}^{s} \left\{ \frac{q_{Ti} \cdot K_i \cdot (c - b_i + |c - b_i|)^{n_i}}{2^{n_i} + K_i \cdot (c - b_i + |c - b_i|)^{n_i}} \right\}.$$

In the cited work the adsorption isotherm was measured in different compounds using one soil sample, or one compound in different soil samples. The exact descriptions of experiments are in the cited articles.

Results and discussion

Using the isotherms the Equilibrium Buffering Capacity was calculated with help of the derivative function.

$$B = \frac{\partial}{\partial c} \left\{ \sum_{i=1}^{s} \left\{ \frac{a_i \cdot k_i \cdot [(c - b_i) + abs(c - b_i)]^{n_i}}{2^{n_i} + k_i \cdot [(c - b_i) + abs(c - b_i)]^{n_i}} \right\} \right\}.$$

The straightforward derivation of the above function is impossible because of the break point of abs function. However, if we know that the abs function is just needed for negative (c-b) data that is not to be taken into account. It means we can make the derivative function as the sum of single Langmuir isotherm in every x region. Therefore the following function can be used as the Equilibrium Buffering Capacity of multistep adsorption isotherms:

$$B = \sum_{i=1}^{s} \left\{ \frac{2^{n_i} \cdot a_i \cdot k_i \cdot n_i \cdot [(c - b_i) + abs(c - b_i)]^{n_i - 1}}{\left\{ 2^{n_i} + k_i \cdot [(c - b_i) + abs(c - b_i)]^{n_i} \right\}^2} \right\}.$$

Using the given parameters the Equilibrium Buffering Capacity function was calculated. We fitted the original adsorption function than we calculated the derivative function by equilibrium concentration. In other cases we calculated the new parameters (Tolner, 2008) (it is a little bit different from the original sorption isotherm parameters, because of the new fitting weighting points). The values of the parameters are given in Table 1.

Table 1. The fitted parameter values of the measured Equilibrium Buffering Capacity data

compound	R^2	a_1	a_2	a_3	k_1	k_2	k_3	b_1	b_2	b_3	e_1	e_2	e_3
Isoproturon	0,9993	9,29	9,93	4,42	0,30	3,79	1,47	0	4,57	13,16	0,45	0,55	3,11
Diazinon	0,9998	31,73	31,89	0,00	0,51	0,28	1,00	0	3,86	1,00	1,84	2,67	1,00
Atrazin	0,9980	9,26	10,97	0,00	0,28	0,49	1,00	0	4,16	1,00	0,95	2,46	1,00
Imidacloprid	0,9960	4,22	9,82	6,01	2,41	0,14	0,01	0	2,33	5,67	1,00	3,00	6,00

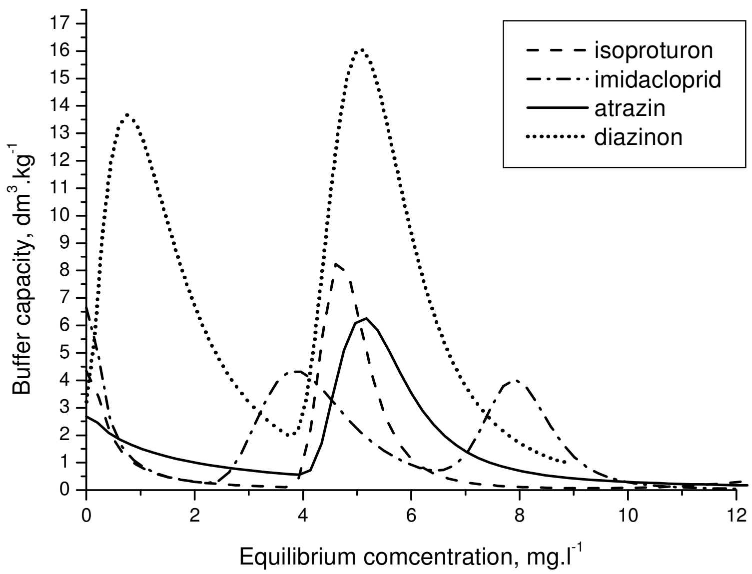

Figure 1. Equilibrium Buffering Capacity functions of different compounds

Fig. 1 shows the calculated functions, as it can be seen, there are very big differences in the EBC values with relatively small equilibrium concentration differences, and in some cases these are almost behave as periodical function.

Conclusions: How to use these results?

If we know the water content of soil, based on the buffering capacity value we can calculate the ratio of adsorbed and dissolved amount of given compound. In the analytical and monitoring practice we measure the concentration change in the liquid phase. Then we draw the conclusion that it is proportional to the changing of pollution amount, but it is not true in aspects of our research. The suggested calculation method step by step is the following:

To calculate the changing of pollution amount of a compound in solid phase in a given water content of soil the following formula can be used:

$$dQ = \frac{1-\Theta}{\Theta} \cdot EBC \cdot dc$$
,

where dQ is the change of the pollution amount in solid phase, [$mg*kg^{-1}$]
dc is the change of the concentration of solution, [$mg*dm^{-3}$]
EBC is the Equilibrium Buffering Capacity, [dm^3*kg^{-1}]
Θ is the water content of soil, [dm^3*dm^{-3}].

To calculate the total amount in milligrams of compound in the soil we must add the solid phase and liquid phase content,

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$$dQ = \frac{1-\Theta}{\Theta} \cdot V_{soil} \cdot \rho_{soil} \cdot EBC \cdot dc + \frac{\Theta}{1-\Theta} \cdot V_{soil} \cdot dc.$$

If we have got one hectare soil and 25 cm plugged layer, *and calculate total amount in kilograms*:

$$dQ = 10^{-6} \cdot \left(\frac{1-\Theta}{\Theta} \cdot \rho_{soil} \cdot EBC + \frac{\Theta}{1-\Theta} \right) \cdot V_{soil} \cdot dc,$$

where ρ_{soil} is the density of solid phase, about 2.6 [kg*dm^{-3}];
V_{soil} is the volume of soil, in this case 2500000 [dm^3]
dQ is the change of the pollution amount in given soil area, [kg].

Let's take an example about the measurement or monitoring causation of this results:
Let the soil water content be 0.2. Based on the isoproturon curve if the equilibrium solution concentration increases from 2 mg*dm^{-3} to 2.1 mg*dm^{-3}, the EBC is 0.35 dm^3*kg^{-1} .The change of the total isoproturon content is 0.1 kg. With the same water condition and isoproturon buffer function if the equilibrium solution concentration increases from 4.5 mg*dm^{-3} to 4.6 mg*dm^{-3}, the EBC is 8.18 dm^3*kg^{-1}. The change of the total isoproturon content is 21 kg.
To the contrary, let's suppose 20 kg*ha^{-1} isoproturon added into the soil, presumably as a plant protection activity. If the original equilibrium solution concentration was 2 mg.dm^{-3} it is increasing by 2 mg*dm^{-3}, i.e. 100 % increase, but if the original equilibrium solution concentration was 4,5 mg*dm^{-3} it would increase by 0,1 mg*dm^{-3}, i.e. 2 % increase. Based on these results we must redefine our original contamination assessment methods to avoid even a magnitude error. In addition to the equilibrium solution concentration measurement we need to know the Equilibrium Buffering Capacity (EBC) function for assessing the real amount of contaminants.

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EFFECT OF DIFFERENT SOIL TILLAGE ON WET AGGREGATE STABILITY

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Abstract: In the years 2008–2009 the effect of different agronomy practices on changes in topsoil and subsoil macrostructure was studied. Macrostructure refers to the ability of soil aggregates to resist dispersion. Three soil tillage treatments were established (traditional tillage with plowing; deep loosening to the depth 0.35-0.40 m; minimum tillage with shallow loosening to the depth 0.15 m). Studies were made on three localities in different crop growing regions (Unčovice locality in a sugar-beet growing region, Hrušovany-nad-Jevišovkou in a maize growing region and Lesonice locality in a potato growing region) with different soil and climatic conditions. The crops grown on the plots were winter wheat and maize. The objective of the study was to determine the effect of different tillage practices on water stability of soil aggregates. There was a marked effect not only of the locality, season and crop but also of tillage practice. Minimum tillage and deep loosening had a more favorable effect on water stability of soil aggregates than plowing.

Keywords: soil tillage, water stability of aggregates, winter wheat, maize

Introduction

Soil aggregate stability is a crucial soil property affecting soil sustainability and crop production. The aim of aggregate stability tests is to give a reliable description and ranking of the behavior of soils under the effect of water, wind and management (Amézketa, 1999). Water stability of soil aggregates is dependent on soil type and texture class, on the content of organic matter (Tisdall and Oades, 2006; Javůrek and Vach, 2009), biological activity of soil (Oades, 2005), fertilizer application (Anabi et al., 2007) and also on soil tillage practice and vegetative cover. The stability of soil aggregates can be enhanced by growing catch crops, reducing mineral fertilizer and pesticide use, and promoting biological activity of soil. A great effect is also exerted by long-term set aside (Eder et al., 1993). Panayiotopulus and Kostopoulou (1989) indicated that natural soils have considerably higher stability of aggregates than cultivated soils. With higher soil tillage intensity the content of organic matter reduces and consequently the stability of soil aggregates gets lower. Caravaca et al. (2004) reported that stability of soil aggregates on cultivated soils is much lower than on forested soils.

Materials and methods

The trial was established in the year 2007 on three localities. The first locality is in the territory of the Hrušovany-nad-Jevišovkou municipality in a maize-growing region at 210 m altitude on modal chernozem. Mean annual precipitation is 461 mm. The second locality is situated near the village of Unčovice in a sugarbeet growing region at 227 m altitude on luvic chernozem. Mean annual precipitation here is 536 mm. The third locality is near the village of Lesonice in a potato growing region at 510 m altitude on gleyic luvisol, mean annual precipitation here is 567 mm. In the year of trial establishment the same crop - winter rapeseed (*Brassica napus* L.) was grown on all localities. Winter rapeseed was followed by winter wheat (*Triticum aestivum* L.) on all

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localities, and in the year 2009 maize *(Zea mays)* was sown. The treatments are on-site with the same crop rotation on all the localities and three tillage systems: 1. Traditional tillage with plowing; 2. Deep loosening to the depth 0.35-0.40 m; 3.Minimum tillage with shallow loosening to the depth 0.15 m. In the years 2008 and 2009 soil samples were taken to determine water stability of soil aggregates, always in spring at the start of the growing season and in autumn at the end of the growing season. Soil samples were always taken from two depths 0-0.3 m (topsoil) and 0.3-0.6 m (subsoil). Water stability of soil aggregates was determined by wet sieving (Kandeler, 1996). This wet sieve procedure enables to separate a fraction of 1-2 mm from the soil sample dried at the laboratory temperature using sieves. A 3 g sample is washed with water over sieves for 5 minutes. Then the samples are dried at 105 °C to a constant weight and after cooling down in the exsicator they are weighed. After weighing a solution of sodium pyrophosphate is added and samples are washed again to wash out all clay particles (only sand particles above 0.25 mm are left), then they are dried and weighed. Water stability of soil aggregates is expressed as the percentage of water stable aggregates in the total amount of aggregates after subtracting the proportion of sand according to the formula: $\% SAS = ((M_2 – M_3) / W – (M_3 – M_1)) * 100$. % SAS - percentage of stable soil aggregates; M_1 - weight of the dish (g); M_2 - weight of the dish, stable aggregates and sand (g); M_3 - weight of the dish and sand (g); $(M_2 – M_3)$ - weight of stable aggregates; $(M_3 – M_1)$ - weight of sand; W - weight of the sample (3 g). The data obtained were statistically analyzed using the program Statistica 7.7 by multifactor analysis of variance and subsequently by the method of least squares (LSD).

Results and discussion

Hrušovany nad Jevišovkou locality:
In the first year of studies water stability of soil aggregates was the highest in spring after trial establishment at a depth of 0-0.3 m in the treatment with deep loosening (Fig. 1). Also in the second year of studies water stability was the highest in spring in the treatment with deep loosening, but at a depth of 0.3-0.6 m. The best values of water stability were recorded in spring of the second year in the subsoil in the treatment with deep loosening. Overall, the lowest values of water stability were reported in both years in the treatment with plowing. Also other authors (Mannering et al., 1975; Tebrügge and Düring, 1999) reported on the basis of their long-tem studies that lower intensity of soil tillage enhances the stability of soil aggregates.

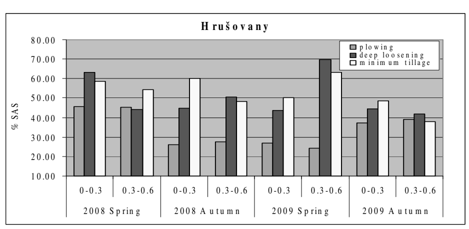

Figure 1. Mean values of water stability (%) of soil aggregates on the Hrušovany locality at two soil profile depths in particular years.

Unčovice locality:
On this locality in the first year of studies the water stability of soil aggregates was generally higher than in the following year (Fig. 2). In the first experimental year minimum tillage gave the best results, in the spring after trial establishment water stability was the highest at a depth of 0-0.3 m. In the second year of studies water stability of aggregates was higher in autumn in the subsoil in the treatment with deep loosening. Like in the above-mentioned locality, the plow treatments produced lower values of water stability than the other treatments.

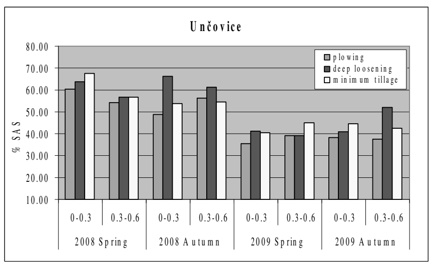

Figure 2. Water stability (%) of soil aggregates on the Unčovice locality at two soil profile depths.

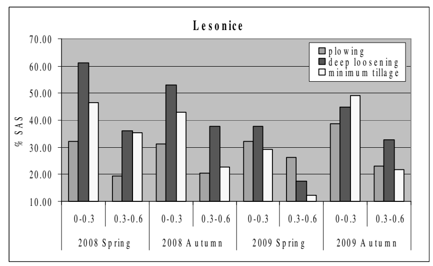

Figure 3. Water stability (%) of soil aggregates on the Lesonice locality at two soil profile depths

Lesonice locality:
In the first year after trial establishment deep loosening had the best effect on stability of soil aggregates (Fig. 3). In the following year water stability was highest in autumn at a depth of 0-0.3 m with minimum tillage. Overall, the highest value of water stability was found in the spring of 2008 at a depth of 0-0.3 m in the treatment with deep loosening. Also, on this locality the plowless systems gave better results than the plow treatment. Javůrek and Vach (2009) in their studies proved that long-term use of soil conservation methods has a positive effect on water stability of soil aggregates.
During overall evaluation of impact of monitored soil treatment on the aggregate stability was found demonstrable and significant difference between plowing and other variants (Tab. 1, 2)

Table 1. Analysis of variance for water stability of aggregates.

Effect	d.f.	Mean square
Locality	2.00	3090.5***
Variation	2.00	1998.3***
Depth	1.00	933.1**
Locality*variation	4.00	366.1**
Locality*depth	2.00	801.9***
variation*depth	2.00	78.3 n.s.
error	130.00	83.8

Table 2. Multiple range analysis for variation (Method: 95 LSD).

Variation	average
1	36.01682 a
2	45.24521 b
3	48.44247 b

*** P = 0.001; **P = 0.01; *P = 0.05; n.s. nonsignificant. Average values indicated by various letters are statistically different (P = 0.05).

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Conclusions

Results of following are in our conditions (transition type of clime) expressive dependent on moisture at processing and annual character. In years with continental clime will be better minimum tillage, in years with seaside ploughing. Last decade is characterized by higher temperatures and clime is approaching to the continental type. The first results indicated a positive effect of plowless systems on water stability of soil aggregates. During two years period of monitoring was statistically proven different influence of plowing and plowless option on the water stability of soil aggregates. The effect of sampling date, depth of sample collection, locality and season with crop was also observed. Explicit conclusions of this experiment will be possible done after longer following.

Acknowledgements

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EFFECT OF SHEEP MANURE COMPOST AND LIMING ON A HEAVY METAL POLLUTED SOIL AND CROP

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Abstract: Heavy metal contamination of soils caused by the worldwide industrialization can lead to human health problems and toxic effects on plants and animals. A typical territory polluted by human activities is situated in the area of the Gyöngyösoroszi metal mine. The spoil-bank of this mine is contaminated with toxic heavy metals (e.g. Zn, Cu, Fe, Mn). Heavy metal contents of soils can reach levels that inhibit the normal growth and development processes of plants. Negative effects of heavy metals depend on their concentrations and different chemical characteristics of soils (e.g. pH, organic matter content). Applications of sheep manure compost (SM compost) and lime were tested as possible ways of supporting plant growth and development on the tested soil. Pot experiments were carried out to examine the effects of the above-mentioned substances on the growth and development of Italian ryegrass (*Lolium multiflorum* L.). Our goal was to obtain detailed information about the feature of the applied materials which can mitigate the unfavourable chemical conditions of the tested polluted soil. We hope these experimental data can contribute to getting acquainted with the resilience of the ecosystem of this polluted area and to enhance this resilience.

Keywords: heavy metal, sheep manure compost, lime, acidic soil, polluted soil

Introduction

The slag sites of Gyöngyösoroszi metal mine are contaminated with residual toxic heavy metals. The biological resilience of plants in the polluted area is based on the chemical and physical properties of the soil. The simplest way to set the soil characteristics is treating with chemical amendments, for example compost and lime (Castaldi et al., 2005).
Application of compost for the purpose of increasing the stress tolerance of plants is widely spread in the agricultural practice (Topcouglu and Önal., 2007; Delgado et al., 2002). However, the effect of composts is not completely clarified in this aspect. It is known that compost contain high amount of organic matters that are very good complex forming agents for some metal ions. Therefore we presume that compost can protect plants from the intoxication caused by different heavy metals (Keresztúri et al., 2008). For checking this assumption, pot experiments were carried out with ryegrass as indicator plant. The main components of the compost are sheep manure and row phosphorite (Monori et al., 2008). In this paper we summarized the conclusions of our studies concerning to the abiotic stress moderating effect of the tested compost.

Materials and methods

Pot experiments
Acidic, heavy metal polluted soil was used in all experiments. The soil was collected from the surface layer of the contaminated area of the former metal mine at Gyöngyösoroszi. Italian ryegrass as test plant was grown in a greenhouse with supplemental lighting by "Cool White" fluorescent lamp to provide a 12 hour photoperiod. The pots were arranged in a completely randomized design with three replications. In each pot 45 seeds of the indicator plant were sown.

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Compost treatment
Italian ryegrass was grown in plastic pots containing 0.6 kg of air-dried soil-compost mix. Treatments consisted of seven sheep manure compost doses, i.e. 0 (control), 1, 1.5, 2, 4, 6, 10 m/m % (30-300 t ha^{-1}).
Lime treatment
This experiment was carried out similarly to the experimental with the compost treatment. The $CaCO_3$ doses were 0, 0.5, 1, 2, 4, 6, 10 m/m % (7.5-300 t ha^{-1}).
Chemical measurement
The pH_w (active acidity) measurement was carried out by Inolab Multilevel 3P, Sen-Tix 81 pH electrode, in soil:water suspension (1:2.5) at room temperature after one day.
For the determination of the total toxic element contents of the plant, the samples were digested in HNO_3/H_2O_2 solution in a ratio of 2:1 while they were heated by microwaves. The metal concentration was determined with a SpectraAA 220FS atomic absorption spectrometer.

Results and discussion

The effect of the different doses of compost on the growth of ryegrass seedlings on the polluted soil was studied in detail. The height of plants was measured after one month (Figure 1). The plant heights increased by the increase of the compost doses 0-4 m/m %, which is in good agreement with several published data (Topcouglu and Önal., 2007). This increase in the height of the plants can probably be caused by the improvement of phosphorus (P) supply and the complex forming ability (with metal ions) of the matter content of the *SM* compost. The positive effects of organic material have already been published by Dömsödi (1989), Máté-Gáspár and Anton (2005). Another possible explanation is the pH increase effect of the compost (Figure 2).

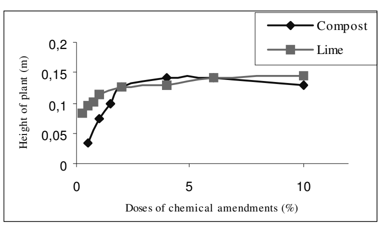

Figure 1. Effect of chemical amendments on the plants

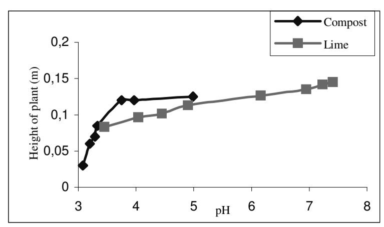

Figure 2. Effect of pH on the height of plants

Increasing the compost content above 4 m/m % did not lead to a further increase in the height of the plants. We supposed that other chemical amendments can also be effective on the growth of plants particularly by pH increase. We applied lime, which is a classical, widely used agricultural amendment for neutralizing of acidic soils.
Figure 1 shows that the height of the plants increases with the increasing lime content ranging 0-2 m/m %, while increasing the lime content above 2 m/m % we experienced an effect similar to the case of the compost amendment. Figure 2 shows the effect of pH-change caused by liming on the plant heights.

In other experiments we measured the uptake of heavy metals by grasses as function of the doses of compost and lime in this polluted soil. The doses of the chemical amendments and pH are plotted against the copper content of the ryegrass for demonstration (Figures 3-4). The figures show the decrease of the Cu-content caused by the increased doses of chemical amendments and the pH increase which is caused by the addition of this material into the soil.

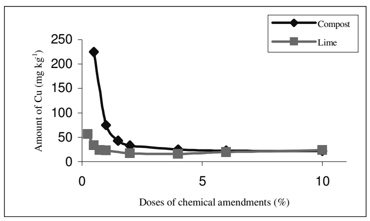

Figure 3. The effect of the chemical amendments the Cu-content of plants

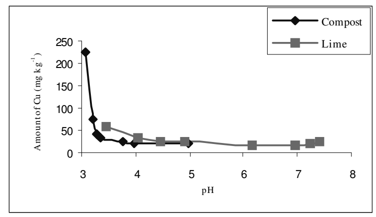

Figure 4. The effect of pH on the Cu-content of on the plants

These results corresponded with the results of several other researchers (Topcouglu and Önal., 2007; Castaldi et al., 2005). We also determined the Mn, Fe, Zn contents of the tested plants. The results are shown in Tables 1-2. The data of the analysis confirmed our hypothesis that compost and lime reduced the uptake of different metals by plants.
Figure 3 shows the changing of pH of the polluted soil caused by the addition of compost and lime. It is clear that lime is more efficient in the pH enhancement than compost. However, similar doses of compost and lime resulted in the same height of the grass seedlings. This result can confirm the above-mentioned causes of the beneficial features of compost in the remediation of the polluted soils from Gyöngyösoroszi (Figure 1-2).

Table 1. The effect of compost on the pH and metal content of the tested plants

Compost		Metal content of plants mg kg^{-1}							
Doses %	Resulted pH	Cu		Zn		Mn		Fe	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
0.00	2.84	*	*	*	*	*	*	*	*
0.50	3.08	225.0	50.1	350.0	41.9	450.0	33.5	1575.0	102.4
1.00	3.20	75.0	15.4	181.3	17.3	237.5	11.6	606.3	75.6
1.50	3.29	43.3	5.6	170.0	18.6	223.3	13.2	573.3	80.9
2.00	3.33	33.3	3.7	168.8	21.7	222.9	14.7	337.5	74.5
4.00	3.75	25.0	3.5	132.1	16.4	216.4	12.8	246.4	48.1
6.00	3.97	22.8	2.2	91.3	10.8	187.0	9.1	139.1	36.7
10.00	4.99	22.4	2.1	71.4	9.9	155.1	8.8	211.2	48.2

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Table 2. The effect of lime on the pH and metal content of the tested plants

Lime		Metal content of plants mg kg^{-1}							
Doses %	Resulted pH	Cu		Zn		Mn		Fe	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
0.00	2.82	*	*	*	*	*	*	*	*
0.50	4.04	34.0	4.1	138.1	11.5	303.0	36.6	526.6	94.1
1.00	4.90	23.5	3.5	127.8	16.7	509.9	12.4	249.5	113.8
2.00	6.16	17.1	3.7	60.2	13.2	426.3	103.9	248.8	54.3
4.00	6.95	16.1	0.6	46.5	4.5	134.0	12.6	243.3	60.4
6.00	7.22	19.9	2.4	51.6	3.2	85.5	5.8	300.0	101.9
10.00	7.41	24.2	3.4	56.3	8.1	71.8	13.4	841.8	56.9

* The plant did not grow.

Conclusions

We have studied the effect of compost and lime on the growth and the metal uptake of ryegrass in an acidic, heavy metal polluted soil. In this pot experiment we established that the increasing doses of compost and lime enhanced the pH of the soil and the height of ryegrass, and resulted in a decrease in the heavy metal content of the plants. The compost and lime help the survival of the plants under these inauspicious living conditions.

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EFFECT OF SOIL CULTIVATION AND NITROGEN FERTILIZATION ON THE WINTER WHEAT AND MAIZE YIELDS AND WEED COVER

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Abstract: Soil cultivation (the factor A) and nitrogen fertilization (the factor B) effects on yields of winter wheat and maize and weeds-cover was tested in the long-term experiment conducted on Keszthely Eutric cambisol (Ramann type brown forest soil) in 2005-2008 period. The bi-factorial trial was arranged in split plot design with four replications (basic plots 435 m^2 and 87 m^2, for A and B, respectively). Conventional tillage (ploughing = PL), no-till drill (NT) and disking (D) were the treatment of soil cultivation, while five rates of nitrogen (kg N ha^{-1}: 0; 120; 180; 240; 300) were applied on blanket application of phosphorus and potassium (kg ha^{-1}: 100 P_2O_5 + 100 K_2O). There was no weed control until our investigation. The weed surveys were made with Balázs – Ujvárosi coenological method. The fewer yields were obtained in the wheat-maize no-tillage system compared to the others. It was proved at high and low level alike (good and unfavourable years). In the average of years the decreasing of yield was 10-15% compared to the traditional cultivation. In survey the weed cover (%) at wheat in springtime it can be said that the weed cover increased parallel with the amount of N fertilizer and above 200 kg/ha N doses declined. The dynamic of relation of weeds v.s. N fertilizer it is similar to the square equation of yield curve. In case of maize there were not significant differences between the N treatments (25-30 %) regarding the weed cover. The results draw ones attention to that facts that with the propagation of the reduced soil cultivation systems it is necessary to modify and harmonize the practice of weed control and fertilization.

Keywords: soil cultivation, weed cover, maize, wheat, yield

Introduction

In the course of conventional soil cultivation, deep ploughing, stubble breaking and other kind of soil preparation mean the limitation of damage caused by weeds in connection with the crop rotation and nutrient supply at the perennial and ephemeral weeds alike. The national and the world-wide literature deal with the weed-limiting effect of soil cultivation systems, the conventional and the conservation systems, both. According to the general results of the weed research the conventional tillage, thus mould board ploughing is effect to reduce the weed suppression and on the other hand the conservation tillage systems (e.g. no-tillage) enhance the injurious effect of weeds (Birkás, 1997; Tuesca, 2001; Shestra et.al., 2003; Farkas, 2004). The crucial question in the conservation and no-tillage for the sustainable agriculture is the weed problem mainly it the technology of weed control unaltered compare to the traditional one. The lower yield in this cultivation system can be attributed to the competition of weeds. To clarify the question some investigation were carried out in exact long-term field experiments (2005-2008) on brown forest soil at the University of Pannonia, Georgikon Faculty Keszthely.

Materials and methods

Soil cultivation (the factor A) and nitrogen fertilization (the factor B) effects on yields of wheat and maize and weeds-cover was tested in the long-term experiment conducted on Keszthely eutric cambisol (Raman - type brown forest soil) in 2005-2008 period.

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The bi-factorial trial was arranged in split plot design with four replications (basic plots 435 m^2 and 87 m^2 , for A and B, respectively). Conventional tillage, ploughing (PL), no-till drill (NT) and disking (D) were the treatment of soil cultivation, while five rates of nitrogen (kg N ha^{-1}: 0; 120; 180; 240; 300) were applied on blanket application of phosphorus and potassium (kg ha^{-1}: 100 P_2O_5 + 100 K_2O). Crop rotation was as follows: winter wheat–winter wheat–maize–maize. There was no weed control until our investigation. The weed surveys were made with Balázs – Ujvárosi coenological method. The investigation of weed flora and species and the biomass-production of weeds were published previously (Kismányoky and Lehoczky 2006; Lehoczky and Kismányoky 2006, 2008). In this study the weed-cover (%) of wheat and maize were investigated in field experiments.

Results and discussion

In connection with the factor A (soil cultivation) and B (N fertilization) the yield of wheat varied 2.5-6.0 t ha^{-1} in the average of the years (Table 1).

Table 1. Impacts of soil cultivation on yields of wheat and maize in 2004-2008.

Year	Cultivation treatments			LSD 5 %	Year	Cultivation treatments			LSD 5 %
	PL	NT	D			PL	NT	D	
	Grain yield of wheat (t•ha^{-1})					Grain yield of maize (t•ha^{-1})			
2004	5.83	5.54	5.73	0.77	2004	7.71	6.93	7.40	0.33
2005	5.58	5.31	5.64	0.29	2005	9.63	8.67	9.18	0.89
2006	4.78	4.32	4.71	0.84	2006	10.08	8.24	9.02	0.28
2007	4.22	3.70	4.06	0.57	2007	5.18	3.91	4.73	0.51
2008	4.68	3.53	4.59	0.23	2008	6.51	6.10	5.99	0.48
Mean	5.02	4.48	4.95	0.61	Mean	7.82	6.77	7.26	0.50

In case of maize the yield obtained were 6-10 ha^{-1} in the same context. The influence of the annual circumstances upon the yield (mostly rainfall) was measurable and from time to time statistically significant.

The different amount of N fertilization increased the yield of maize and wheat significantly. The highest increasing was found at 50-100 kg ha^{-1} N fertilizer compare to the N0 plots. the efficiency of the additional doses were negligible. The maximal yield was obtained of maize and wheat at 200-250 kg ha^{-1} N both. (Table 1)

During the 30 years there were not significant differences between the ploughing and the disking in the average of the years in long-term field experiments regarding the wheat yield. Without cultivation (no-tillage variant) the yields was significantly less than it the other cultivation systems. It was proved in the dry and rainy years alike. In the rainy years (favorable years) there were not any differences between the treatments (A) (Fig. 1).

The question is coming up; why the most successful cultivation system is the ploughing in every year and in all N variations and why the least yield was measured in the disking or in the no-tillage methods? It is presumable that the competitions of weeds played a great part in this experience.

In case of maize the winter ploughing resulted the best yield among the treatments, the differences were significant. The no-tillage in the average of the years and in the majority of years was less productive. It was obviously because of the water preserving role of ploughing in the winter time, as well as its weed suppression effect. In this topic some our publication had appeared earlier (Tóth and Kismányoky 2001). In the above mentioned research period (2005-2008) the yield fluctuation was only partly in connection with the climatic changing (precipitation). The damage caused by weeds paid role considerably in the yearly fluctuation of yield.

According to the soil cultivation systems there were differences between the spring weediness of wheat (Fig. 2). In the average of years the largest cover of weeds (28%) was in the no-tillage treatment, the least in case of ploughing (10-15%). On an average of treatments and years the biggest covering were measured at the N_2-N_3 nutrient doses (24-25%). In the winter wheat trial after harvest the least cover was found in the ploughing treatments (11%). the biggest in case of no-tillage (44%).

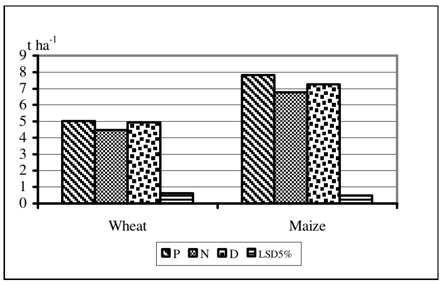

Figure 1. Effect of soil cultivation. on the yield of wheat and maize (on average A·B factors)

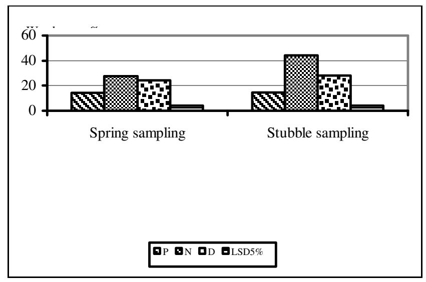

Figure 2. Effect of soil cultivation on the weed cover in wheat (A factor on average of B)

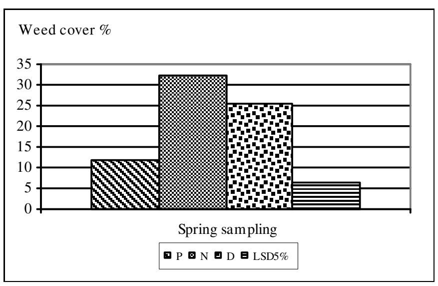

Figure 3. Effect of soil cultivation on the weed cover in maize (A factor on average of B)

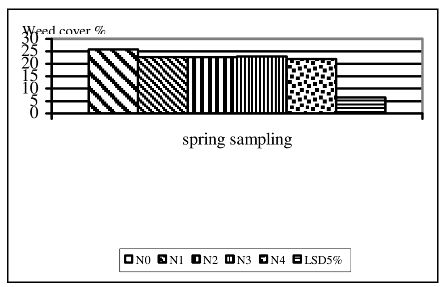

Figure 4. Effect of N fertilization on the weed cover in maize (B factor on average of B)

In the maize trial on the average of years and factor B the order of weed cover as follows A_1 12% - A_3 26% - A_2 32% in other words the extent and order coverage seems to be a mirror reflection of the yield order (Fig. 3). At the same time the increasing amount of N fertilizer (B) did not increase weed-cover significantly it was 20-25 % in every treatments. when the trend slightly decreasing (Fig. 4). These results prove that the proper and optimal fertilization increase the competitive ability of maize and the crop-plant obtain oppressive role.

According to the herbologists the weed-cover % mean the same % yield decreasing (Kolbe 1977; Ujvárosi 1973) but this is determined by the competitiveness of the crop

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and the species of weed (Czimber, 2002). These statements were proved in our investigations, as well.

Conclusions

The crucial question in the conservation and no tillage for the sustainable agriculture is the weed problem mainly if the technologies of weed control unaltered compare to the traditional one. The lower yield in these cultivation systems can be attributed to the competition of weeds. To clarify the question some investigation were carried out in exact long-term field experiments (2005-2008) on brown forest soil.

The fewer yields were obtained in the wheat-maize no-tillage system compared to the others. It was proved at high and low level alike (good and unfavorable years). In the average of years the decreasing of yield was 10-15% compared to the traditional cultivation.

In survey the weed cover (%) at wheat in springtime it can be said that the weed cover increased parallel with the amount of N fertilizer and above 200 kg/ha N doses declined. The dynamic of relation of weeds v.s. N fertilizer it is similar to the square equation of yield curve. In case of maize there were not significant differences between the N treatments (25-30 %) regarding the weed cover.

The results draw ones attention to that facts that with the propagation of the reduced soil cultivation systems it is necessary to modify and harmonize the practice of weed control and fertilization. Instead of schematic process of weed control and fertilization we should urge the application of scientifically well established methods.

Acknowledgement

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EFFECT OF ZN ON THE YIELD COMPONENTS AND CHEMICAL COMPOSITION OF MAIZE (*ZEA MAYS* L.)

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Abstract: In 2009 we launched a foliar fertilization experiment with alkaline zinc-carbonate on brown forest soils poorly supplied with zinc on the farm of Farkas Agricultural Co. Ltd. in Zimány. We treated NK Symba maize hybrids with alkaline zinc-carbonate before flowering during the vegetation period. Experiments were launched under large scale circumstances. We applied zinc in following doses: 0.1; 0.15; 0.2; 0.25 kg/ha. In this paper we evaluated the following parameters: ear mass, mass of the shelled kernels, corn-cob ratio, Zn-content of the leaves. In general we can establish that Zn-treatments influenced the parameters studied. The application of Zn increased the values of the parameters. As a general tendency there was a significant difference between the values measured at the lowest and at the highest Zn-treatments. On the basis of the results it is probable that higher Zn doses should be applied in the future.

Keywords: maize, zinc, foliar fertilizer, yield components, chemical composition

Introduction

Maize is a very important industrial and fodder plant as it can be used and applied many sided. In Hungary maize is grown on a considerable acreage: about 1-1.2 million hectares. Besides the food industry, many other branches of industry use maize: it is processed to alcohol and starch, or is used as a raw material for producing medicines, paper-, textile- and wrapping materials. To maintain safe quantity and quality of growing we should satisfy the plants' nutrient demands (Kádár, 2005; Petróczki et al., 2005). One-sided fertilization practice upsets the nutrient balance (Németh, 2002; Tury and Szakál, 2008). The developed ion antagonism and ion synergism can cause symptoms of deficiency (Füleky and Kovács, 1993; Kádár, 1992). Potassium enhances the transport of assimilates, so it has an effect on the starch development. Among micro elements copper, zinc and iron have a determining role in the nutrient supply of maize, but its role in the enzyme activity is important as well. Zinc-uptake is inhibited on lime-soils with high pH value. A high rate of soils in Hungary shows zinc deficiency. On lime-soils well supplied with phosphorous zinc demanding cultivars (like maize) may require zinc fertilization (Kádár, 2008; Szakál and Szalka, 2008). Zinc deficiency can be eliminated by the application of zinc on the soil or on the leaves. Different zinc complexes are used for foliar fertilization. We used for supply zinc the alkaline zinc-carbonate compound, which we gained from wastes (Barkóczy et al., 1989).

Materials and methods

In 2009 we launched a foliar fertilization experiment with alkaline zinc-carbonate on brown forest soil poorly supplied with zinc on the farm of Farkas Ltd. in Zimány. NK Symba maize hybrids were tested under large scale circumstances. The experiment was launched in random block design with four replications. The treated units were 120m long and 18m wide (matching the working widths of the sprayer and harvester). Replications were separated by protective strips of 4.5m. Treatments were applied in one phenological state: before flowering.

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Table 1: Soil analysis results, Zimány, Hungary

pH		K_A	$CaCO_3$	Humus	AL-soluble			Mg	EDTA-soluble		
H_2O	KCl				P_2O_5	K_2O	Na		Zn	Cu	Mn
			%		$mgkg^{-1}$						
-	5.98	41	1.1	1.61	84	206	15	198	0.8	4.2	394

The applied zinc doses were 0.1; 0.15; 0.2; 0.25 kg/ha. The machine used to apply the test substances was a RAU field sprayer with precision control. This special sprayer mixed the plant protecting agents and foliar fertilizer into a permanent water flow in precisely controlled quantities. Maize samples were manually harvested in the centre of the plot in one row at a length of 10 metres. We measured the mass of the ears, the mass of shelled kernels and their thousand-weight mass. For monitoring the Zn content of the leaves we collected leaf samples from the position opposite to the ears. Chemical analysis of the kernels was carried out at an accredited laboratory (UIS Hungary) according to the respective standards. The statistical analysis of the experimental results was done by SPSS 12.0 for Windows program (SPSS Inc., Chicago, USA).

Results and discussion

Farkas Agricultural Co. is running his farm in Zimány, SW Hungary. Out of the total 420 ha area 300 ha are deficient in Zn, i.e. the Zn content was lower than 2.5 $mgkg^{-1}$ EDTA soluble Zn.

Ear mass

The mass of the ears varied between 29 and 305.8 g. Due to the application of the Zn compound the mass of the ears increased. The tendency of the increase is almost regular; there is only a minor difference at the Zn-dose of 0.2 kg/ha^{-1}. The lowest (control and 0.1 $kgha^{-1}$ Zn) and the highest (0.25 $kgha^{-1}$ Zn) values differ significantly from each other.

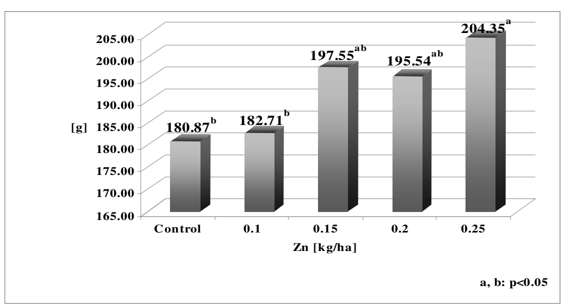

Figure 1. The effect of Zn-treatments on the ear mass

Mass of the shelled kernels

A similar tendency can be established in the case of the shelled kernels. The mass of the kernels increased parallel with the increasing Zn doses. We can measure the lowest kernel mass at the control at 0.1 $kgha^{-1}$ Zn dose. The increase of the mass of the shelled kernels is regular and in spite of the relatively high standard deviation values, it is significant at the control, the 0.1 $kgha^{-1}$ and the 0.25 $kgha^{-1}$ Zn dose respectively.

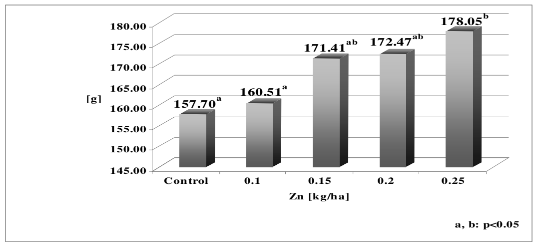

Figure 2. Changes in the mass of the shelled kernels due to Zn-treatments

Corn-cob ratio

The corn-cob ratio was calculated in order to study how the treatments modified the proportion of the generative and vegetative parts. We observed the same tendency as in the case of the other parameters, i.e. the lowest and the highest values differed significantly from each other. This is also supported by the fact that while the corn mass increased due to the treatments, there were no significant changes in the cob mass, therefore the ratio changed.

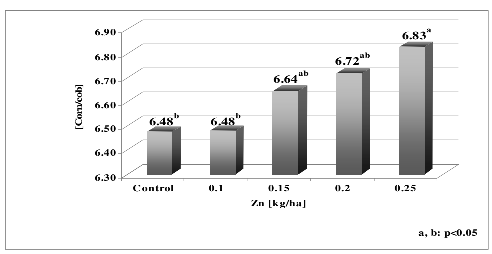

Figure 3. Changes in the corn/cob ratio as a result of the Zn-treatments

Zn content of the leaves

The Zn-content of the leaves also responded to the treatments positively. The Zn-content of the sample leaves varied between 12 $mgkg^{-1}$ and 22.9 $mgkg^{-1}$. We measured the lowest value in the case of the control and the highest one at the 0.25 $kgha^{-1}$ Zn treatment. The statistical analysis proved the same fact; the control and the 0.1 $kgha^{-1}$ Zn treatment did not differ statistically. There was also no significant difference between the two treatments in the middle (0.15 and 0.2 $kgha^{-1}$ Zn). The Zn-content of the control and the plants treated with 0.1 $kgha^{-1}$ Zn dose is 13.92 $mgkg^{-1}$ and 15 $mgkg^{-1}$ respectively and that of the plants collected form the plots treated with 0.25 $kgha^{-1}$ Zn is 19.6 $mgkg^{-1}$. The difference between the 0.25 $kgha^{-1}$ Zn and the 0.1 $kgha^{-1}$ Zn

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treatments is significant at 5% probability level, between the control and the 0.25 $kgha^{-1}$ Zn at 1% probability level.

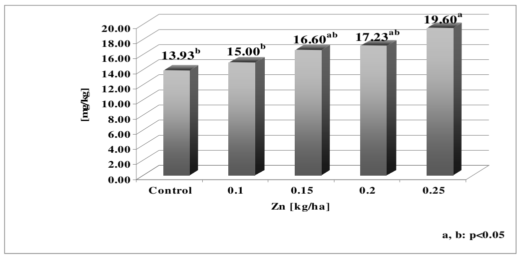

Figure 4. Zn-content of the maize leaves in the experiment

Conclusions

We carried out a foliar fertilisation experiment in a Zn-deficient brown forest soil in Zimány, SW Hungary. We applied Zn in the following doses: 0.1; 0.15; 0.2; 0.25 kg/ha. Experiments were launched under large scale circumstances. We applied zinc in following doses: 0.1; 0.15; 0.2; 0.25 kg/ha. The following parameters were evaluated: ear mass, mass of the shelled kernels, corn-cob ratio, Zn-content of the leaves. The application of Zn increased the values of the parameters. As a general tendency there was a significant difference between the values measured at the lowest and at the highest Zn-treatments. Zn treatments influenced plant growth positively in the Zn-deficient soil, though the doses seem to be a little low and should be increased in the future.

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The authors express their special thanks to Farkas Agricultural Ltd. for supporting their work.

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EFFECTS OF SOIL CULTIVATION SYSTEMS ON THE FACTORS OF THE SOIL CARBON CYCLE

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Abstract: There have been in situ measurements aiming the determination of the CO_2-emission of the soil since 2002 in the complex soil cultivation experiment at Karcag. Contrary to our previous results and the literature data, the highest values of CO_2-emission were measured in the conventionally ploughed treatment. The main goal of these measurements was to determine the effect of soil cultivation technologies and certain agrotechnical elements on the factors of the soil carbon cycle. The changes in quality and quantity of the organic material of the soil are monitored through laboratory examinations. The light absorption of the humus substances extracted by different solvents (NaOH, NaF, hot water) was measured in the UV-VIS range. The results show the rates of the organic materials being at the different phases of humification. Any disturbance by soil cultivation can partly mobilise the C-stock of the soil. Frequent ploughing, loosening etc. intervene into the dynamics of the natural processes contributing to the C-loss of the soil by the accelerated aeration. This increased aeration results in the emission of greenhouse gases, changes the CO_2 concentration and increases the oxygen concentration, therefore the oxidative processes become dominant in the soil. Experimental data provided information about the length of the time period when CO_2 emission increasing effects of soil cultivation are observable. These data can characterise the resilience of ecosystems of arable lands.

Keywords: cultivation systems, CO_2-emission, soil structure and moisture, organic carbon, humus matter fractions

Introduction

Applying alternative soil cultivation methods based on the reduced disturbance of the soil more favourable conditions can be created in order to increase the organic matter content of the soil and the availability of moisture for the crops. Forgács and Czimbalmos (2008) established that the machinery and tools of the soil protective production technology are well applicable under the frequently extreme climatic conditions characteristic for the investigated area.

The carbon balance of terrestrial ecosystems can be changed markedly by the direct impact of human activities (Bolin, 1981). An increased concentration of C in the soil will accelerate microbial processes, as will warmer and moister soil (Davidson, 1994).

Lower energy consumption, low mechanical inputs, improved soil structure and soil porosity, adsorption capacity and appropriate water management are the advantages of the alternative tillage systems. Soil compaction rarely occurs because of the lower mechanical inputs. The use of heavy tools in conventional tillage significantly contributes to the formation of compact layers appearing near the soil surface (Birkás et al., 2002). Extreme soil load results in the degradation of the A-horizon, increased soil compaction, decreased porosity which all lead to the unfavourable water and heat balance of the soil, the decreased nutrient support ability and microbiological activity (Nyíri, 1997).

The volume and intensity of CO_2-emission is in close correlation to the structural state and organic content of the soil. Any disturbance by soil cultivation can partly mobilise the C-stock of the soil.

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The relationship between soil structure and soil organic matter dynamics is integral to the C sequestration capacity of agricultural soils. It is widely accepted that soil aggregates physically protect certain organic matter fractions, thus increase their residence time in soil (Beare et al., 1994; Golchin et al,. 1994). Different tillage systems affect the organic carbon content and humus status of the soil (Slepetiene and Slepetys, 2005).

Reducing human activities and intervention the soil as a resilient buffer system would return to its original state determined by the given ecological conditions.

Materials and methods

The CO_2-emission measurements and soil sampling were carried out at the Karcag Research Institute of University of Debrecen, CASE. The Institute has been dealing with soil cultivation experiment including conventional (CT) and reduced (RT) tillage on 15.8 hectares for 13 years. The soil type of the investigated plot is meadow chernozem solonetzic in the deeper layers, a soil type that is characteristic for the Trans-Tisza Region of Hungary.

The plots of this experiment provide good opportunity to measure the CO_2-emission from the soil. In situ CO_2-emission of soil was measured by means of an ANAGAS 98 infrared gas analyser. In order to measure CO_2-emission on a larger area without deep disturbance of the soil, a special metal frame was created with a matching bowl (Zsembeli et al., 2006). Soil moisture content (necessary for the evaluation of CO_2-emission results and soil compaction) was determined with gravimetric method. The extent of soil compaction was deduced from the penetration resistance measured with a "3T SYSTEM" electronic soil layer indicator.

The organic carbon content of the samples was determined by the Tyurin method. Fractions of the humic substances and humus quality were examined according to Kononova and Hargitai. The "mobile humic matter" was extracted with 0.1 M NaOH and separated by acidifation into fulvic and humic acid (Búzás, 1988). The bounded fraction was obtained by extraction with NaF solution (Hargitai, 1957). Extinction of the different fractions were measured in the 360-920 wavelength range.

Results and discussion

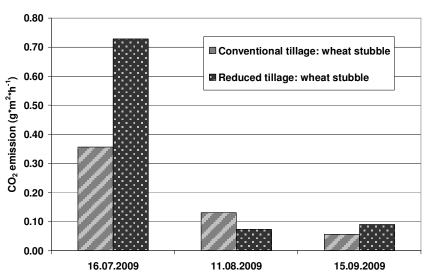

Figure 1. CO_2-emission values in the soil tillage experiment in 2009

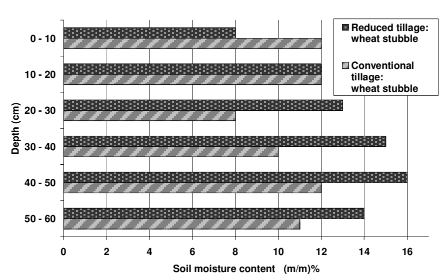

Figure 2. Soil moisture content values in august 2009

Figure 1. shows the CO_2-emission values determined for the treatments of the soil tillage experiment in 2009. Three measurement dates are indicated, the first measurement was done after harvest and before the relevant tillage application. In July higher emission was detected in the reduce tillage system. In August the measurements were done after the tillage application. This period was very dry (*Figure 2.*) that could explain the very low CO_2-emission values. The meteorological conditions and so the emission levels were similar in September. Of course the shortness of the investigated period can not let us to conclude general conclusions, but there is no doubt that we gained remarkable results about the correlation between the soil status and the CO_2-emission from the soil. Experimental data provided information about the length of the time period when CO_2 emission increasing effects of soil cultivation are observable.

Table 1. Penetration resistance and soil moisture content in August 2009

Depth (cm)	Penetration resistance (MPa)		Soil moisture (m/m%)	
	RT	CT	RT	CT
0 - 10	2.0	1.9	8	12
10 - 20	2.8	3.2	12	12
20 - 30	3.1	3.7	13	8

Due to the extremely low soil moisture content the penetration resistance values were rather elevated. We found a significant difference between the tillage systems measuring penetration resistance in the 10-20 cm and 20-30 cm layers (Table 1.). The high values in the case of the conventional tillage refer to a compact soil structure, where the water transport and airing process are hindered.
At the date of the first emission measurement and penetration resistance examinations we took average soil samples from the 0-20 cm layer for the investigations on the organic carbon content and humus quality (i.e. fractional composition) of the soil.
Table 2. shows the organic carbon content of the soil samples and of the isolated fractions of humic matter.

Table 2. Organic carbon content of the different fractions

		CT	RT
		(m/m)%	(m/m)%
Total Organic Carbon		2.18	2.11
Mobile fraction (NaOH-soluble)	Total	**0.34**	**0.23**
	Humic acid	0.12	0.11
	Fulvic acid	0.04	0.06
Bounded fraction (NaF-soluble)		**0.26**	**0.29**

There was no significant difference between the total amount of organic carbon of the soils cultivated with different tillage systems. However the analysis of mobile and carbon stable (calcium-bounded) fractions showed that reduced tillage resulted in an increase in the stable humus forms.
Figure 3. shows that the ratio of extinction of the NaF and NaOH extracts (humus stability number) at different wave-length was significantly higher in the case of the reduced cultivation confirming the information obtained by organic carbon content measurements.

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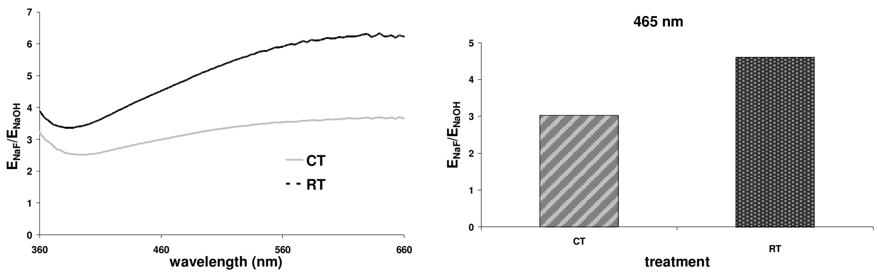

Figure 3. Effect of cultivation on the Ext. NaF/Ext. NaOH ratio of humic acids

Conclusions

On the base of our results it can be concluded that the application of reduced cultivation supported the soil in approaching its natural equilibrium state that manifested in the investigated factors of the soil carbon cycle. Under favourable soil moisture conditions microbiological activity (indicated by the level of CO_2-emission) was increased where reduced tillage system was applied. Analysing the amount and fractional composition of the soil organic matters we found that reduced tillage produced an increased ratio of the stabile humic materials that bound to the soil minerals taking part in the formation of a more favourable soil structure. These data can characterise the resilience of ecosystems of arable lands. These results motivate us to continue our investigations.

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ENVIRONMENTAL VULNERABILITY AS A TOOL IN PLANNING FOR SUSTAINABLE AGRICULTURAL LANDSCAPES

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Abstract: Agriculture is the most important land use in Europe and because of it plays a central role in the quality of the wider environment. Whilst European landscapes have experienced rapid changes in agricultural land use and have changed considerably in recent times, further changes are likely as a result of the influences of policy reform, socio-economics and climate change. Therefore the need for sustainability in agriculture is putting a high demand on methodologies in planning of agricultural uses that will ensure it. One of the methodologies developed within the landscape planning area offers environmental vulnerability as tool to assess sustainability of the proposed land use at planning stage. This paper presents a vulnerability approach for integration of environmental protection issues within the planning process. The methodology of vulnerability modelling is presented in a case study of agricultural land-use within the planning process for a rural area of continental Croatia. The vulnerability models were developed for specific environmental qualities that will be exposed to impacts by a proposed agricultural activity The results of the paper presented indicate spatial distribution of such environmental protection interests in space. Finally, the models are acknowledged as relevant tool in the planning process that equally assesses developmental and protection interests in landscape.

Keywords: planning, sustainability, agriculture, landscape, environment, vulnerability

Introduction

Agriculture has shaped many European landscapes over centuries, and now uses 53% of the European land surface, as recorded by CORINE land cover map. This has given rise to unique semi-natural environments with a rich variety of habitats and species dependent on the continuation of farming. The way they will be managed has profound impacts on the quality of the wider environment.

European landscapes have experienced rapid changes in agricultural land use throughout the second half of the twentieth century, arising from developments in technology and management, driven by socio-economic and political forces supported by the Common Agricultural Policy (CAP) (Rounsevell et al., 2003.). Those changes reflect economic causes, policy measures as well as spatial planning objectives and show a wide range of impacts, including biophysical and socio-economic changes and feedbacks between land use and its drivers (Busch, 2006.).

Despite the variety of definitions, or perhaps because of it, sustainable development is now the dominant paradigm guiding development planning. Given the importance of agriculture as the ultimate provider of food, fibre and shelter for the human population, no sector has a greater role in moving towards development that is sustainable.

Materials and methods

Many have agreed on the requirements of sustainable agriculture, such as food sufficiency, environmental stewardship, socio-economic viability and equity but operational definitions and methodologies for agricultural policy making and land use planning are more difficult to determine. Two approaches could be recognised: (1)

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sustainability indicators valuable for assessing the sustainability of agricultural systems, (2) assessment of agricultural sustainability at the planning stage (new agricultural land use and practices options) (Smith and McDonald, 1998).

Good philosophical basis for defining sustainable agriculture is generally accepted approach in defining sustainability - a mosaic approach (ecological, economic and social sustainability). 'Environmental stewardship' as one of four dominant paradigms in interpreting sustainability (Smith and McDonald, 1998), defined in terms of controlling environmental damage, is the one that could be achieved through planning procedures. The need to ensure that agricultural development is sustainable creates a significant challenge for land use planners.

Present practice in assessing sustainability in agricultural land use planning offer tools as land suitability studies (Dent, 1991; Koscak Miocic-Stosic et.al., 2008.), environmental impact assessment (EIA) and its derivate, strategic environmental assessment (SEA). Whilst EIA is a project level methodology for identifying, predicting and evaluating the environmental consequences of development proposals SEA is targeted at higher level proposal such as a policies, programs and plans (Therivel, 1993). They are both dealing with the results of planning (specific locations and plans) and none of them is used within the planning process.

Environmental approach in planning as determined by Marusic in 1993. (Mlakar, 2009) start with basic assumption that protection of the values and resources is effectively realised thought spatial planning and management by proper activity placement. The reduction of a negative impact by diverse vulnerability analyses appoints environmental protection process as a part of the spatial planning process.

We superimpose to the methodologies (Smith and McDonald, 1998) that interpret sustainability as ability of the system to continue (in response to stress) - sensitivity and resilience based concepts; vulnerability based concept that is classified as a multi-dimensional assessment used *ex ante,* within the planning process.

The concept generally expresses how exposed environments are to be changed by external impacts or "degree of sensitivity to environmental change by external impacts" (Kværner, 2006). The term is actually used to designate a form of spatially oriented evaluation model within the land suitability analyses as defined by Hopkins (1977), and earlier by McHarg (1969) and represent procedure in term of applied analytical technique (Marusic et al, 2004). Evaluation can be defined as analysis of possibilities for achieving a environmental protection goal. Vulnerability models are used to discern more sensitive spaces, in which particular programmes or development shouldn't occur.

The methodology was tested in the pilot zone - the Zumberak area, rural area situated at the north-western part of the Croatia. It has been designated in 1999. As a protected area due to its distinctive cultural landscape features formed by past agricultural activities.

Landscape qualities or vulnerability of the area for development activity tested the interest for the intensive vineyard production in particular. The vulnerability analysis was performed using geoinformation (GIS) software package ProVal® whereas homogeneous spatial unit for analyses was 30m x 30m. The data base consisted of spatial data on land cover and land use.

The concept of vulnerability assessment comprised the value system of three different conservational requests: (1) protection of the naturalness and/or authenticity of the space (2) protection of natural resources and (3) protection of unpolluted human habitat.

Vulnerability analysis means the potential impact of an intervention on the environment. The assessment of the future situations requires the use of models meaning that vulnerability analysis is modelling of impacts and the calculations of the model are the results of the analysis. Commonly used tool - two dimensional matrixes (Glasson et.al, 1994.) – was used for identification of the needed vulnerability analysis and respective results - graphic representations, i.e. vulnerability maps with 5 levels of vulnerability/possible impact. Total vulnerability was assessed by integrating all three models into integrated vulnerability map. Data on best agricultural land was tested by superimposing vulnerability maps which allowed as to define agricultural land areas with different environmental sustainability as a basis for decision on the agricultural land use.

Results and discussion

The results can be interpreted first as three maps representing environmental conservation efforts of a specific environmental quality in a form of spatial distribution of the vulnerability areas to the proposed agricultural activity. On a second level environmental vulnerability maps have been joined using fuzzy logic rule max into one evaluation model, Figure.1.

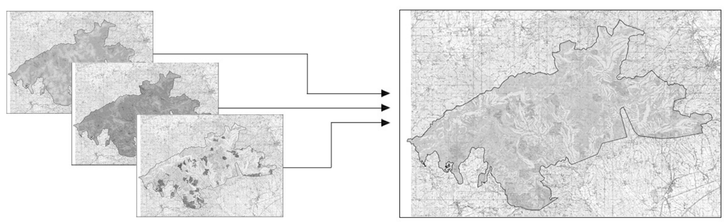

Figure 1. Spatial representation of vulnerability due to vineyard production: green – natural qualities, red – natural resource qualities, blue – human habitat qualities, orange - integrated vulnerability: darker areas are more vulnerable

Superimposing the integral vulnerability map over the best agricultural land map, we have identified 5 vulnerability classes in which, due to environmental protection values, vineyard production should not, or is more or less acceptable to occur, Figure.2.

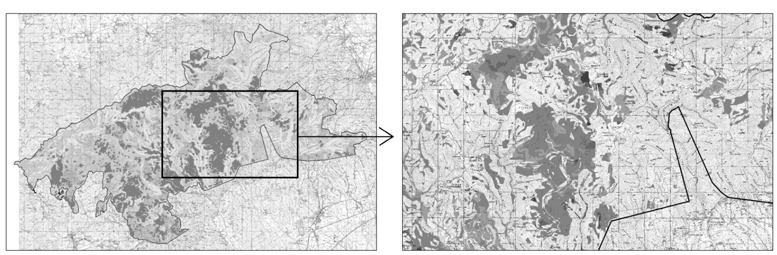

Figure 2. Best agricultural land (purple) tested with environmental vulnerability (orange): darker areas are less acceptable

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Conclusions

The basic hypothesis that underpins this work showed that environmental vulnerability analysis can be used as a tool in planning - searching for more sustainable decisions in agricultural land use. Testing the performance of the model against proposed best agricultural land suggest that the approach has the capacity to be used for assessment of future changes in agricultural land use.

The vulnerability analysis enables conception of more and less sensitive areas and also regarding the area's separate components thus allowing objective assessment of environmental impacts. It also upgrades the sector guidelines by preparing conceptually clearer directions for the protection and development of individual environmental components. Vulnerability analysis may serve as an appropriate optimization tool for placing interventions and activities. At the same time the environmental assessment phase enables more objective decision on the acceptability of the activity in a specific area. The impact on the 'affected' area thus can be compared to the impacts of other potential areas for intervention allocation. Therefore, intervention must be assessed in the context of a strategic conservation of an environmental component or the environment as a whole. Methodologically, the proposed environmentally protective mechanism is introduced into beginning phase of planning, allowing least degradation of the environment.

Acknowledgements

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EVALUATION OF ANTHROPOGENIC IMPACT ON SOIL PHYSICAL CONDITION IN DIFFERENT PRODUCTION SITES OF HUNGARY

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Abstract: Increasing environmental stresses have affected soils conditions. On one hand the harmful effects damage the soil conditions according to the resilience of agro-ecosystems; on the other hand, the damaged soil itself also has a negative impact on other elements of the agro-ecosystems. The aim of our study was to evaluate of anthropogenic impact on soil physical condition using penetrometer in different production sites of Hungary. Our results have shown that the conventional tillage methods in Hungary are usually followed by soil degradation. Soil compaction caused by human activities is on the one hand the result of cultivation and is detectable under the depth of tillage along the path of the cultivator instruments; on the other hand it is the result of trampling which is caused by agricultural machinery traffic on the soil surface. By applying conventional tillage methods the intensity of factors causing soil degradation exceeded the speed of soil regeneration. Land users must support the regeneration of soil conditions by choosing a tillage system conforming to the soil conditions and reducing factors causing soil degradation.

Keywords: conventional tillage, penetration resistance, soil compaction, anthropogenic impact

Introduction

In the past century increasing environmental stresses have affected soils conditions. On one hand the harmful effects damage the soil conditions according to the resilience of agro-ecosystems; on the other hand, the damaged soil itself also has a negative impact on other elements of the agro-ecosystems. To a certain extent soil filters the negative environmental effects, but in many cases the rate of amelioration is behind the rate of degradation. Both natural factors and human activities can cause degradation of the soil's physical condition and soil compaction, but mechanization and non-proper soil cultivation are the primary reasons for these. Soil cultivation that is suited to the natural as well as to the cultivating conditions makes it possible to satisfy the needs of the cultivated plant and serve the interest of soil protection (Várallyay, 1996; Birkás, 2002; Birkás, 2004; Gyuricza et al., 2007).

Materials and methods

We carried out the examinations in a multifactorial long-term tillage experiment on the Látókép Experimental Station and in different production sites of Hungary. Látókép Experimental Station of the Centre of Agricultural Sciences, Debrecen University located in the eastern part of the Great Hungarian Plain (calcareous chernozem soil, Site 1). The investigations were part of a multi-factorial (irrigation, tillage, fertilization, plant density) long-term field experiment. Field experiments was carried out on meadow soil at Gyomaendrőd (Site 2), at Kisújszállás (Site 3) and at Kunszentmárton (Site 8), and Karcag (Site 4) on meadow chernozem soil at Túrkeve (Site 5), on chernozem

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meadow soil at Nádudvar (Site 6), on brown forest soil at Tard (Site7). We carried out the penetrometer measurements on the investigate sites on the stubble-field following the harvesting of wheat and rape with high replication (Table 1). The penetrometer measures the pressing- and shearing strength of the soil. During the penetration of the probe cone the registered soil resistance values allow the determination of the layers with different strength within the soil profile. The aim of the study is to evaluate of anthropogenic impact on soil physical condition in different production sites of Hungary.

Table 1. Characteristics of the soil profile at the experimental sites

Name	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8
pH-KCl	5.6	6.39	6.65	7.01	6.88	7.19	4.51	7.09
Plasticity index according to Arany (A_k)	42	67	56	52	55	43	40	50
$CaCO_3$ m m^{-1}	<0.1	<0.1	1.1	2.2	1.3	0.4	<0.1	<0.1
Humus %	2.72	2.73	3.81	2.45	2.46	3.03	2.7	2.62
P_2O_5 mg kg^{-1}	133	113	95	202	151	307	89	73
K_2O mg kg^{-1}	240	279	346	534	271	398	252	385

Results and discussion

In spite of the available new methods, the proportion of conventional tillage methods is high in Hungary, however degradation and compaction of soil structure is a concomitant effect of conventional, intensive tillage caused by actions involving frequent soil turning regardless of the soil conditions. Soil compaction caused by improper tillage was detectable in almost every sites involved in the analysis. As a result of tillage carried out on wet soil and in the same depth repeatedly (in multiple years) as well as the lack of deep tillage (deep loosening) 1-2 compacted layers have been formed in the analysed soil profiles (Figure 1). Soil compaction which developed at the investigated sites on the one hand the result of tillage on the other hand it is the result of trampling (Site 4). It is hard to distinguish these two reasons of degradation, they often emerge together. (Site 1; Site 3; Site 6; Site 7; Site 8). Despite the difference in the depth of primarily tillage at Site 1, the almost identical penetration resistance profile measured beneath 35 cm proves that the soil compacting powers of the tools are limited to the 5-10 cm layer. In the lower layer, the compaction forces of the machinery's wheels are of primary importance. Compaction caused by trampling is caused by machinery traffic in the soil subsurface.

Soil compaction caused by cultivation is detectable under the depth of tillage along the depth of the tillage equipment. The penetration resistance was growing along with depth. The highest penetration resistance (Te_{max}) was measured in the compacted layer (tillage-pan layer) that evolved owing to the several years of tillage of the same depth.

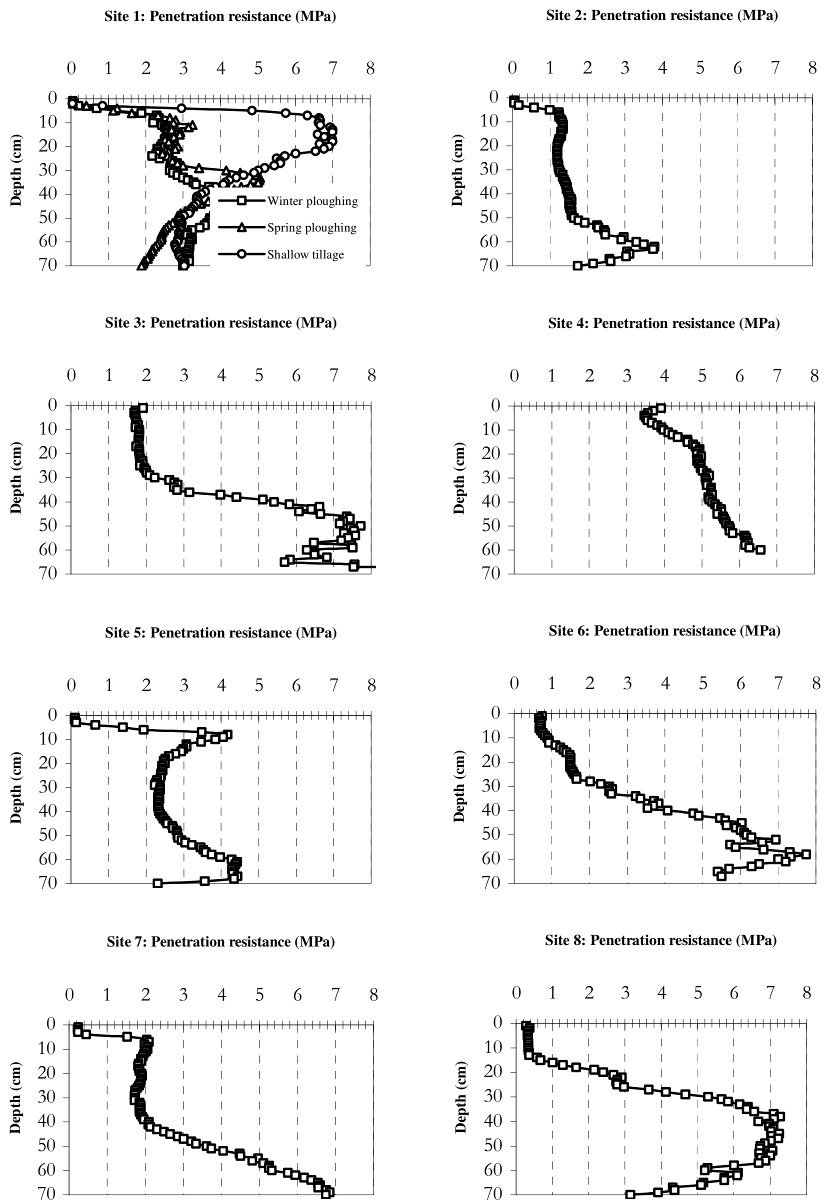

Figure 1. Anthropogenic impact on soil physical condition as shown in penetrometer readings.

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Plough-pan compaction is indicated in the soil profile by the layers of highest soil resistance depending on the depth of ploughing (Site 1; Site 3; Site 6; Site 8). Disk-pan compaction – as a result of shallow tillage – is formed close to the surface, the depth of 5-15 cm depending on the depth of tillage (Site 1; Site 5).

Conclusions

Soil compaction was detectable in almost every conventional tillage plot involved in the analysis. Long-term conventional tillage management without deep tillage causes compaction on the investigated soil types. Soil compaction caused by anthropogenic impact is on one hand the result of tillage and is detectable under the depth of tillage; on the other hand it is the result of trampling which is caused by agricultural machinery traffic on the soil surface. By applying conventional tillage methods the intensity of factors causing soil degradation exceeded the speed of soil regeneration. Land users must support the regeneration of soil conditions – one of our most important natural resources – by choosing a tillage systems conforming to the soil conditions and reducing factors causing soil degradation.

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EVALUATION OF SEWAGE SLUDGE BASED COMPOSTING TECHNOLOGY TO INCREASE SOIL BUFFERING CAPACITY

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Abstract: Composting is not only a waste-disposal procedure. Its aim is - through microbial processes - produce a final product, which can be used as a fertilizer or a soil-conditioner in plant production. The given final product, the compost because of its characteristics (complex-composing ability, mould content, acid-base balance, etc.) assists the increasing of soil-buffering capacity and soil quality-conservation. The correct selection of raw materials basically affects the mechanism of the composting process. The sludge that produced during sewage treatment is highly applicable for composting because of its high organic matter content. The basic condition of sludge utilization during composting is the strict source control and ensuring the quality exigencies because the use of sludge is limited by its high heavy metal content. The used bulking agents also influence the effectiveness of the composting process and the quality of the final product. The aim of our research is establishing an effective compost mixing rate, which can increase the effect of composts on soil buffering capacity with minimal heavy metal input. During our analyses we examined the changes of compost characteristics according to the mixing rate and the effects of composts with different mixing rates on soil-stability.

Keywords: sewage sludge, mixing rate, heavy metal, potassium, calcium

Introduction

The depositing directive of the European Union orders the diminishing of the amount of the deposited organic wastes – like sewage sludge. This directive accelerated the spread and improvement of the composting technologies. With the eastern expansion of the EU the market of by-products of waste treatment technologies also expanded. There is a large demand for high-class quality organic fertilizers.

Sewage sludge is a great raw material for composting because its advantage characteristics do not change during the degradation (Tamás, 1998.), but the utilization may be limited by its high heavy metal content (Simon et al., 2000; Kovács and Füleky, 2007.).

The efficiency of composting is mainly determined by the rate and quality of the added bulking agents. The mostly used bulking agents during sewage sludge composting are straw, wood clipping, grass clipping and sawdust (Marek et al., 2003; Eftoda and McCartney, 2004.).

Next to the rate of bulking agents the composting process is affected by several other physical, chemical and biological parameters. These parameters are particle size distribution, homogeneity, moisture content, organic matter content, oxygen-balance, pH and C/N ratio (Ebstein, 1996; Liang et al., 2003; Ponsá et al., 2009.).

The given final product, the compost because of its characteristics (complex-composing ability, mould content, acid-base balance, etc.) assists the increasing of soil-buffering capacity and soil quality-conservation (Lu et al., 2009.).

The optimal degradation process is based on the selection of the raw materials (Cekmecelioglu et al., 2005.).

The degradation mechanism is affected by the mixing rate of the raw materials and the pre-treatment technologies (Smith and Hughes, 2004; Lu et al., 2009.).

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The metal content and other characteristics of the bulking agents also affect the quality of the final product. The calcium content influences the quality of the produced humus-compounds.
The aim of this paper is the examination of how the different mixing rates affect the quality of the final product and the soil buffering capacity.

Materials and methods

During our research we used sewage sludge and rape straw as raw materials to establish the different compost mixtures. With the utilization of the raw materials we made a mixing series, in which we increased the rate of the rape-straw with 10% of the whole volume. The mixing was fulfilled 2 times with 3 times repetition (6 series in total). The mixing series is shown on figure 1.

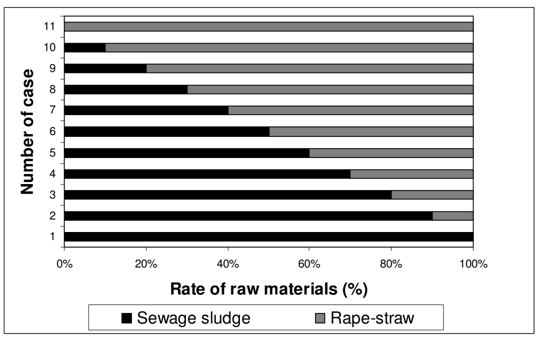

Figure 1: The set mixing series

During our research instead of the rate of mass we used the rate of volume because in practice the mixing is based on the rate of volume.
The element content was determined with second generation FPXRF NITON XLt 700 equipment, with x-ray fluorescence spectrometry. The equipment determines the element content by the characteristic x-ray radiation of the elements with a super-sensitive BASP x-ray-detector (Shefsky, 1997.).
The FPXRF enables a full-range element determination with the consideration of matrix effects which are corrected with Compton-normalization (Nagy et al., 2006.).
The measurement was made with agglomerated samples covered with thin foil during a determined time (1 minute). Each measurement was repeated 3 times and the comparisons were based on the average of the results (Kalnicky and Singhvi, 2001.).

Results and discussion

During our research we examined how the element content of the mixture changes according to the increase the rate of rape straw. From the heavy metals only the copper was provable, the used sewage sludge and rape straw did not contain any other potentially hazardous heavy metal. From the macro- and mezzo-elements we examined the amount of calcium and potassium.

We used regression analysis to examine the changes of the amount of the three elements depending on the mixing rate. In each case the value of r^2 was between 0.97 and 0.98, which means the value of the elements changes collinearly with the increase of the rate of rape straw. In the case of copper and calcium the increase of straw caused decrement, meanwhile the amount of potassium increased with the utilization of rape straw.

During our experiments we were looking for the exact mixing rate that fulfils the demands of 36/2006 (V.18.) regulation (by the Hungarian Ministry of Agriculture and Rural Development) which contains the requirements of good-quality compost products. To handle the three elements together we introduced a rate-index. The rate-index is the quotient of the measured value (in %) and the required limitation level (in %) which is determined by the regulation. The changes of the given rate-indexes and the limit values are shown on figure 2.

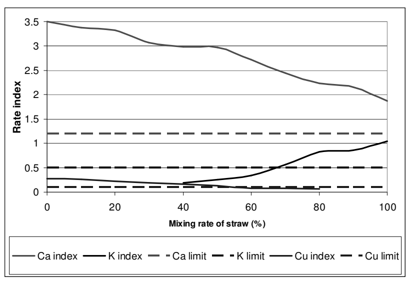

Figure 2. Changes of rate index (limitation value %/measured value%) according to the mixing rate

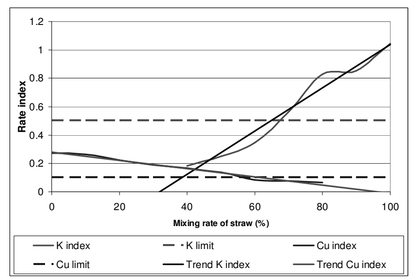

Figure 3. Changes of K and Cu rate index (limitation value %/measured value%) according to the mixing rate

The regulation sets bottom limit value for potassium and calcium, but upper boundary for copper. Figure 2 shows that the rate-index of calcium is larger than the limit value independently of the mixing rate. That means the calcium content of the mixture fulfils the requirements of the regulation. We have a different situation in the case of copper and potassium. Because of this it is feasible to handle these two parameters together (figure 3.).

Form the equation of the lines of copper and potassium we can calculate the minimal rate of rape straw that fulfils the requirements of the regulation, where the line of rate index crosses the line of the limit value. Calculating from the equation of the line of potassium we got 64%. That means the minimal rate of straw should be 64% to ensure the minimal potassium content, which was set by the regulation.

Against this to avoid the upper boundary limit of copper we need minimum 62% straw in the mixture. To fulfil both requirements we should use 64% straw and 36% sewage sludge.

Nevertheless, the degradation of the given compost mixture is influenced by the moisture content, C/N ratio and other parameters. The use of large amount of rape straw causes destruction of the structure, the mixture will be loose, collapses easily and by this cannot be used effectively as a fertilizer. Additionally the humus producing ability

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of the sewage sludge also decreases. With the utilization of the given mixing rate we only reach the required amount of potassium, so it is better to use the mixing rate that we got for copper and supply the potassium-need with zeolit.

Conclusions

From the examined mixing rates the 40% sewage sludge and 60% rape straw ratio fulfilled the requirement of the regulation. The compost, which is set with this mixing rate, has an acceptable structure; it is not too wet and not too loose. The large calcium content assists the process of humification. It assists the puffer-capacity of the soil with its complex-composing ability, and cation-change ability. The potassium-content needs supplement, which can be solved economically with zeolit at the beginning of the degradation. During the determination of the mixing rate we need to take into consideration the copper-content of the mixture, because the large amount of copper not only decrease the quality of the compost but also negatively affected the characteristics of the soil. The given compost-material can be effectively used on sandy-soils.

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EVALUATION OF THE PRODUCTION FACTORS AFFECTING CROP GROWTH USING CONJOINT ANALYSIS

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Abstract: Conjoint analysis has been an efficient tool for marketing research since the 70's. It is used to show customer habits and expectations concerning products and services on a uniform scale, as well as to evaluate them. As far as we are aware, this method has not been used in agronomic research projects, but the production procedure can be referred to as a product or service which can be characterised by the combination of production factors.

The aim of our current study is to determine the most favourable production method and the main production factors by using experimental data. The data involved in the research originate from 18 different monoculture production methods of a long term multifactoral maize experiment established on calcareous chernozem soil with loam texture at the Látókép experimental site of the University of Debrecen, Centre of Agricultural Sciences and Engineering between 1990-2009. The examined production factors are irrigation, cultivation and fertilisation. We evaluated and scored the success of the different production methods on the basis of maize yield.

Keywords: conjoint analysis, statistical method, crop production, agrotechnical factors

Introduction

Conjoint analysis has been an efficient tool for marketing research since the 70's. It is used to show customer habits and expectations concerning products and services on a uniform scale, as well as to evaluate them (Lehota, 2001).

As far as we are aware, this method has not been used in agronomic research projects, but the production procedure can be referred to as a product or service which can be characterised by the combination of production factors. The method uses a "full concept" approach which means that crop growth depends on all characteristics of the production method together.

The aim of our current study is to determine the most favourable production method and the main production factors by using experimental data.

Materials and methods

During the conjoint analysis, we assigned values to the factor levels by regression analysis so that the yield data belonging to the combinations of the production factors fit the measured data of each year the best possible way. During the regression, we minimised the sum of squares. We verified the accuracy of the established model by the correlation between the estimated and measured preferences. By using the model, we determined the most important production factor, the relative importance of the factors and the utility of the factoral levels.

We carried out our research on calcareous chernozem soil with loam texture at the Látókép experimental site of the University of Debrecen, Centre of Agricultural Sciences and Engineering (latitudinal degree: 47°56', longitudinal degree: 21°44'). The preceding crop was maize, the applied cultivation method was winter ploughing, spring ploughing and disk cultivation, the fertilisation treatments were: N_0: non-fertilised;

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N_120: 120 kg ha^{-1} N; 90 kg ha^{-1} P_2O_5; 106 kg ha^{-1} K_2O; N_240:240 kg ha^{-1} N; 180 kg ha^{-1} P_2O_5; 212 kg ha^{-1} K_2O (Nagy, 2008).

The data involved in the research originate from 18 different production methods between 1990-2009. These data constitute the PLAN files of the conjoint analysis. When judging the production methods, we evaluated the examined period jointly, but this method also makes it possible to separate crop years (drought, average, wet).

We carried out the evaluation using SPSS 13.0 (SPSS, 2004). In this software, conjoint analysis cannot be accessed via a dialogue panel, therefore, we prepared a short program which can be run from the syntax editor window. The program connects the plan and data file and it defines the factor and preference characteristics. When we established the conjoint model, we considered irrigation to be a category factor and we assumed that irrigation increases maize yield (more discrete). We also set cultivation to be a category factor, but we did not establish a hypothesis for the correlation between cultivation and yield (discrete). We considered fertilisation to be an ideal factor. The highest yield is the ideal level and yield decreases when we go up or down from this level. We evaluated and scored the success of the different production methods on the basis of maize yield per year, therefore, we set yield to be the subject factor of the model, constituting the DATA file of the conjoint analysis.

Results and discussion

We evaluated the accuracy of the model by the correlation coefficients between the estimated and measured preferences (Pearson's R = 0.961, Sign. = 0.00001. Kendall's tau = 0.895, Sign. = 0.00001). Values close to 1 show a very close correlation and they verify the accuracy of the model. The measured significance values are lower than 0.05, therefore, the correlation can be considered real.

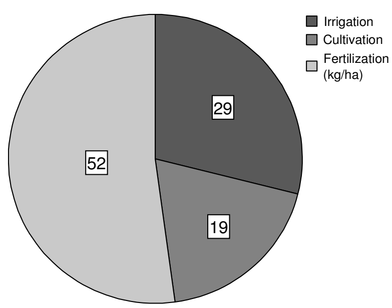

Figure 1. Summary averaged importance, Debrecen, 1990-2009.

During the examined period, the most important production factor is nutrient replenishment, which influenced the success of the methods by 52% (Figure 1). The second main factor is irrigation (29%). As fertilisation was more important than irrigation among the climatic and soil conditions of the experiment site, irrigation development can only be considered after professional nutrient replenishment is carried out. Cultivation influenced yield by 19%. This extent is mainly due to the chernozem

soil which has a good structure and it is easy to cultivate it. Also, the different cultivation methods modify crop yields to a small extent.
We considered the utility of fertilisation to be an ideal factor, therefore, we obtained the parameters of the quadratic function, as well as the optimal levels of fertilisation. Here, the optimal level is the fertiliser dose belonging to the maximum maize yield (Figure 2).

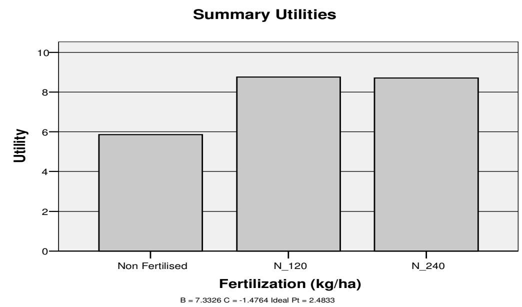

Figure 2. Utility of fertilisation, Debrecen, 1990-2009.

The optimal level is the 2.4833 level of fertilisation which is equal to 178 kg N ha^{-1} in the average of treatments.

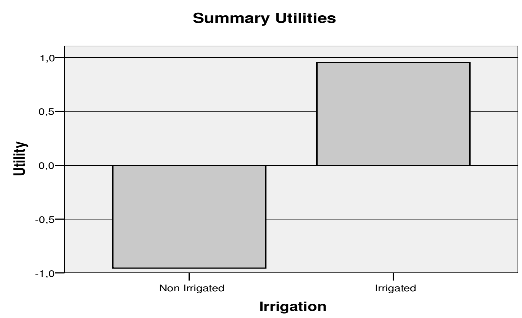

Figure 3. Utility of irrigation, Debrecen, 1990-2009.

As there are two irrigation treatments, the conjoint analysis provides the effects symmetrically, therefore, the utility of irrigation will be the reciprocal of the non-irrigated treatment. The index of utility was the quantity of maize yield, therefore, the effects measured in t ha^{-1} can be seen on the vertical axis (Figure 3). Irrigation increased the average yield of the experiment by 956 kg ha^{-1} and it decreased by the same amount in the non-irrigated treatment. On average, the difference between the irrigated and non-irrigated treatments were 1912 kg ha^{-1}.
Among the applied cultivation methods, autumn ploughing was the most useful one, as it clearly caused higher yield in the examined period – increasing the average yield by 558 kg ha^{-1} (Figure 4). The other two cultivation methods (spring ploughing, disk

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cultivation) had negative effects on average yield. The highest yield drop (-384 kg ha^{-1}) was observed in the case of disk cultivation.

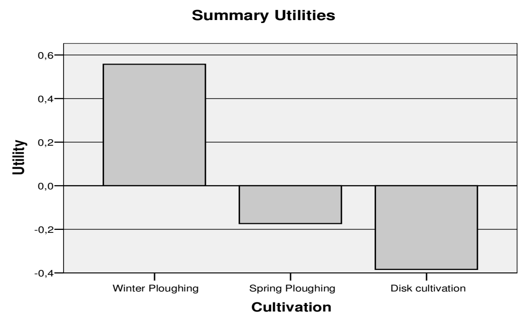

Figure 4. Utility of cultivation, Debrecen, 1990-2009.

Based on the results above, we can establish that the most successful production method from the aspect of maize production is to apply 178 kg N active ingredient per hectare under irrigated conditions in the case of autumn ploughing. Any deviation from this combination decreased the yield of maize between 1990-2009.

Conclusions

Conjoint analysis has not been used in agronomic research projects or to analyse production factors. Our examinations show that the analysis could be an alternative method besides the widely used variance analysis. In conjoint analysis, the examined factors can simultaneously be of categorical, ordinal and scale types, whereas the dependent variable can be scale and ordinal. This method is simple, robust, it does not have so strict applicability requirements as variance analysis, therefore, it could be used in a wider range. Nevertheless, it can only be used to analyse the main effects, interactions can only be examined in an indirect way. During the analysis carried out in the long-term experiment, we obtained a professionally correct result, therefore, we consider this method to be suitable to evaluate multifactoral long-term experiments and other field experiments.

Acknowledgements

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EVIDENCES OF ACID-BASE BUFFER CAPACITY CHANGES OF A CHERNOZEM SOIL IN A FIELD ECOSYSTEM

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Abstract: Tolerance of soils to acidifying effects is determined by different acid-base buffer systems existing in soils. These buffer systems work in different pH intervals and determine a titration curve characteristic to the resilience of the given soil in case of soil acidification. Sensitivity of soils to the acidification and their resilience can change by time according to the actual buffer capacity. The pH changes of soil of plots treated with different artificial fertilizer doses and acidifying effects of the applied fertilizers were examined in the National Uniformed Long-term Fertilization Experiments established on meadow chernozem soil at Karcag in 1967. Experimental data of a 25-year-long period were processed in this paper. At the beginning of the trial period the soil contained some carbonate which could prevent the soil from the decrease of pH values. Results proved that the tested soil had a period when it was very sensitive to the acidifying effects of the applied fertilizers. Hence, very big pH changes and no resilience of the soil were observable that time. This period started at the time when the soil was out of carbonate content and it lasted until the considerable acidification of the soil. When the soil was highly acidic other buffer systems started working which prevented the soil from the further acidification and provided resilience to the soil again on a lower pH level.

Keywords: soil acidification, acidifying effects of fertilization, sensitivity of soils to acidification, long-term fertilization experiment, acid-base buffer capacity

Introduction

Accurate examinations were carried out by Murányi and Rédly (1986, 1987) with the purpose of establishment of pH changes of different soil samples representing the main soil types of Hungary. On the base of features of titration curves three groups of soils were distinguished according to their sensitivity to acidifying effects as follows:

1. Calcareous soils: The pH decreases happen in the upper interval of buffer curves and they can be characterized by lines of slight slope. The buffer capacity of soil is determined by their carbonate content.
2. Strongly acidic peaty soils: The pH decreases happen in the lower interval of buffer curves and they can be characterized by lines of slight slope.
3. Non calcareous mineral soils: The pH changes happen in the inflexional section of the titration curve. The biggest pH decrease is caused by the initial acid load, further acid loads result in a pH decrease of decreasing degree.

Vozbuckaja (1968), Stefanovits (1977) and Murányi and Rédly (1986) established that the buffer capacity of soils is determined by a complex interaction of several soil properties. The classification system of soils mentioned above was further developed by Várallyay et al. (1989) with taking these interactions into consideration.
Unfortunately, the pH changes of soils are characterized by researchers on the base of differences of pH values determined in two measuring times, hence the time dynamics of the pH changes and the resilience of soils are not analyzed. Long-term fertilization experiments can provide accurate data for the examination of changes of pH value and acid-base buffer capacity (which can be an important parameter of resilience) of soils. Results of examination of pH changes of a meadow chernozem soil of the National

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Uniformed Log-Term Fertilization Experiment (NULTFE) at Karcag are summarized in this paper.

Materials and methods

The B17 variety of the NULTFE was established in 1967. The number of the fertilization treatments was twenty. After harvests of winter wheat grown in the 20th year of the experiment we used lime of 14.5 t ha^{-1} on the plots of I. and III. replications. After each crop rotation cycle soil samples were taken from each plot. The $pH_{(KCl)}$-, y_1-, AL-P_2O_5- and AL-K_2O values of the soil samples were determined. Beyond the obligatory soil sampling, we regularly took additional soil samples from each plot of B17 experiment with the purpose of determination of the above mentioned parameters between 1987 and 2004. We made the statistical processing of data by the methods of Manova, regression analysis and principal component analysis by Sváb (1973, 1979).

Results and discussion

Changes of average $pH_{(KCl)}$ values of control plots and plots treated with different N doses can be examined in Figure 1.

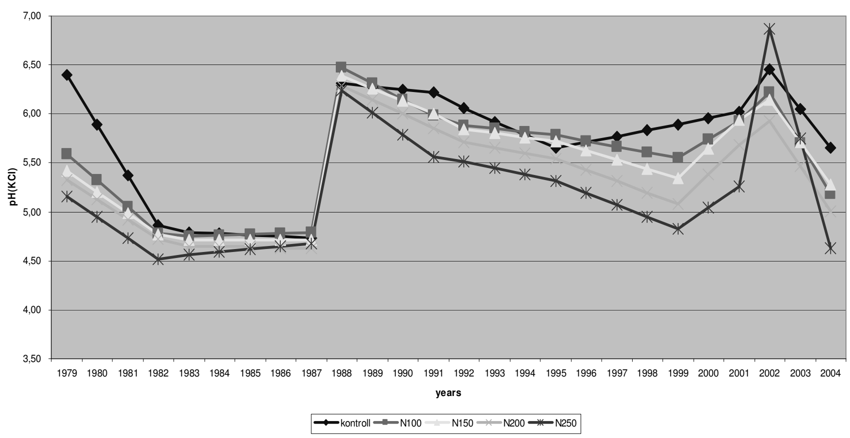

Figure 1. Changes of pH(KCl) values in different plots of the experiment between 1979 and 2004

On the base of the experimental data we established that there were significant differences among the $pH_{(KCl)}$ values of plots of different fertilizer treatments in 1979. While the $pH_{(KCl)}$ of control plots did not indicate considerable acidification, the regular N fertilization resulted in significant acidification during the first twelve years of the experiment. The soil was originally slightly calcareous which provided considerable acid-base buffer capacity for the soil. But the calcium-carbonate content of the soil was lost supposedly in the case of plots of N fertilization treatments before 1979. As a result of regular acid load, the soil of plots of 250 kg ha^{-1} N dose was the most acidic.

Between 1979 and 1982 the biggest $pH_{(KCl)}$ value was measurable in the soil of control plots, because their calcium-carbonate content was lost by that time too. The soil of control plots had no resilience in this period and the pH changes happened in the inflexional section of the titration curve. On the base of this founding we established that the fertilization is not the only reason of the acidification of the tested soil. There are many other acidifying effects in the ecosystem of arable lands like dry and wet sedimentation from the air, cation uptake of crops, cation leaching out processes, microbiological activity, etc. Results made us think that buffer capacity, hence resilience of soils of the different treatments differed from each other in this period.

As we can see, the rate of the $pH_{(KCl)}$ decrease gradually moderated between 1979 and 1987. The time dynamics of pH changes of plots could be characterized by hyperbolic regressions, but the number of the measurements was not sufficient to determine the regression exactly. Between 1982 and 1987 the acid-base status of the plots was very similar, and significant changes of $pH_{(KCl)}$ values were not observable. The probable reason of this is that another buffer system started working that time which provided a new resilience status for the soil.

The change of $pH_{(KCl)}$ of the soil due to liming in 1987 is shown in Figure 1. Due to liming $\Delta pH_{(KCl)} = 1.62$ was the increase of pH-value. After liming, a new cycle of acidification started as a result of continuous effects of acidifying factors.

We made principal component analysis in more steps to characterise the dynamics of the effects of different fertilizer doses on the $pH_{(KCl)}$ value of the soil. We established that in a less acidic state of the soil the change of $pH_{(KCl)}$ values of the plots had the closest relations with the initial $pH_{(KCl)}$ values, hence the higher were the initial $pH_{(KCl)}$ values, the higher was the change (decrease) of $pH_{(KCl)}$ values in the investigated period between 1979 and 1983 (Figure 2). After higher degree of acidification of the soil the further changes in $pH_{(KCl)}$ (between 1983 and 1987) had no correlation with fertilization (Figure 3).

In such a state the reaction of non-calcareous mineral soils to acidic impacts could be similar to of strongly acidic peaty soils.

The determinant role of initial pH-values in the change of pH-values and the acidifying effects of N-fertilization was observable again in the new cycle of soil acidification started after the liming in 1987.

To sum up our observations we established that the buffer capacity and the sensitivity of the tested soil to the acidification changed during the examined period. At the beginning of the experiment the soil was slightly calcareous with considerable buffer capacity. When the calcium-carbonate content of the soil was lost, the pH changes of high degree happened in the inflexional section of the titration curve and the soil had no resilience in the field of acid-base reactions. When the tested soil was in acidic state its reactions to acidifying impacts was similar to of strongly acidic peaty soils and it had considerable acid-base buffer capacity again.

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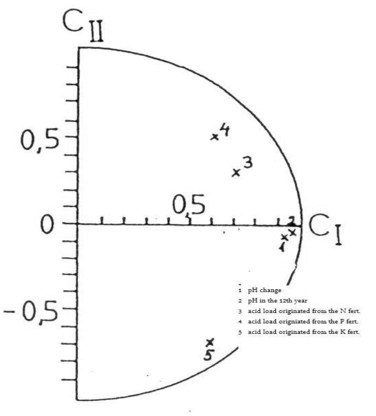

Figure 2.
Configuration of different parameters by the results of PCA carried out with the purpose of establishment of the pH changes taking place between the 1979 and 1983

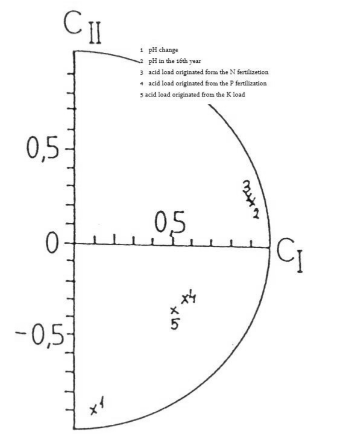

Figure 3.
Configuration of different parameters by the results of PCA carried out with the purpose of establishment of the pH changes taking place between 1983 and 1987

Conclusions

During the examination of pH changes of plots of the NULTFE at Karcag it was concluded that the acidity and the buffer capacity of the soil changed during the examined period. At the beginning of this period the soil contained some carbonate which could prevent the soil from the pH decrease. Results proved that the soil had a period when it was very sensitive to acidification. Hence, very big pH changes and no resilience of the soil were observable that time. This period started at the time when the soil was out of carbonate content and it lasted until the considerable acidification of the soil. When the soil was highly acidic other buffer systems prevented it from the further acidification and provided its resilience again on a lower pH level.

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IMPACTS OF LIMING ON MAIZE AND SOIL STATUS

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Abstract: In this study impact of liming on soil and maize status was shown. The field experiment with increasing rates of dolomite meal (56% CaO + 40% MgO) was started in spring of 2003 on soil of moderate fertility (pH in KCl = 4.30). Dolomite was applied together with ordinary fertilization (160 N + 150 P_2O_5+ 100 K_2O) in the amounts as follows (t ha^{-1}): *a* = control (0); *b* = a + 5 t ha^{-1} ; *c* = a + 10 t ha-1 and *d* = a + 15 t ha^{-1}. The trial was conducted in four blocks each of 369.6 m^2 area ordered in sequence of treatments from *a* to *d*. Each block was divided in four subplots of 92.4 m^2 which represented four replicates. Maize (the hybrid OsSK 552) was grown in the experiment for the 2003 and 2004 growing seasons. The ear-leaf of maize at flowering (July 26, 2004) and grain at maturity (October 15, 2004) were taken from each plot for chemical analysis. Plant status (the ear-leaf vs grain on dry matter basis) was as follows (lime 0 and 15 t ha^{-1}): % = 0.35 and 0.36 P vs 0.25 and 0.30 P, 2.10 and 1.59 K vs 0.33 and 0.37 K, 0.39 and 0.79 Mg vs 0.095 and 0.093 Mg; mg/kg = 170 and 154 Fe vs 20.6 and 20.7 Fe, 178 and 63 Mn vs 4.6 and 3.5 Mn, 71.2 and 26.9 Zn vs 20.1 and 16.5 Zn, 0.08 and 0.99 Mo vs 0.04 and 0.19 Mo. Liming had significant impact on increase of soil (NH_4-Acetate + EDTA extraction) -P, -Ca and -Mg mobile fraction, decrease of Mn- fraction as well, while available soil- K, -Fe- and -Zn- status differences were non-significant. The growing season 2004 was very favourable for maize growing because of adequate precipitation (June-August: 225 mm) and favourable air-temperatures (mean 19.7 ^{o}C) and under these conditions maize yields were high and similar for applied treatments (mean 12.41 t ha^{-1}).

Keywords: grain yield, maize, liming, soil characteristics

Introduction

Soil acidity is major constraint to crop production in many countries and is important in areas with low-input agriculture (Adams, 1984; Bergmann, 1992; Eswaran et al., 1997; Matsumoto, 2004; Mengel and Kirkby, 2001; Rengel et al., 2003¸ von Uexkull and Mutert, 1995) and in Croatia (Janekovic, 1971; Škorić et al., 1985). In general, liming of these soils is a usual recommendation for their improvement (Antunović, 2008; Grgić, 1991; Kovačević et al., 2006). Aim of this study was testing liming impacts on soil properties and nutritional status of maize in the 2004 growing season, while response of field crops (yields in the period 2003-2007 for rotation as follows: maize – maize – wheat – maize- barley) was shown by Rastija et al. (2010).

Material and methods

The field experiment: The experiment with increased rates of dolomite meal (56% CaO + 40% MgO) was conducted in spring (April 20) of 2003 in Badljevina (Pakrac municipality, Pozega-Slavonia County). Total four treatments of dolomite were applied together with ordinary fertilization (160 N + 150 P_2O_5+ 100 K_2O) as follows (t ha^{-1}): *a* = control (without dolomite); *b* = a + 5 t ha^{-1} ; *c* = a + 10 t ha^{-1} and *d* = a + 15 t ha^{-1}. The field trial was conducted in four blocks each of 369.6 m^2 area ordered in sequence of treatments from *a* to *d*. Each block was divided in four subplots of 92.4 m^2 which represented four replicates.

Sampling and analyses of plant and soil samples from the experimental field

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Soil sampling (depth 0-30 cm) from different fertilization treatments was made in October 5, 2004. Mobile fractions of elements in soil were extracted by the AL-method (Egner et al., 1960) and NH_4-Acetate + EDTA (Lakanen-Ervio, 1971). The ear-leaf at flowering (July 26, 2004: 25 leaves in the mean sample) and grain at maturity (October 20, 2004: five cobs in mean sample) were taken from each plot for chemical analysis. The total amounts of phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), iron (Fe), manganese (Mn) and zinc (Zn) in maize leaves and grain were determined using ICP after their microwave digestion by conc. HNO_3+H_2O_2. Plant and soil (only NH_4-Acetate + EDTA extraction) analyses were made by Jobin-Yvon Ultrace 238 ICP-OES spectrometer. Data obtained from the measurements and analyses were evaluated statistically by the analyses of variance and F-test, using limited significant difference (LSD) test for comparison of means.

Weather characteristics: The growing season 2004 was mainly favourable for maize growing with aspect of precipitation and temperature regimes. Precipitation for 5-month period (May-September) were in 2004 about 10% lower, and air-temperature for 0.5 ^oC lower in comparison with LTM (Table 1). In general, under middle and eastern European conditions, the lower maize yields are in close connection with water shortage and the higher air-temperatures, especially during two summer months of July and August (Kovačević et al., 2009; Maklenovic et al., 2009) and these findings are in accordance with Corn Belt (USA) experiences (Shaw, 1988).

Table 1. Weather characteristics for the 2004 maize growing season

	Daruvar * Weather Bureau: the growing season 2004 and long-term means (LTM) 1961-1990											
	Precipitation (mm)						Mean air-temperatures (^oC)					
	May	June	July	Aug.	Sept.	Total	May	June	July	Aug.	Sept	Mean
2004	55	97	65	63	103	*383*	14.2	18.7	20.4	20.2	14.9	*17.7*
LTM	86	99	86	91	65	*427*	15.7	18.9	20.6	19.7	16.1	*18.2*

* Daruvar = 10 km toward N-direction from the experimental field.

Results and discussion

Liming considerably influenced on increased of soil pH (pH in 1nKCl = 4.20 and 6.87, respectively) and elimination of hydrological acidity (from 4.92 to 0.01, for the control and lime 15 t ha^{-1}, respectively). Liming with 15 t ha^{-1} of dolomite had significant impact on increase of mobile (NH_4-Acetate + EDTA extraction) soil -P, -Ca and –Mg-fraction, decrease of Mn- fraction as well, while available soil K, Fe and Zn status differences were non-significant (Table 2).

Mean concentrations of tested nutrients in the leaves found by our study were as follows (on dry matter basis): 036 % P, 1.86 % K, 0.63 % Mg, (mg kg^{-1}): 44.0 mg Zn kg^{-1}, 100 mg Mn kg^{-1} and 157 mg Fe kg^{-1} respectively (Table 3).

Liming (comparison treatment of 15 t ha^{-1} with the control) considerable influenced on leaf-K (decreasing for 24%), -Mg (increasing for twofold) -Mn (decreasing for 65%) and -Zn (decreasing for 62%) status. However, grain-P and -K were significantly increased as affected by liming, while grain-Mn and -Zn were decreased (for 23% and 18%, respectively) in accordance with liming influences on leaf composition (Table 3).

Golmick et al. 1970 (cited by Mengel and Kirkby, 2001) reported appraisal of the nutrient status in the ear-leaf of maize at flowering stage in ranges as follows: from 0.2 to 0.5% P, 1.5 to 3.0% K and from 0.2 to 1.0 % Mg, from 20 to 70 mg Zn kg^{-1}, from 20 to 200 mg Mn kg^{-1} and from 10 to 300 mg Fe kg^{-1}. According to this criterion adequate concentrations of tested nutrients were found in maize leaves for with emphasis that liming decreased K- and Zn- nutritional status close to low limit (Table 3).

Table 2. Liming effects on soil characteristics

Effects of liming (L) with dolomite (t ha-1) in spring of 2003 on soil (0-30 cm) status (October 5, 2004); HA = hydrolitical acidity calculated in Cmol/kg; AL=AL-method												
L	pH		AL mg/kg		%	NH_4-Acetate + EDTA (pH =4.65) extraction (mg kg^{-1})						
t ha^{-1}	KCl	HA	P_2O_5	K_2O	Humus	P	K	Ca	Mg	Fe	Mn	Zn
	Soil status at end of the second year of the experiment (Oct., 4, 2004)											
0	4.20	4.92	48.0	102	2.05	36.7	84.0	793	141	294	218	5.52
5	6.08	1.48	48.0	93	2.14	53.1	90.3	1568	546	291	210	5.22
10	6.22	0.01	71.5	105	2.02	57.8	94.3	1656	620	274	168	4.71
15	6.87	0.01	69.8	102	1.96	57.8	92.4	2310	892	277	140	3.90
	Analysis of variance (LSD test in levels of 5% and 1%)											
5%	0.29	1.55	13.0	n.s.	n.s.	10	ns	528	289	ns	25	ns
1%	0.41	2.23	18.7			15		759			35	
Mean	5.84	1.61	53	101	2.04	51.3	90.2	1582	550	284	184	4.84

Table 3. Influences of liming in spring of 2003 on leaf and grain composition in maize

Liming with dolomite (April 20, 2003) and maize status (the growing season 2004)												
Lime	The ear-leaf at silking (July 26, 2004)						Grain at maturity stage (October 20, 2004)					
t ha^{-1}	% in dry matter			mg/kg in dry matter			% in dry matter			mg/kg in dry matter		
	P	K	Mg	Fe	Mn	Zn	P	K	Mg	Fe	Mn	Zn
0	0.35	2.10	0.39	170	178	71.2	0.25	0.33	0.09	20.6	4.60	20.1
5	0.36	1.94	0.63	163	86	44.9	0.27	0.34	0.09	20.6	3.80	18.0
10	0.35	1.79	0.70	141	72	33.2	0.29	0.37	0.10	19.8	3.80	18.4
15	0.36	1.59	0.79	154	63	26.9	0.30	0.37	0.09	20.7	3.53	16.5
	Analysis of variance (LSD test in levels of 5% and 1%)											
5%	ns	0.30	0.11	ns	15	13.1	0.03	0.01	ns	ns	0.42	1.9
1%		ns	0.16		22	18.8	ns	0.02			ns	ns
X	0.36	1.86	0.63	157	100	44.0	0.28	0.35	0.10	20.4	3.93	18.2
	Limit for appraisal status (Bergmann, 1992; Mengel and Kirkby, 2001)											
	0.20	1.50	0.20	10	20	20						

Table 4. Response of maize (the hybrid OsSK552) to liming

Impacts of liming with (April 2003) on maize (hybrid OsSK 551) properties (the growing season 2004)									
Dolomite (t ha^{-1})				LSD	Dolomite (t ha^{-1})				LSD
0	5	10	15	5 %	0	5	10	15	5 %
Plant density in percent(100% =51 948 plants ha^{-1})					Grain yield (t ha^{-1})				
88.6	90.0	94.8	94.2	ns	12.01	12.57	12.61	12.45	ns
Grain moisture at harvesting					Sterile plants contribution (%)				
33.1	32.5	32.9	32.0	ns	1.5	1.8	0.8	1.0	ns

* ordinary fertilization of the liming treatments for both 2003 and 2004 (kg ha^{-1}: 160 N + 150 P_2O_5+ 100 K_2O)

Under favourable weather conditions of the 2004 growing season (Table 1) maize responded to liming by non-significant yield increases up to 5 % only (Table 4). As

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previously mentioned, Rastija et al., (2010) reported about yield of field crops for the 5-year period (2003-2007) of this study. Liming had moderate influence on grain yields of maize because they were significantly increased for 22% (2003: mean of the trial 10.42 t ha^{-1}) and for 9% (2006: mean 12.41 t ha^{-1}). Also, winter barley more responded to liming (yield increase for 33% in 2007: mean 7.70 t ha^{-1}) in comparison with winter wheat (yield increase for 10% in 2005: mean 6.73 t ha^{-1}). Significant effects of liming on the field crops yield were found by application of 5 t (winter barley for 2007), 10 t (maize for 2003) and 15 t (wheat for 2005 and maize for 2006) of dolomite ha^{-1}.

Conclusions

In general, liming was usual soil management practice regarding the field crops yield increases. Also, soil and maize nutritional status under liming effects were between limits of normal ranges with exception that leaf-Zn and -K status inclinated to low supplies.

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IMPACTS OF LIMING WITH DOLOMITE ON MAIZE, WHEAT AND BARLEY GRAIN YIELDS

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Abstract: The effect of liming on maize, winter wheat and winter barley grain yields were studied in a five-year (2003 to 2007) field trial in the part of central Croatia (45°30' N, 17°11' E). The experiment with increased rates of dolomite meal (0, 5, 10 and 15 t ha^{-1}) containing 56% CaO and 40% MgO was conducted in spring 2003 on the acid soil with $pH_{(KCl)}$ 4.30 and low phosphorus and potassium availability. Liming significantly affected crops yield, but the range of the yield increment varied among years due to different environmental condition. The best response to liming showed barley and maize in 2003, as their grain yield were increased by 33% and 22%, respectively. Although the highest yield of all crops was attained at the treatment with15 t ha^{-1} dolomite, results revealed that some lower rates were equally efficient, especially in the case of wheat and barley. Economic analysis showed that liming also increased production profit as it was very strong related to achieved yield.

Keywords: liming, maize, winter barley, winter wheat, grain yield

Introduction

In many regions of the world, soil acidity is one of the major factor that affects crops growth and limits yield (Eswaran et al., 1997) Acid soils with a pH lower than 5.5 are widespread in Croatia and cover large area of arable land (Kovacevic et al. 1993, 2006; Loncaric et al., 2005). Liming is widely recognized method for correcting surface soil acidity, although positive responses may not be gained instantly (Edmeades and Ridley, 2003). Liming influences the solubility and availability of nutrients through the changes of soil pH, thus improving crops growth. There are plenty of liming materials which could be used to neutralize soil acidity, but majority of them derives from ground limestone, such as calcite ($CaCO_3$) or dolomite ($CaCO_3$, $MgCO_3$). The purpose of this study was to investigate the impact of liming with dolomite on maize, wheat and barley grain yields which were growing during five years period, and to evaluate their profitability results.

Materials and methods

A five year liming experiment (2003-2007) was conducted in the location near Daruvar, central Croatia (45°30' N, 17°11' E). The field trial was set up in the spring of 2003, in a randomized complete block design with four replications. The size of basic plot was about 90 m^2. The main chemical characteristics of the 0-30 cm soil layer on the experimental field before liming were following: very acid reaction (pH in KCl 4.30), low level of plant available P and K (4.5 and 6.31 mg 100 g^{-1} soil, respectively) according to AL-method (Egner at al., 1960); low Ca and Mg (670 and 148 mg kg^{-1}, respectively) and high Mn values (219 mg kg^{-1}) have been measured by ICP-OES after extraction with ammonium acetate-EDTA (Lakanen - Erviö, 1971).

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Liming treatments consisted of increasing rates of dolomite containing 56% CaO and 40% MgO, as follows: no liming (control), 5, 10 and 15 t ha^{-1}. Basic mineral fertilization was applied each year in average amounts of 140 N, 100 P_2O_5 and 120 K_2Okg ha^{-1}. Following crop rotation was performed: maize (2003-2004) - winter wheat (2005) - maize (2006) - winter barley (2007). Maize was sown at the end of April or beginning of May and harvested manually at the end of September or the first half of October. Wheat and barley were sown at the end of October and harvested at the beginning of July. Area of 1.00 m^2 was harvested from each plot for yield and ears number determinations.

Data were statistically analyzed by ANOVA on year basis, and treatment means were compared using t-test and LSD at 0.05 probability level. Economic analysis was conducted according to cost-benefit method. Liming costs were included only in 2003 maize calculation. Total income was based on related redemption prices and governmental subsidies. Regarding mechanization management, profitability analysis takes into account agro-technical services.

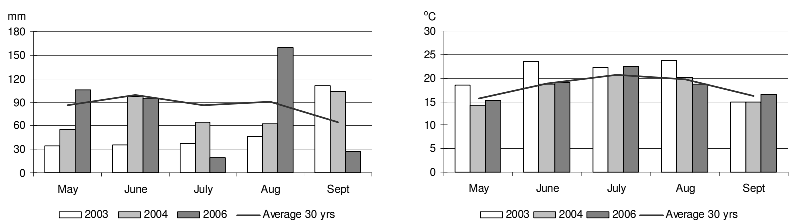

Figure 1.
Monthly amount of rainfall (mm) and average air temperatures (°C) for maize growing seasons (2003, 2004, 2006) and 30-year mean values for the experimental site

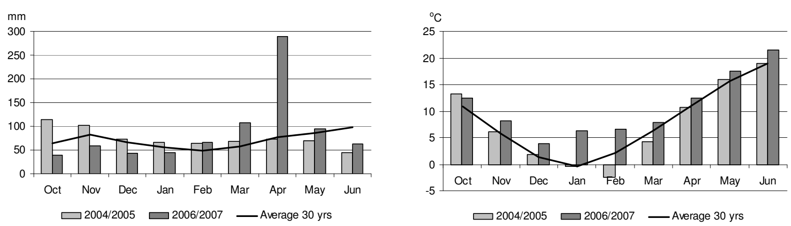

Figure 2.
Monthly amount of rainfall (mm) and average air temperatures (°C) for wheat and barley growing seasons (2004/2005, 2006/2007) and 30-year mean values for the experimental site

Weather conditions considerably differed during experimental period. The 2003 was extremely warm and dry, while the 2004 and 2006 were more favourable for maize growing (Figure 1). The season 2004/2005 was less adequate for winter crops growing compared to the 2006/2007 due to water excess in autumn and lower air-temperatures during the winter period (Figure 2).

Results and discussion

Liming increased crops yield in all years, except in 2004, when liming effect was not evident on maize grain yield. The best response of maize to liming was observed in the first year of research, as grain yield was significantly increased at all treatments, although between rates of 15 and 10 t ha^{-1} no difference was found (Table 1). In the third year after dolomite application (2006) liming impact on maize grain yield was less expressed, although statistically proved. However, in the 2003 the lowest average yield (10.42 t ha^{-1}) was achieved, because of very warm and dry conditions. Since the next year was more favourable regarding water supply (Figure 1), the highest maize grain yield (12.41 t ha^{-1}) was recorded, but without significant impact of liming.
It is well known that lower maize yields in Croatia are usually related to lack of rainfall and higher air temperatures during July and August (Kovačević and Josipović, 1998). Berzseny and Lap (2005) also stressed the significant effect of year on maize grain yield. In the field experiment with increased rates of refuse lime from a sugar factory Kovacevic et al. (2006) have found that maize grain yield increased up to 50 % in the first, and 36% in the second year after liming, but in many cases expected liming effect failed, mostly due to different environmental conditions.

Table 1. Influences of liming with dolomite on maize grain yield

Dolomite t ha^{-1}	Grain yield t ha^{-1}				
	Maize (2003)	Maize (2004)	Wheat (2005)	Maize (2006)	Barley (2007)
0	9.21 c#	12.01	7.33 b	10.58 b	5.55 b
5	10.09 b	12.57	7.64 a	10.81 b	6.91 a
10	11.11 a	12.61	7.76 a	11.01 ab	7.04 a
15	11.29 a	12.45	8.05 a	11.54 a	7.41 a
Mean	10.42	12.41	7.70	10.99	6.73
F test	*	ns	*	*	*
$LSD_{0,05}$	0.97		0.47	0.69	1.00

#Values followed by the same letter are not significantly different at $P \leq 0.05$ level
* significant at $P \leq 0.05$ level

Wheat and barley yield ranged from 7.33 to 8.08 t ha^{-1}, and from 5.55 to 7.41 t ha^{-1}, respectively. The highest yield of both wheat and barley was attained with 15 t ha^{-1} dolomite, but this increase was the same statistical relevance as that at the lowest rate (Table 1). Tsadilas et al. (2000) reported about high correlation of wheat yield with soil pH after liming. In a study of a liming effect on chemical soil properties at same experimental field, Kovacevic et al. (2010) have found that the highest dolomite rate raised soil pH to near neutral value, while significant increases of AL-soluble P and K, as well as Ca an Mg were found at all liming rates, one year after application. It seems that the residual effect of liming became more prominent in combination with adequate weather conditions in season 2006/2007, what have led to better response of barley to liming as compared to wheat.
Liming investment isn't very expensive agro-technical measure; in this experiment it amounts for 66 to 198€ per hectare (for 5 up to 15 tons per hectare of liming material respectively). The most profitable crop was maize after liming with 10 t ha^{-1} in 2004

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(556€ per hectare). On the other hand, the poorest results was noticed in barley production due to low sale price and relatively low yields (from -8€ on no liming treatments up to 185€ on the highest liming treatment).

Conclusions

Liming with dolomite up to 15 t ha^{-1} significantly affected crops yield in all investigated years, except in 2004, when the highest average maize grain yield (12.41 t ha^{-1}) was achieved, due to very favourable weather conditions. Yield increases are closely related to soil pH increases and improvement of soil nutrient balance. The best response to dolomite application showed barley and maize in 2003, as their grain yield were increased by about 33% and 22% compared with the control, respectively. Although the highest crops yield was attained at the highest rate, results showed that lower rates were equally effective, especially in the case of wheat and barley. Also, the range of a yield increment as affected by liming is under great influence of environmental condition. Expectedly, production profit was very strong related to achieved yield.

Acknowledgements

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INFLUENCE OF DIFFERENT METHOD OF SOIL TILLAGE ON ITS PHYSICAL PROPERTIES

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Abstract: In this experiment, effects of three different variants of soil tillage on physical properties of soil and on changes in the soil environment were studied. Measurements were performed since 2007 always in three depths and in three experimental localities situated in different production regions. The experiment had three variants: Variant 1 – conventional method of soil tillage with ploughing to the depth of 0.22 m; Variant 2 – deep loosening of soil to the depth of 0.35 – 0.40 m; Variant 3 – minimum tillage with a shallow loosening to the depth of 0.15 m. It was found out that Variant 1 reduced bulk density and water content in soil. The worst physical properties of soil were found out in the locality situated in the potato-growing region and, above all, in the autumn. The technology without ploughing (Variant 3) showed a positive effect on water content in all monitored localities and also the best yields were always obtained in variants without ploughing. The obtained results indicated that the effect of different methods of soil tillage on the physical properties was significant. Variants without ploughing showed a positive effect on yields.

Key words: soil; physical properties; tillage; water kontent; density; crop yields

Introduction

When evaluating individual types of soil, the fertility is one of their essential properties. Soil fertility cannot be characterised only with regard to its one and/or several properties. It is the result of the action of a very complex set of properties, which influence each other. These parameters may be very variable (e.g. temperature, water content in soil etc.) so that their final and synergic effect results in qualitative changes in soil properties and, thus, in a change in the soil fertility. Changes in soil fertility under the effect of various methods of tillage were studied by Birkás et al. (2007). She demonstrated that physical properties of soils belonged to the group of primary factors influencing the soil fertility. Changes resulting from the application of different methods of tillage were reflected at most in the reduced specific volume of soil, which influenced a whole complex of soil physical properties, i.e. its porosity, water and air holding capacity, heat conductivity etc. Simultaneously, there were also changes in the content, avalability and transport of soil water (Pokorný et al., 1998).

Materials and methods

The studies on the effect of different methods of tillage on physical properties of soil were carried out as a field trial in three localities situated in different growing regions. The experiment was established in 2007 in the following localities: Hrusovany nad Jevisovkou (maize growing region), Uncovice (sugar-beet growing region), and Lesonice (potato growing region). Under the crop rotation (winter rape, winter wheat, grain or silage maize, winter wheat, spring barley) the basic physical properties of soil and soil water content were studied in winter wheat preceded by wheat. The physical status of soil was examined using soil samples designed by Kopecký. Samples were

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taken in three depths (viz. 0 – 0.1; 0.1 – 0.2 and 0.2 – 0.3 m) and at the beginning and the end of the growing season.

The experiment was established in the following three variants:
Variant 1 – conventional method of soil tillage with ploughing to the depth of 0.22 m;
Variant 2 – deep soil loosening to the depth of 0.35 – 0.40 m; and
Variant 3 – minimum tillage with a shallow loosening of soil to the depth of 0.15 m.
Crop yields were evaluated within the framework of studies on the crop growth also in the following years 2008 and 2009.

Soil and climatic conditions
Locality Hrusovany nad Jevisovkou – altitude 210 above sea level, average annual precipitation 461 mm, a warm and dry locality with modal chernozem.
Locality Uncovice – altitude 227 above sea level, average annual precipitation 536 mm, a warm and slightly humid locality with luvic chernozem;
Locality Lesonice – altitude 510 above sea level, average annual precipitation 567 mm, a slightly warm and slightly humid locality with gleyic luvisol.

Results and discussion

Physical properties of soil
The bulk density (BD) of soil can be influenced by tillage; however, the method of tillage itself influences stabilisation of the soil to a lesser extent. The BD value is usually used as the most important parameter of the physical condition of soil and its increase or decrease influences the speed of mineralisation of organic matter. The results are in Tab. 2. Blecharczyk et al. (2007) have found higher bulk density in soil surface layer of direct sowings than in soils of other tillage systems. In the layer of 10 – 20 cm BD of soil in both the direct sowing and the surface tillage systems was higher than in the variant with the conventional tillage.
Differences in BD values, as recorded in individual localities and expressed by means of error line segments are presented in Fig. 1. As one can see, the differences between individual variants of tillage and indvidual localities were statistically not significant.
The soil humidity was changing in dependence on the method of tillage and locality, i.e. in dependence on the type of soil. Values of momentary water content (MWC) are presented in Tab. 3. As one can see, the lowest soil humidity was recorded nearly always in Variant 1. Also other authors observed that higher contents of soil water occurred in variatns with reduced (or minimalised) tillage (Czyz and Dexter, 2009). A significant diference in soil humidity between Variants 1 and 3 was observed in the locality Unčovice (Fig. 2). Statistically significant difference is processed in Table 1.

Table 1. Analysis of Variance

	Ploughing		Deep loosening		Minimum tillage		
	Mean	SD	Mean	SD	Mean	SD	*Value P*
A	21.94	6.3283	22.10	4.2494	21.19	5.1561	0.952
B	21.49	2.7029	23.76	1.9440	26.71	3.5076	0.018
C	20.49	2.1124	23.18	2.0551	22.48	1.5583	0.072

A higher value of bulk density changed the relationship between water and air holding capacity in favour of the former; it also reduced the overall soil porosity and increased the share of capillary pores (Czyz, 2006). The tillage technology influenced the development of soil structure, its porousness, and BD value; this observation was corroborated also by Badalíková and Hrubý (2008) and it was concluded there was also an association with the yields of individual crops.

Table 2. Values of soil bulk density as influenced by different methods of soil tillage (g.cm^{-3})

Variant	Depth (m)	Hrusovany		Uncovice		Lesonice	
		2008	2009	2008	2009	2008	2009
1	0 - 0.1	1.57	1.35	1.37	1.31	1.44	1.30
	0.1 - 0.2	1.56	1.50	1.32	1.40	1.60	1.54
	0.2 - 0.3	1.67	1.55	1.50	1.49	1.74	1.61
2	0 - 0.1	1.45	1.23	1.40	1.23	1.62	1.35
	0.1 - 0.2	1.58	1.50	1.56	1.59	1.66	1.52
	0.2 - 0.3	1.63	1.52	1.63	1.49	1.66	1.59
3	0 - 0.1	1.54	1.16	1.45	1.29	1.60	1.34
	0.1 - 0.2	1.53	1.49	1.45	1.53	1.70	1.60
	0.2 - 0.3	1.57	1.52	1.48	1.51	1.72	1.67

Table 3. Effect of different methods of tillage on water content in soil (% vol.)

Variant	Depth (m)	Hrusovany		Uncovice		Lesonice	
		2008	2009	2008	2009	2008	2009
1	0 - 0.1	21.24	26.01	22.86	24.14	21.59	17.01
	0.1 - 0.2	14.98	28.01	18.63	24.00	20.58	22.45
	0.2 - 0.3	13.80	27.58	17.86	21.49	19.06	22.25
2	0 - 0.1	22.88	21.97	24.96	23.58	26.11	23.87
	0.1 - 0.2	17.91	27.60	26.20	24.26	20.74	23.53
	0.2 - 0.3	16.65	25.59	23.04	20.49	20.85	23.94
3	0 - 0.1	22.92	24.73	31.23	24.76	21.68	23.44
	0.1 - 0.2	14.80	25.21	30.38	24.28	20.89	24.37
	0.2 - 0.3	14.45	25.06	27.14	22.50	20.78	23.73

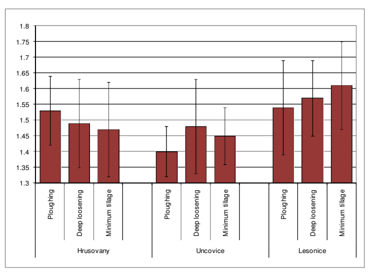

Figure 1. Differences in soil bulk density (g.cm^{-1}) between individual variants of tillage

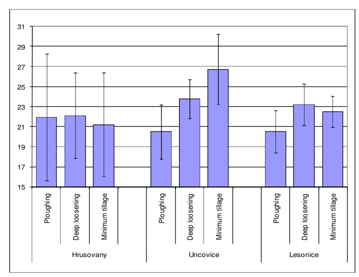

Figure 2. Differenceas in water content in soil under different systems of tillage (%vol.)

Crop yields

The results in two years are in Figure 3. The lowest yield of winter wheat and both grain and silage maize was recorded in Variant 1 in all localities. In Central and Southern Europe, no-till farming gave generally equal or even higher yields than on farms with conventional ploughing and cost savings, especially on larger farms, might function as a powerful stimulus to a further application of no-till in the aforementioned territory. In localities where soil and water conservation are an important issue (e.g. in Mediterranean countries), no-till and the preservation of surface residues seem to become standard farming practice (Soane et al., 2009).

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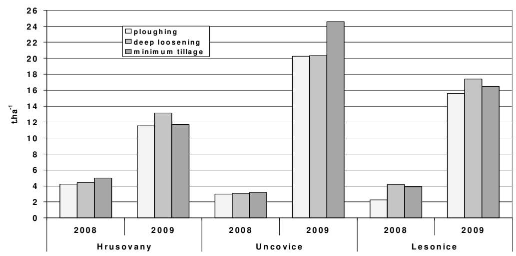

Figure 3. Crop yields as influenced by different methods of tillage (2008 – winter wheat; 2009 – corn maize or silage maize)

Conclusions

Basing on comparison of different methods of tillage applied under field conditions it can be concluded that the minimum tillage increases bulk density of soil but that it also stabilises reserves of soil water within the periods of a lack of precipitation. A higher percentage of soil moisture was always recorded in non-ploughed variants. There was a statistically significant difference in soil water contents recorded in Variant 1 and Variant 3 on the chernozem in Unčovice. Values of bulk soil were recorded on the gleyed brown soil in Lesonice. In 2008 and 2009, the lowest yields of winter wheat and of maize grown for silage and grain, respectively, were recorded in all localities always in Variant 1.

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INFORMATION ON THE PHOSPHORUS-BASED SOIL CONDITIONER GRANULES USED IN ORGANIC FARMING

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Abstract: In crop production, the nutrient supply of plants with phosphorus is a basic requirement. Depending on the heavy metal (mainly Cd) content of rock phosphates used as raw materials, the applied P-fertilizers might pose risks in the long-term to the soil life and, through the food chain, to the human health.
By using a new biotechnological method the objective has been to produce a product containing micro-organisms (primarily *Trichoderma* strains) fixed to solid carrier where bone carbon with *Trichoderma* strains, i.e. the natural phosphorus source is used which will, furthermore result in the improvement of the soil's microbiological activity.
The bone carbon produced from the recycling of agricultural by-products (wastes of animal origin) with heat treatment above 600 °C is a growth medium that can contain microbiological organisms of microporose structure and rich in P and Ca.
Trichoderma species can break down different organic materials and transform plant nutrients into easily available forms.
Summarizing the results of small-plot field trials carried out with the authorized preparation Protector it is confirmed that the studied bone carbon can be used both as plant nutrient and living space of micro-organisms. Biological efficacy of the *Trichoderma* fungal strain placed on bone carbon is also properly confirmed. As a result, the soil's P-content available to the plants increased, followed by an increase in yields. Additional research and development are required and the combined microbiological preparation may be an alternative for phosphorus nutrition in horticultural crops.

Keywords: *Trichoderma*, phosphorus, fertilization

Introduction

The consumers' gradually increasing demands and the compliance to the environmental and food safety requirements of the European Union pose great challenges to the agricultural producers.
It is a requirement that the volume of agrochemicals posing a risk to the human health and the environment should be reduced, by increasing food safety from farm to fork.
In several cases, disposal and reuse of agricultural by-products cause serious problems. It is no more allowed to use ground bones in a conventional way (e.g. feedstuffs) which had been used as bone meals, because it may cause accumulation of wastes produced at slaughter-houses. The bones have high phosphorus content therefore alternatively they may be used as nutrient sources available for plants (Warren, Robinson, Someus, 2009).
The wide-spread *Trichoderma* species have multiple activities in the soil. They can break down different organic materials, e.g. cellulose or bone carbon (phosphorus mobilisation).
The *Trichoderma* strains effective under laboratory conditions show no efficacy if used in the field. This phenomenon may be caused by two facts, one is the low number of fungi, the other being that the inadequate carriers, i.e. the fungi could not well establish in the soil and in the risosphere (Someus, 2009).
The innovative element of the present development is the sterile carrier (bone carbon) which is of high purity, free from toxic materials, and produced from agricultural by-products.

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It is, however, not enough to select a proper P-mobilizing microorganism, it has to be steadily present in the soil and, at the same time, the mobilizable phosphorus should also be present. The product developed by our team offers such a solution. The bone carbon is the mobilizable phosphorus itself for the microorganisms.
The described product developed by biotechnological methods with heat treatment above 600 °C is a mixture of *Trichoderma* strains "placed" on bone carbon.

Materials and methods

The biological efficacy trials aiming at official authorization were carried out, in 2007 and 2008, by the Agricultural Office of county Fejér Plant Protection and Soil Conservation Directorate which has GLP certification. The trials were carried out under glasshouse (pot) conditions and in small-plot field trials.
The physical and chemical composition, the nutrient and heavy metal content of the product were studied.
The field efficacy trials were carried out in paprika and tomato. Trial conditions: four replicates, pseudomicellar (calcareous) chernozem soils rich in macro- and micro-elements.
In the trials, 600 kg/ha of bone carbon alone, and 400, 600 and 1000 kg/ha of the combination of bone carbon + *Trichoderma* were applied. The preparations were spread before planting and immediately incorporated into the soil. The plots were regularly irrigated because of the dry weather conditions. Yield evaluations were made three times in paprika and only once in tomato due to the delay of ripening. The nutrient content of plants was analysed on the basis of leaf samples and, at the end of the trial, the soil nutrient content/plot was tested.
In all cases the results were processed by one way analysis of variance.

Results and discussion

Laboratory results confirm that the product has high dry matter content and slightly alkaline chemical reaction. Furthermore it has favourable volume weight, particle distribution and water soluble total salt content. Its phosphorus and calcium contents are very good (17% and. 27%), furthermore contains 1,87 % nitrogen, 0,31 % potassium and 0,57 % magnessium. The toxic element content is always very low for all the studied compounds (As, Cd, Co, Cr, Cu, Hg, Ni, Pb, Se), it is much below the accepted levels.
It is therefore emphasised that the product complies with the criteria of ecological production in all respects.

Trial results with paprika:

The first marketable and ripe fruits were harvested two months after planting and in all treatments they were bigger than the untreated control (3-5%) but the differences between the treatments were not significant.

The effect of treatment was similar during the second harvest. The biggest fruits were obtained with 1000 kg/ha of bone carbon + *Trichoderma* (+8,6%).
Results of the last evaluation showed that the yield harvested from the plots treated with 600 and 1000 kg/ha of bone carbon containing P-mobilizing fungus significantly exceeded that of the control.
Summed-up results of the three harvests uniformly proved the effect of phosphorus. The bone carbon used alone increased the yield by 3,5%. The fungal culture placed to solid carrier caused further yield increase. The rates of 400 kg/ha and 600 kg/ha produced 4,2% and 6,3% higher yields, respectively, than the untreated control. The highest yield (~ +11%) was obtained with 1000 kg/ha and the increment is significant.
Test results obtained with soil samples taken at the end of trials confirmed that the soil's phosphorus content available for the plants increased as a result of the treatments. These results prove the P-mobilizing capability of the *Trichoderma* fungal strain. Following the application of 1000 kg/ha the available phosphorus content increased significantly.
Results of plant tests reflect the effect of treatments: the N, P and K concentrations of leaves increased as compared to the untreated control. Generally, the most harmonised levels of nutrients were obtained with the application of 1000 kg/ha.

Table 1. Results in paprika

Yield and soil test results					
Treatments	Dose (kg/ha)	Yield (t/ha)	Control %	P_2O_5 (mg/kg)	Control %
Control	-	27,70	100,0	182	100,0
Bone carbon	600	28,68	103,5	186	102,5
Bone carbon+ Trichoderma sp.	400	28,86	104,2	194	106,7
Bone carbon+ Trichoderma sp.	600	29,43	106,3	198	108,8
Bone carbon+ Trichoderma sp.	1000	30,78	111,1*	216	118,8**
$SzD_{10\%}$= *		2,62	9,50	22,03	12,1
$SzD_{5\%}$= **		3,20	11,60	26,93	14,8
$SzD_{1\%}$= ***		4,49	16,20	37,76	20,8

Trial results with tomato:

Because of the late planting and the necessity of ending the trials, only one harvest was made in tomato. That time, only some 25-30% of the total yield was red, most of the fruits were harvested green. Both the ripe and green fruits/plot were separately weighted and the total weight was also evaluated.
There were practically no differences in the ripe fruits between the treatments. The 2-3% increase compared to the control was not significant.
Some effects caused by the treatments were observed between the unripe green fruits. Their weight greatly exceeded that of the ripe fruits. In case of the treatment with the highest rate, the fruit weight was 10% higher than the untreated control.
As for the total yield, this treatment showed the highest – 7,5% – yield increase.

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It must be emphasised that yield increases are compared with a control of very good average yield, therefore the effects of treatments could be even more pronounced under worse conditions.

The trends of changes observed in the results of soil and plant tests are practically similar to those obtained with the paprika trials. The treatments of bone carbon + fungus of 600-1000 kg/ha resulted in significant increase of the soil's available P-content. (Gyulai – Tóth - Pálmai, 2007)

Table 2. Results in tomato

Yield and soil test results					
Treatments	Dose (kg/ha)	Yield (t/ha)	Control %	P_2O_5 (mg/kg)	Control %
Control	-	69,17	100,0	194	100,0
Bone carbon	600	69,97	101,2	206	106,2
Bone carbon+ Trichoderma	400	70,94	102,6	216	111,1
Bone carbon+ Trichoderma	600	71,91	104,0	225	115,8*
Bone carbon+ Trichoderma	1000	74,37	107,5	235	121,0**
$SzD_{10\%}$= *		5,49	7,90	25,18	13,0
$SzD_{5\%}$= **		6,71	9,70	30,78	15,8
$SzD_{1\%}$= ***		9,40	13,60	43,15	22,2

During the observations of growth stages, phytotoxicity, symptoms of nutrient deficiency or appearance of pests and diseases were not detected. No differences between the treatments were experienced in this respect.

Conclusions

As a summary it can be concluded that the studied formulation of bone carbon can be used both as plant nutrient and living space of micro-organisms. Biological efficacy of the *Trichoderma* fungal strain placed on bone carbon is also properly confirmed. As a result, the soil's P-content available to the plants increased, followed by an increase in yields.

Based on the above results, the product was granted an authorization for use with the trade name Protector Agrocarbon.

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MAINTENANCE OF SOIL FERTILITY IN THE ORIGINAL ECOSYSTEM, OCCURRENCE AND TOLERANCE OF UNFAVOURABLE EFFECTS

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Abstract: Soil fertility is regulated by all soil characteristics (chemical, physical, biological) and by all processes in the root zone (nutrient-, air-, water-supply, microbial activity) which are necessary to ensure the optimal essential condition of the crops under given ecological circumstances. At the present time only few cultivated areas can be found within original ecosystems that have the protective functions defined by Ghimessy (1984) as the long-term preservation of the natural elements of a land without damage, e.g. the soil fertility. The unfertilized soils of the Hungarian National Long-term Fertilization Experiment Network set up in 1967 are suitable for studying this topic. In those years mineral fertilization was not very much used in Hungary (59 kg NPK ha^{-1} in the ratio of 1:0.7:0.4 on the average of years 1961-65, according to the data of the Hungarian Statistical Office). Maize grain yield data of the experimental years 1967-2001 at Bicsérd (BI) site (chernozem brown forest soil) and Iregszemcse (IR) site (calcareous chernozem soil) are presented here. Maize grain yields of unfertilized control and the lowest level mineral NPK treatments in crop rotation with winter wheat-maize biculture and maize monoculture are compared. Yield results in the period of the 34-year long-term fertilization showed that growing in monoculture hindered the preservation of the soil fertility balance compared to no-fertilization in crop rotations. On the soil at IR, mineral fertilization, however, partly compensated this unfavorable effect.

Key words: soil fertility, original ecosystem, long-term field experiment, unfertilized maize

Introduction

The most fertile chernozem soils are not poor in lime, have excellent water economics, form aggregates or crumbs also in the deep layers due to their clay-humus-complex, because they remained undisturbed for millennia. The originally perfect structure of the cultivated soils can not be conserved, but purposeful soil cultivation can slow down the destruction of the soil structure (Kemenessy, 1959). Madari Kreybig (1944) considered the clay and humus contents of good quality as soil properties of cardinal importance with a view of nutrient and water supply of plants as well. He attached great importance to the region of the root development, thickness of the utilizable rooting zone, depth of the subsoil water-level, chemical, physical and biological balance of the different layers, first of all from soil water economics point of view. The effect of drought is very critical on plants if the top/surface layer is shallow. According to Ghimessy (1984), the preservation of the natural fertility is practically not possible even in original ecosystems, under controlled circumstances, because it is not static, it changes through time.

In the 19th century, mainly farm-yard manuring, but also different agro-technical means (crop rotation, previous crop, green manuring etc.) and new varieties were applied in order to recover the nutrients removed by plants and to increase yields. In the western countries more and more NPK fertilizers were used already in the 20th century, while in Hungary mineral fertilizers were applied far later and in lesser quantities. In 1961-65 the applied active ingredients amounted to 59 kg NPK ha^{-1} in our country. In the period 1970-90, however, our fertilizer use increased considerably (218-282 kg NPK ha^{-1}) in

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order to increase cereal yields then from 1991 much lower NPK amounts were used. In 2002 fertilizer application rates were reduced to 57 kg N ha^{-1}, 8 kg P_2O_5 ha^{-1} and 9 kg K_2O ha^{-1} in the home agricultural practice (Wodsak et al., 2003).

The objective of this study was to investigate the natural soil productivity during a longer period through the changes of soil characteristics and yield results. Long-term field fertilization trials maintained for many decades are the most suitable means for that purpose. In a given agro-ecological region, grain yields reflect the "stability and sensitivity" of the soil against seasonal climatic changes and long-term nutrient removal by plants in different production practices (monoculture and crop rotation) the most reliably.

Materials and methods

The Hungarian National Long-term Fertilization Experiment Network (OMTK) was set up in 1967 at different agro-ecological regions of the country. These small-plot field experiments were established according to uniform experimental plan with different four-year crop rotations and with a maize monoculture, in four replicates, on plots of 50 m^2 at every location. Twenty fertilizer treatments were uniformly applied with increasing NPK rates at all sites in every experimental year. (For more information see Debreczeniné and Németh, 2009.) In the present study maize grain yields on the chernozem brown forest soil of BI site and on the calcareous chernozem soil of IR site were compared in the unfertilized control (coded: 000) and in the lowest level mineral NPK (coded: 111, Table 1) treatments in crop rotation with winter wheat-maize-maize-winter wheat and in maize monoculture in the experimental years 1967-2001. Changes in the most important soil characteristics of the sites were also detected.

The soil type of BI is a clay loam with good soil texture and has deep top soil layer. It is medium for organic matter content and has good water economics. The soil type of IR is slightly clayey, calcareous under the surface, neutral to slightly alkaline, has a deep humus layer, stable texture and favorable water economics. It is the most fertile soil in the region.

Table 1. N, P_2O_5, K_2O doses (kg ha^{-1} yr^{-1}) in treatment coded 111

Nutrients	Crop rotation 1 (1967-71)		Crop rotation 2-3 (1972-79)	Crop rotation 4-5 (1980-1987)	From crop rotation 6 (1988-2001)	
	Winter wheat	Winter wheat	Winter wheat - maize	Winter wheat - maize	Winter wheat	Maize
N	35	40	50	50	100	100
P	35	35	50	50	60	60
K	70	100	100	100	100	200

The yield results of the 34 experimental years were averaged for ten-year periods (1967-77, 1978-87, 1988-97) and for a four-year period (1998-2001). The precipitation amounts during the growing season of maize in the above ten- and four-year periods are shown in Table 2.

Table 2. Precipitation (mm) during the vegetation period of maize (01 May – 30 Sept.) at the sites.

Site	Years			
	1968-1977	1978-1987	1988-1997	1998-2001
BI	3342	3054	3121	1530
IR	3255	3030	3012	1493

Results and discussion

Soil characteristics in the 12th and 32nd years are shown in Table 3, grain yield results in Figure 1.

Table 3. Most important soil characteristics of the test soils in the 12th and 32nd years of long-term fertilization

Sites and treatment codes	pH_{KCl}		Humus (%)		AL-P_2O_5 (mg kg^{-1})		AL-K_2O (mg kg^{-1})	
	Years							
	12th	32nd	12th	32nd	12th	32nd	12th	32nd
BI, 000	6.40	5.04	2.30	2.30	58	51	263	268
BI, 111	6.44	5.11	2.00	2.09	64	122	299	337
IR, 000	7.35	7.35	2.26	2.07	151	146	169	141
IR, 111	7.32	7.42	2.76	2.13	212	306	238	269

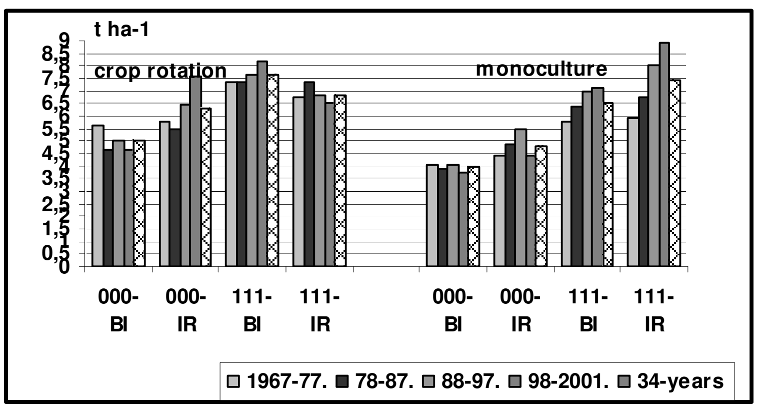

Figure 1. Maize grain yields (t ha^{-1}) on unfertilized (000) and fertilized (111) soils, in crop rotation and monoculture (1967-2001)

Changes in the soil characteristics: During the tested 34 experimental years the soil at BI site turned slightly acidic. Practically no changes could be detected in the original fertility of the unfertilized soil, which was poor for phosphorus and good for potassium. The fertilized soil has changed into medium supplied for phosphorus and into well

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supplied for potassium. At IR site the unfertilized soil of originally medium phosphorus and potassium status has changed into well supplied for these elements as an effect of long-term fertilization.

Grain yield results: Maize grain yields gained on unfertilized or fertilized soils were higher in crop rotation than in monoculture at both sites. The yield fluctuations effected by unfavorable precipitation and temperature can be considered as acceptable. The higher yield in crop rotation can be due to the fact that maize is able to utilize the moisture remaining in the soil after winter wheat. The yield differences between the sites on unfertilized and fertilized soils were considerable. At IR site of more favorable soil properties, on unfertilized soil in crop rotation as well as in monoculture, the yield results of the ten-year periods were higher than at BI, because of the more favorable nutrient supply and water economics of its calcareous chernozem soil. The precipitation amounts in the ten-year periods were nearly the same, they did not exceed 300-400 mm pro year. Precipitation was higher in the last four years, which effected higher grain yield in monoculture. On the soil at BI, which is poorer in nutrients, the fertilizer effect was higher in crop rotation than in monoculture, while at IR on the contrary.

Conclusions

Maize grain yields during the tested 34-year period were generally higher in crop rotation than in monoculture. Due to the more favorable soil properties, yield averages were higher at IR than at BI, both in rotation and monoculture. The effect of fertilization was more beneficial in crop rotation at BI, while in monoculture at IR. The maize grain yields gained during 34 experimental years on the unfertilized soils of the long-term trials prove convincingly that the tested experimental soils have excellent productivity and give balanced reactions to the favorable and unfavorable seasonal effects. Due to the favorable nutrient supply and water economics of these soils, considerable yield fluctuations were not detected.

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MICROBIOLOGICAL INDICATION OF THE PRESENCE OF HEAVY METALS IN SOIL

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Abstract: The natural environment is contaminated with numerous organic and inorganic compounds, among which heavy metals stand out. Bearing in mind the cumulative capacity of soil as well as the response of cultivated plants to different xenobiotics, we assume that it is very useful to consider possible microbiological indication of soil contamination with heavy metals by monitoring the presence of some systematic groups of microorganisms. The research, carried out under laboratory conditions at the Faculty of Agronomy Cacak, included monitoring of the effect of a stepwise increase in heavy metals on total counts of bacteria, fungi and actinomycetes in the alluvial soil (non-contaminated with heavy metals). The presence of the tested groups of microorganisms was determined by an indirect dilution method on appropriate selective nutritive media in five replications. Nutrient media inoculated with appropriate (0.5 cm^3) soil suspensions were supplemented with 0.5 cm^3 of increasing concentrations of heavy metals. The following issues were monitored: the effects of mercury in the form of $HgCl_2$ (2.220 mg dm^{-3}; 0.220 mg dm^{-3}; 0.022 mg dm^{-3}), cadmium in the form of $CdSO_4$ (2.700 mg dm^{-3}; 0.270 mg dm^{-3}; 0.027 mg dm^{-3}), lead in the form of $Pb(NO_3)_2$ (6.250 mg dm^{-3}; 0.625 mg dm^{-3}; 0.125 mg dm^{-3}) and copper in the form of $CuSO_4$ (6.00 mg dm^{-3}; 0.60 mg dm^{-3}; 0.160 mg dm^{-3}). The cultured nutrient media supplemented with 0.5 cm^3 of distilled water served as the control. The obtained results suggest that soil microbial counts are governed not only by microorganism type but also by the type and concentration of heavy metals applied. Mercury and cadmium had the most pronounced toxic effect, whereas soil fungi were somewhat more tolerant of the heavy metals studied.

Key words: microorganisms, heavy metals, soil

Introduction

Heavy metals are defined as a group of metals having an atomic density greater than 5g cm^{-3}. They generally enter the environment through a variety of human activities, eventually becoming incorporated into the food chain and accumulated in the biomass of both soil microorganisms and plants (Yao et al., 2003). Some heavy metals, including cobalt, chromium, nickel, iron and zinc, when present at low concentrations, play an important role in plant and microorganism nutrition, as opposed to cadmium, mercury and lead, for instance, which can have adverse effects on the biogeosphere even at low concentrations (Bruins et al., 2000). High concentrations of both groups are toxic to both soil biological components and the ecosystem as a whole (Giller et al., 1998). Different methods are used to identify relevant indicators of the presence of heavy metals in the biogeosphere, specifically the soil. Due to their extremely high susceptibility to heavy metals present in the soil, certain microbial groups are becoming increasingly used as indicators for evaluating the degree of soil contamination as well as potential toxicity to other biological components (Djukic and Mandic, 2000; Rajapaksha, 2004). The indication of the effect of heavy metals found in the soil is determined based on changes in microbial growth, morphology, biochemical activity and, finally, biomass and species diversity reduction (Wang et al., 2007; Rathnayake et al., 2009). Conversely, there are certain physiological groups of microorganisms that have the ability to adapt to and resist the harmful effects of contamination with heavy metals by using them as terminal electron acceptors in aerobic respiration and other

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metabolic reactions (Geoffrey and Griffiths, 1997; Spain and Alm, 2003). Most studies undertaken to evaluate the effect of heavy metals on soil microorganisms are based on monitoring their effect in natural environments (Lugauskas et al., 2005; Wang et al., 2007). However, laboratory experiments conducted in vitro, without absolute interpolation, can also be used in defining the effect of heavy metals on certain groups of soil microorganisms (Brookes, 1995; Diaz-Ravina and Baath, 1996).
The objective of this study was to identify the degree of toxicity exerted by different concentrations of heavy metals (copper, lead, cadmium and mercury) on the total counts of bacteria, actinomycetes and fungi in the alluvial soil under laboratory conditions.

Material and methods

This experiment was conducted under laboratory conditions at the Faculty of Agronomy, Čačak to investigate the effect of a stepwise increase in concentrations of heavy metals (lead, copper, cadmium and mercury) on the total counts of bacteria, fungi and actinomycetes in the alluvial soil (pH_{KCl}- 6.4, humus-1.7%, N-0.1%, P_2O_5-0.068 mg g^{-1}, K_2O- 0.1 mg g^{-1}) non-contaminated with heavy metals. The trial involved four independent experiments set up to monitor the effect of each metal at three different concentrations in five replications, being as follows:
- Pb^{2+} in the form of $Pb(NO_3)_2$ at concentrations (mg dm^{-3}): 6.250; 0.625; 0.125;
- Cu^{2+} in the form of $CuSO_4$ at concentrations (mg dm^{-3}): 6.00; 0.60; 0.160;
- Cd^{2+} in the form of $CdSO_4$ at concentrations (mg dm^{-3}): 2.700; 0.270; 0.027, and
- Hg^{2+} in the form of $HgCl_2$ at concentrations (mg dm^{-3}): 2.220; 0.220; 0.022.

The counts of the tested groups of microorganisms were obtained by indirect plating on appropriate selective media. Total bacterial counts were determined on the plate count medium (Pochon and Tardieux, 1962) by inoculation with 0.5 cm^3 10^{-6} of soil dilution, and the counts of fungi and actinomycetes on Czapek's agar and Krasilnikov's synthetic medium, respectively, by inoculation with 0.5 cm^3 10^{-5} of soil dilution (cit. by Govedarica and Jarak, 1993). Each cultured medium was supplemented with 0.5 cm^3 of the above heavy metal concentrations. The cultured nutrient media supplemented with 0.5 cm^3 of sterile distilled water, and replicated five times as well, served as the control. Following incubation at 28°C, total counts of the test microorganisms were determined.
The obtained data were subjected to an analysis of variance (Statistics SPPS 5). The Dunnett test was used to test the significance of differences between treatment means and the control mean.

Results and discussion

The obtained data suggest that the observed change in the counts of soil microorganisms was induced by the heavy metals applied in this study. Their effect was governed by the type and concentration of heavy metals.
The three lead concentrations (6.250 mg dm^{-3}, 0.625 mg dm^{-3} and 0.125 mg dm^{-3}) caused a significant decrease in the count of actinomycetes, as opposed to the other groups of microorganisms, which were identically affected by only the first two higher concentrations (Tab. 1). The effect is related to protein denaturation and cell membrane

disintegration in microorganisms (Diaz-Ravina and Baath, 1996; Sobolev and Begonia, 2008), resulting in a decrease in their numbers.
The soil bacterial count was substantially reduced by the copper concentrations used, whereas the soil actinomycetes were inhibited only by copper concentrations of 6.00 and 0.60 mg dm^{-3} (Tab. 1). In contrast to the present study, the results obtained by Rathnayake et al. (2009) suggest that the toxic effect of Cu^{2+} on the bacterial population isolated from non-contaminated soils does not substantially decrease even at a concentration of 0.011 mg dm^{-3}. A significant decrease in the fungal count was observed only in the treatment with 6.0 mg dm^{-3} copper. A somewhat higher heavy metal tolerance in soil fungi, as compared to the other test microorganisms, was due to a reduction in cell membrane permeability and enzymatic detoxication (Khan and Scullion, 2002).
The cadmium concentrations used in this study induced a considerable decrease in the counts of the test microorganisms (Tab. 1), the extent of the decrease being higher than that produced by copper. This finding is inconsistent with the results of Bruins et al. (2000) who report the inhibitory effect of Cu^{2+} as being more significant than that of Cd^{2+}, particularly in the case of certain Gram positive bacteria. The effect of cadmium as identified in this study can be related to the specific soil type tested and the specific soil microflora.

Table 1. Effect of diverse concentrations of lead, copper, cadmium and mercury on the total counts of bacteria (10^6 g^{-1} absolutely dry soil), actinomycetes and fungi (10^5 g^{-1} absolutely dry soil)

Treatments	Concentration (mg dm^{-3})	Total bacterial count	Count of actinomycetes	Fungal count
Control		89.2	75.4	18.2
Pb^{2+}	6.250	25.6 **	34.6 **	12.0 **
	0.625	65.2 **	35.6 **	14.2 *
	0.125	87.8 ns	47.6 **	15.6 ns
Cu^{2+}	6.000	27.2 **	17.2 **	10.2 **
	0.600	43.6 **	43.4 **	16.4 ns
	0.160	71.6 *	70.6 ns	16.6 ns
Cd^{2+}	2.700	24.2 **	23.6 **	6.4 **
	0.270	27.6 **	31.4 **	12.6 *
	0.027	31.6 **	45.6 **	13.0 *
Hg^{2+}	2.220	15.8 **	13.6 **	1.4 **
	0.220	25.6 **	17.4 **	6.6 **
	0.022	30.6 **	34.2 **	12.2 *

*, **) significant at 0.05 and 0.01, respectively, after the Dunnett test
ns) non-significant

A marked inhibitory effect on the test microorganisms was exhibited by mercury (Tab. 1). The effect was most likely due to the following: inactivation of active enzyme centres, disturbance of the electron transfer in the respiration chain, and destruction of the microbe cell diffusion barrier as induced by the said metal. A weak inhibitory effect

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as exhibited by lower mercury concentrations was also observed here, this finding being in agreement with the results obtained by other authors (Casucci et al., 2003; Šmejkalova et al., 2003).

Conclusion

All the test heavy metals (Pb, Cu, Cd and Hg) induced a reduction in the total counts of bacteria, soil fungi and actinomycetes, their effects decreasing with depleting concentrations. The most toxic effect was exerted by mercury and cadmium. Among the test microorganisms, soil fungi were somewhat more tolerant of the heavy metals. The obtained data suggest that soil microorganisms can serve as indicators of soil contamination with heavy metals.

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NUTRIENT SUPPLY EXPERIMENTS BY REVEGETATION OF MINING WASTELANDS

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Abstract: Revegetation of mining wastelands in Hungary is extremely complicated because of the lack of soil layer. Tailing tips and ponds were created after the abandonment of the uranium mining activities. After topsoiling the waste-rocks, nutrient replacement was carried out by treated organic by-products. The planted species were selected under consideration of the potential vegetation type of the area. Survival rate and plant growth have been monitored during our experiment. Significant differences were detected in the survival rate of the used species, however, there were smaller deviations in the case of the applied nutrient treatments. Our results may contribute to the successful rehabilitation of similar wastelands in the region.

Keywords: composted waste, sewage mud pellets, native trees, uranium mines, rehabilitation, Hungary

Introduction

Revegetation of mining wastelands has always been a great environmental challenge (Martínez-Ruiz et al., 2007). To achieve a successful restoration the soil has to be remediated and the vegetation re-established (Bradshaw, 1997). Spontaneous colonization of plants on a detrital surface is a fairly long lasting process, therefore an appropriate fertile layer needs to be created for speeding up the revegetation. It was proved that topsoiling of wastelands increases richness and diversity from the first year of revegetation (Martínez-Ruiz and Fernández-Santos, 2005). The covering layer usually originates from the topsoil that was stockpiled into so-called 'topsoil heaps' before the mining activity, or from an external transport. Due to lack of dense vegetation and biologically active soil media, these anthropogenic surfaces are however exposed to extreme water supply, heat, erosion and deflation and the nutrient content of the substrate decreases quickly. These factors reduce the chance of plant growth and the survival rate. Nutrient could be replaced by composts produced out of industrial and communal organic wastes. Such as composts of high protein content sludge from leather manufacturing, chopped plant matter-waste and sewage mud pellets. Similar investigations were carried out by Kádár et al. (2009), Kádár and Morvai (2009 a,b) in the case of agricultural crops.

The South Transdanubian region in Hungary is known as one of the most polluted areas in Hungary. Two centuries of mining activity resulted degraded areas and accumulation of pollutants in the environment. Managing and storing the by-products of industrial production are also problems to be solved. For solving these problems a big project was launched in 2001 (NKFP 3/050/2001), its main goal was land reclamation on mining wastelands by using composted wastes. In this paper the results of revegetation researches, which were accomplished on two different uranium wastelands (uranium tailing ponds and tips) are discussed. Our results focus on the effect of the applied nutrients, on the survival and growth ability of the planted trees.

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Materials and methods

Site description

Uranium tailing ponds is an area of 120 ha that can be found south of the Mecsek Mountains (46°01′N, 18°08′E). It is surrounded by agricultural land. The material in the tailing ponds contains the residual isotopes of the uranium decay series after the ore processing. Tailing ponds were dried out and covered by a 150 cm layer (Juhász et al., 2001).

Uranium tailing tips is an area of 17.1 ha in the South-Western slope of the Mecsek Mountains (46°05′N, 18°05′E). It is surrounded by natural and semi natural forests from the north and by robinia plantation and weed vegetation from the south (Morschhauser and Milics, 2009). The tailing tips are of Permian sandstone; its uranium content is rather low. Topsoling of tailing tips was carried out in a depth of 20 cm and the surface was grass-covered. Few years later the experimental plots were covered by another 60 cm of soil.

Experimental plots

Experimental plots were 60×80 m big and were divided to 48 10×10 m subplots. We used randomized block design with two factors for the experimental setup. „A"- factor – five different nutrient input types, plus a control. „B"- factor - four kinds of planted tree species. Number of treatments was 24.

Applied nutrient types

The nutrient used in the case of the different plots originated by composting and processing the following by-products (their compost code, C/N ratio and the used quantity are in parenthesis): 1. detoxified leather cut-offs (a; 15:1; 13 t ha^{-1}); 2. protein solutions from leather and skin industry (b; 19:1; 8.8 t ha^{-1}); 3. sewage sludge containing high percentage of proteins (c; 19:1; 9.4 t ha^{-1}); 4. green waste from public parks (d; 12:1; 14 t ha^{-1}); 5. communal sludge (sm; 8:1; 5 t ha^{-1}). This resulted four kinds of composts and a so called sewage mud pellet. Composts were dispersed and implicated equally 15-20 cm into the soil before the planting.

Applied tree species

The planted tree species were selected under the consideration of the potential vegetation type of the area and of a previous experiment that tested 14 potential tree and shrub species (Borhidi and Morschhauser, 1997). At the uranium tailing ponds the following taxa were used: *Acer campestre*, *Populus alba*, *Prunus spinosa* and *Quercus pubescens*; while at the tailing tips *Acer campestre*, *Quercus pubescens*, *Tilia tomentosa* and *Viburnum lantana* were planted. Planting carried out in autumn 2002. Spacing applied at the plantation was 200×50 cm. The total number of planted trees was 4320 per site. After nutrients and trees had been set out a grass-seeding was applied.

Data collection and analysis

During the censuses the following information was gathered from 2880 randomly selected trees: survival, shoot growth, trunk diameter. Data collection was carried out in from 2002 continuously. In this paper, survival and sprout growth results are analyzed according to the 2008 data. Survival rate was analyzed by non parametric probes (Kruskal-Wallis test), while sprout growth by parametric probes (One-way ANOVA). The data is presented on box plots.

Results and discussion

Tree saplings planted in autumn 2002 started to grow in the vegetation period however; the extreme drought during the summer of 2003 significantly reduced their number. Mortality was 72% on the uranium tailing ponds and 37% on the tailing tips. Investigating the survival rate in case of uranium tailing ponds results show in the averages of species that composts had no significant effect, moreover sewage mud pellets significantly decreased the survival.

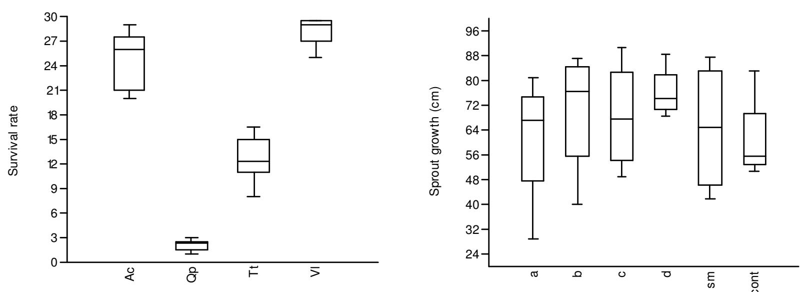

Figure 1. a., b. Survival rate of trees in the averages of the nutrient types (a) and sprout growth of the trees in the averages of the species (b) on the uranium tailing tips in 2008. Explanation for abbreviations: Ac: *Acer campestre*; Qp: *Quercus pubescens*; Tt: *Tilia tomentosa*; Vl: *Viburnum lantana*; a, b, c, d: different compost types; sm: sewage mud pellet; cont: control.

Regarding the survival rate in the averages of the nutrient types there were significant differences ($p<0.05$) between all planted tree species, except between *Populus alba* and *Prunus spinosa*. The best survival can be experienced in case of *Acer campestre* while the greatest mortality was found with *Quercus pubescens*.

A similar tendency could be observed at the uranium tailing tips; composts had no significant effect on the survival rate in the averages of species. However, significant difference ($p<0.005$ and $p<0.01$) was detected between all planted tree species (Figure 1a), except between *Acer campestre* and *Viburnum lantana*.

If we look at the sprout growth results on the uranium tailing ponds according to the different nutrient types, a significant increase ($p<0.001$) can be experienced in the case of two composts (a, c) while a significant decrease ($p<0.001$) (compared to all other nutrient types) is visible at the sewage mud pellets (sm).

On the uranium tailing tips all applied nutrient types appeared to have a positive effect on sprout growth compared to the control (Figure 1b), however these differences were statistically not significant.

There were significant differences between the growths of species in the averages of the different nutrient types. *Populus alba* on the tailing ponds grew significantly higher ($p<0.05$) compared to all other species in the averages of the used nutrients.

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On the uranium tailing tips *Viburnum lantana* ($p<0.005$) and *Tilia tomentosa* ($p<0.001$) appeared to be the best growing species compared to *Quercus pubescens* in the averages of the nutrients. Differences were also significant ($p<0.05$) between *Acer campestre* and *Viburnum lantana*.

Conclusions

Our results suggest that species selection and nutrient supply of topsoils by revegetating mining wastelands have a major importance to achieve successful rehabilitation. Significant differences were found at both research sites according to the survival rate of the planted tree species. Different composts had a positive effect on sprout growth however, differences deviated according to the planted tree species. Common trees performed similarly at the two wastelands. *Acer campestre* was the most successful survivor, while *Quercus pubescens* showed the greatest mortality. The best growing plants were *Populus alba*, *Viburnum lantana* and *Tilia tomentosa*.

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OPTIMIZATION OF SOIL SAMPLING IN SUSTAINABLE AGRICULTURAL SYSTEMS

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Abstract: A traditional measurement of soil characteristics using soil sampling provides accurate information on current levels of soil conditions. However, with regard to cost and labour consumption, it does not allow the effective expression of spatial variability. At two different locations in the Czech Republic, were verified the use of soil electrical conductivity (EC) measurement and aerial imaging which gives rapid, inexpensive, and at the same time, precise description of spatial variability of pH value. EC and aerial imaging demonstrated a similar potential for detecting the change in soil characteristics because they are significantly affected by soil factors such as soil texture, moisture and organic matter. The results of indirect methods were used to optimize soil sampling designs and therefore they were compared to a regular sampling grid with different density. The results suggest that not only the sampling density but also the sampling design are of crucial importance for the desired accuracy of soil maps generated from soil sampling. The optimization of the sampling grid based on indirect methods enables the achievement of a considerable reduction in sample numbers (from 25 to 48 %) while keeping final accuracy of soil maps.

Keywords: soil sampling, soil electrical conductivity, aerial imaging

Introduction

The knowledge of soil environment is necessary for good agricultural practice. The spatial level of its determination depends on the scale of agronomic decision processes and the implementation of cultivation treatments. Modern ways of crop management known as site-specific management or precision agriculture meet high requirements for spatial details. These take into consideration spatial variability within fields and optimize the production inputs, thus fulfilling the objectives of sustainable agriculture (Corwin and Plant, 2005).

Conventional soil sampling provides an accurate way of obtaining information about the soil, but for a more detailed mapping of spatial variability is very time and labour consuming. Therefore it is in some cases replaced by indirect sensory measurement such as the on-the-go systems (Adamchuk et al., 2004) or remote sensing. These methods have more intense spatial coverage but are less accurate compared to laboratory procedures (Christy, 2008). Indirect methods can also be used for optimizing of soil sampling. Kerry and Oliver (2003) show that the ability of indirect methods to identify the differences in soil characteristics can be used for determination of the sampling interval. Lesch (2005) describe the optimization of the sampling design based on measurement of soil electrical conductivity (EC). The objective of this study was to test the methods of soil EC measurement and aerial imaging for optimization of soil sampling for pH level detection.

Materials and methods

Verification was carried out in two different South Moravian (Czech Republic) localities – Field A (52.5 ha) with chernozem soil type and sandy clay loam texture

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with altitude 176 – 182 m, and Field B (37.8 ha) with haplic luvisol and silt loam texture in altitude 280 – 342 m.

Soil sampling
Soil sampling was made in 2004 (Field A) and 2007 (Field B) in a regular grid 50 × 50 m (see Table 3 for sampling parameters). Soil samples were taken from depth 0 - 30 cm in a circle of 5 m in diameter, and analysed for $pH/_{KCl}$ and basic elements.

Measurement of soil electrical conductivity (EC)
In Field A, the measurement of soil EC was carried out in spring 2004 using EM38 device (Geonics Ltd, Canada) driven by an off-road vehicle. In Field B, the measurement was performed in 2009 by walking with the device CMD (GF Instruments s.r.o., Czech Republic). Both of the devices are based on the principle of electromagnetic induction and they are similar regarding their construction and function.

Aerial survey
Aerial imaging of bare soil was carried out in March 2008. The following device was used: digital single lens reflex (DSLR) camera Nikon D80, multispectral camera DuncanTech MS3100 and thermocamera Fluke Ti-55FT. Aerial survey was completed using the aircraft Cessna TU206F about 2000 m above the ground.

Results and discussion

Basic statistical characteristics of pH and the results of soil EC measurements are for both localities mentioned in Table 1. The maps created from point data by the method of ordinary kriging and aerial images of bare soil are shown in Figure 1. Of aerial images, individual bands have been selected (R,G,B, NIR, thermo), and the first (PC1) and second (PC2) component of principle component analysis (PCA) of images in a visible spectrum (R,G,B). From data layers EC, DEM and aerial images, values of the soil sampling points with 5 m buffer were deducted by intersection, and correlation analysis with pH was made subsequently (Table 2).

Table 1. Summary statistics of pH and EC for both localities

		Mean	Min	Max	Variance	Std.dev.	Skew	CV (%)	Count
Field A	pH	6.47	4.40	7.93	0.90	0.95	-0.58	14.64	214
	EC ($mS.m^{-1}$)	9.07	1.40	31.40	30.78	5.55	1.19	61.20	1771
Field B	pH	6.80	4.86	7.82	0.30	0.55	-0.91	8.12	149
	EC ($mS.m^{-1}$)	46.63	21.76	111.74	123.68	11.12	1.23	23.85	4151

Generally, higher correlations were obtained in Field A, which showed higher pH variability. In Filed A, the highest correlation was obtained in EC ($r = 0.565^{**}$) and DSLR PC2 ($r = 0.564^{**}$); in Field B it is the red band of the DSLR image ($r = -0.394^{**}$) and PC1 ($r = -0.391^{**}$). EC and remote sensing show a similar potential of identification of soil property changes, as they are significantly influenced by soil factors such as texture, soil moisture and organic matter.

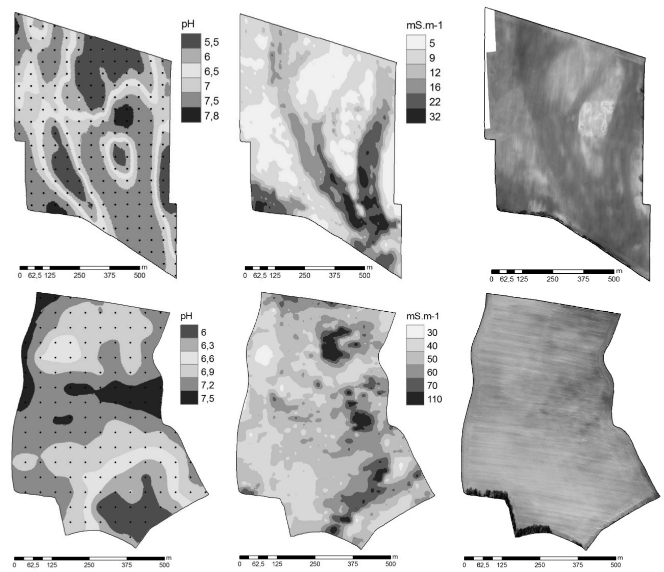

Figure 1. Maps of pH value (with 50m sampling grid), soil EC and aerial image in visible spectrum of Field A (upper) and Field B (lower)

Table 2. Correlation coefficients comparison of the pH values with indirect methods

	DEM	EC	DSLR					NIR	Thermo
			R	G	B	PC1	PC2		
pH (Field A)	-0.260**	0.565**	-0.452**	-0.318**	-0.082	-0.371**	0.564**	-0.379**	0.424**
pH (Field B)	0.056	-0.161	-0.394**	-0.380**	-0.374**	-0.391**	0.082	-0.300**	0.044

significance level *α = 0.05; ** α = 0.01

Comparison of sampling grids

Two types of sampling grids have been compared, which were created by selection of points from the basic 50m-grid – i) regular grids (50m, 100m, 150m) and ii) irregular grids (OPT, ESAP_1, ESAP_2), in which the points have been selected subjectively or using the programme ESAP-RSSD (Lesch et al., 2000) based on the results of sensory measurement. The principle of optimization is selection of samples which cover the whole range of sensory measured values with the greatest distance between them. In the case of ESAP_1 variant, the results of EC measurements were used for optimization, whilst in the case of ESAP_2, a combination of DEM and DSLR data as the first principle component were used. The OPT variant was only used in the Field A by subjective selection of 40 samples from the original 50m-grid based on a EC map. The output of ESAP-RSSD is the position of sampling points to which pH value of the

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nearest points of the initial 50m-grid was assigned. Continuous maps were generated from points of both regular and irregular grids using the ordinary kriging method (OK), and root mean square error ($RMSE_{50}$) from the initial point 50m-grid was surveyed.

Table 3. Results of comparison between regular and irregular grids in both fields

		50m	100m	150m	OPT	ESAP_1	ESAP_2
Field A	Samples count (density per ha)	214 (4.08)	53 (1.01)	27 (0.51)	40 (0.76)	20 (0.38)	20 (0.38)
	pH $RMSE_{50}$	0.215	0.724	0.987	0.758	0.925	0.693
Field B	Samples count (density per ha)	152 (4.02)	41 (1.08)	18 (0.48)	-	20 (0.53)	20 (0.53)
	pH $RMSE_{50}$	0.248	0.387	0.579	-	0.448	0.469

The comparison of variants of the sampling grids with the interpolation method OK (Table 3) showed a decreasing reliability of pH prediction in regular grids with lower density. Irregular grids obtained approximately the same prediction accuracy as the 100m regular grid, but with a lower number of samples (25 % reduction of samples in the OPT variant, and 38% or 48% reduction in optimization using the ESAP-RSSD). The variant ESAP_1 in the Field A is the only exception where the $RMSE_{50}$ value was at the same level as the 150m variant.

Conclusions

The results confirm that not only the sampling density, but also the sampling design has an important effect on the final accuracy of soil maps. Optimization of the sampling grid, based on preliminary analysis of spatial variability using indirect methods, allows to obtain a significant reduction of sample numbers while keeping the final accuracy of soil maps even at low level of correlation between indirect and direct methods.

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ORGANIC MATTER STATUS IN SOILS OF EASTERN CROATIA

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Abstract: The aim of this research is to collect data of soils organic matter percentage intended for intensive production and to evaluate spatial distribution. Organic matter has a huge impact on physical, chemical and microbiological soil characteristics and water storage capacity and plant nutrients. Organic matter has important place on soil fertility. Intensive vegetable production processes increases the mineralization of organic matter, and it is necessary to add organic fertilizer, to use appropriate crop rotation and regulation of soli reaction to maintain an optimal content of organic matter in soil. Informations about the content of organic matter were colleced through the project "Soil fertility control on family farms" which started in 2003 on agricultural soils of the Eastern Croatia. Soil sampling sites are located by Global positioning system (GPS) and all date are placed in GIS date base. The percentage of organic matter in top soil layer (0-30 cm) was determined spectrometrically using bichromate method and results were classified according to the author-Gračanin. Through the project 16,179 samples of soil were analyzed. The obtained results indicate that over 90% of monitored area , has a value of organic matter less than 3%.

Keywords: content of organic matter**,** Eastern Croatia, distribution**.**

Introduction

The aim of this paper is to show percentage of organic matter of East Slavonian soils. Usefulness of soil organic matter is closely connected with the fertility of soil, because acting as a storehouse for nutrients, contributes areation soil and reduces soil compaction, (Zdruli, 2006). It also increases the capacity of the soil water and slow the negative processes in soil (Vukadinović et al., 1996, 1998.)

The most important change makes a man different interventions in the soil, especially in intensive plant production (Blažinkov et al., 2005;Kadar et al.,1991,1997; Kovacevic et al., 2005; Petošić et al., 2003). Soil based on conventional, standard technology,constant anthropogenic causes soil compaction, structure deterioration and destruction of fertility (Birkas et al.,2007).

Soil properties, such as percentage of organic matter is important factor of agricultural crops yield. This paper analyzes the datebase of 16,179 samples, or 54,163 hectares. Department of soils and soil protection from year 2003 on agricultural soils of Osijek-Baranya County, Vukovar-Srijem County, Brod-Posavina County, Požega- Slavonija - County and Virovitica - Podravina County conducts project “Soil fertility control on family farms”. The aim is to introduce agricultural manufacturers with basic agrochemical properties of their soils and admission to adequate organic and mineral fertilization in order to gain high and stabile yields. Listed counties and municipalities finance the project and project is conducted in cooperation with Agricultural faculty of Osijek. Through this project 21 % of agricultural soil owned by family farms of Osijek-Baranja County has been analyzed (54163 ha).

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Materials and methods

On East Slavonia area within project"Soil fertility control on family farms" 16,179 soil samples has been sampled and analyzed. All the samples were taken by trained sampler. Soil sampling sites are located with Global positioning system (GPS) and all data are in GIS database. Samples were taken from May 2003 to November 2008 after harvests and with depth from 0-30cm.Samples preparation and analyses are done in Department of soils and soil protection laboratory. The percentage of organic matter (%) was determined spectrometricaly using bichromate method and the results were classified according to Gračanin, than very low (<1 %), low (1-3 %), medium (3-5%), good (5-10%) and rich (>10%) organic matter,(Škorić, 1991)
Involvement of soil in agricultural production intensifies degradation processes, hence the tendency of agricultural soils reduce organic matter content,(Nemeth et al., 1988).

Results and discussion

In the period, from 2003 to 2008, 16,179 samples of soil in order words 54,000 ha, have been analyzed and it was found that the range of values for organic matter was from 0.32 -14.6 %, with Standard Deviation 0,685331, (Fig.1).

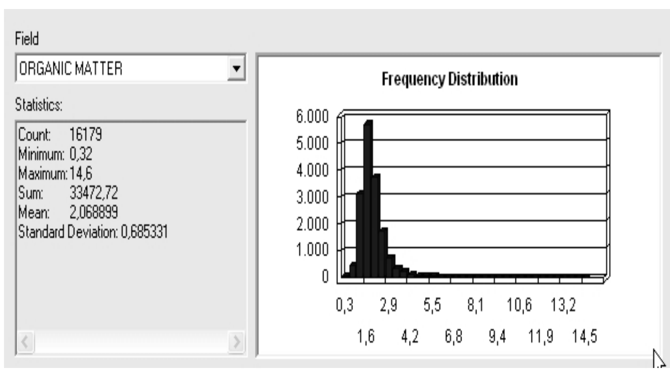

Figure 1. Distribution organic matter (%) in soil of the Easter Croation

Results of organic matter analysis show that of all processed agricultural areas, 0.46% - (247 ha) areas are very low (<1 %) with organic matter ; 92.16% - (49917 ha) are low (1-3 %); 6.96% % - (3,772 ha) medium (3-5%); 0.40% - (219 ha) good (5-10%) and 0.02% - (9 ha) of areas are rich (>10%) with organic matter, (Fig.2).

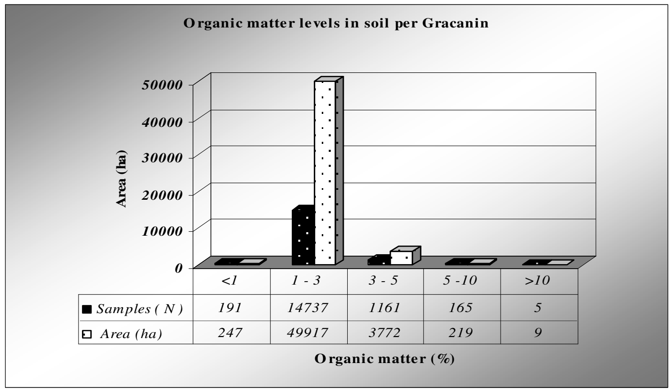

Figure 2. Organic matter levels per Gracanin, area (ha) and number sample (N)

Due to analysis of organic matter data, on average level, by the county, it can be concluded that the values of soil organic matter are included within the group of soils with low organic matter content, (Fig. 3).

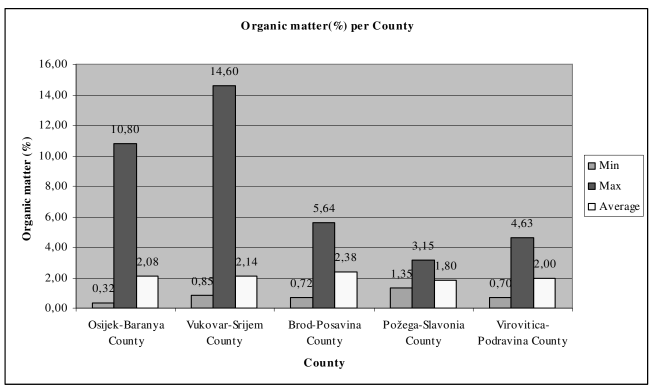

Figure 3. Organic matter (%) - average values per County (min.-max)

Analyzed area deals with intensive vegetable production, narrow crop rotation, irregular arrangement of precipitation in vegetation period and insufficient application of organic fertilizer results with organic matter decrease in soils,(Bertić et al.,1994)

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Conclusions

On 92.16 % of arable agricultural areas the content of organic matter is from 1 to 3% (with the tendency of organic matter decrease), with the consequence of disturbed water-air relation, structure and decrease of microbiological activity.
Intensity of organic matter decrease, dependents of the soil management systems. Therefore, the implementation of each agro-technical measures should be considered, due to positive affect of organic matter balance.. It should be noted, that the rather slow decline of organic matter content in the soils under normal conditions of use of soil is considerd normal. The obtained data suggest that the need to apply new technologies in intensive plant production, which will be aimed on soil fertility protection.

Acknowledgements

We would like to thank Osijek-Baranya County, Vukovar-Srijem County, Brod - Posavina County, Pozega-Slavonia County and Virovitica - Podravina County for providing us with data on soil.

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RAINFALL KINETIC ENERGY, EROSIVITY, AND THEIR POSSIBLE IMPACT ON SOIL RESILIENCE IN TEN GROWING PERIODS

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Abstract: Rainfall kinetic energy (KE) is proposed to be used as an indicator of potential soil erosion and degradation of ecosystems. Direct measurements of KE require an array of sophisticated and expensive instrumentation. An alternative solution is relating KE to rainfall intensity (I) by relationships usually developed by different approaches and in unequal climatic conditions. For this purpose we have used 5 different KE-I relationships and the rains from the growing periods with depths greater than 10 mm. Potentially erosive rains were separated from 1-minute recordings covering a decade (1998-2007) at two locations (Myjava and Dudince, Slovakia). Also the Wischmeier-Smith rainfall erosivity factor (R) was estimated and compared with previously computed values for these locations. A strong belief is held among climatologists that the frequency of extreme rainfall events is increasing with an altered annual distribution. However, in contrast to this paradigm, our analysis did not confirm any significant increase in the values of rainfall intensity and kinetic energy. The effect of stress factors on soil resilience is not strengthening in the scope of our research.

Keywords: soil erosion, rainfall kinetic energy, erosivity factor R

Introduction

Stability or plasticity are commonly used terms to express the health status of a living system. According to this theory ecosystem with stable, invariant properties is considered healthy. Actually properties of dead system under the destabilising influences are also invariable and this system could be wrongly stated as healthy, therefore the concept of resilience is widely used. Resilience means ability of a system to develop new dynamic equilibrium or to recover its original structure against disturbing effects (Holling, 1986; Greenland and Szabolcs, 1994). As pointed out in the work of Várallyay (2007) nowadays, soil is globally exposed to these natural or anthropogenic stress factors (physical, chemical, or biological):

- extreme climatological or hydrological situations
- inappropriate agricultural management
- industry, mining, infrastructure, rural and urban development

A strong belief is held among many climatologists that the occurrence of extreme rainfall events is increasing together with its intensity. This alteration of the stress factor can be exposed especially in agrocoenoses, which are ecologically extra sensitive (Farkas et al., 2009). According to the forecasts of IPCC the probability, frequency, duration and intensity of extreme hydrological events, will be increasing in the future because of climate change and its consequences. There is also an expectation of increase in the occurrence of the rains with greater depths and *vice versa*. Especially for Slovakia an outstanding increase of daily precipitation sums and enhanced risk of local floods in different regions is reported in the 4th national communication of the Slovak republic

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on climate change (2005) but in general opinion, this compound event is already in progress since 1990. Presence of heavy precipitations in agrocoenoses is strongly related to the soil erosion and the soil degradation processes. In the study of these process, specifically the detachment of soil particles by raindrop impact, the rainfall kinetic energy (KE) is a commonly suggested indicator of the raindrop's ability to detach soil particles from the soil mass (Fornis et al. 2005). According to Salles (2002) the rainfall kinetic energy results from the kinetic energy of each individual raindrop that strikes the soil. Physical measurements of the drop diameter (D) and the fall velocity (V) require an array of sophisticated and expensive instrumentation therefore KE is alternatively estimated from empirical laws linking KE to rainfall intensity (I) often based on non-continuous, site-specific, drop size distribution measurements (DSD) combined with empirical V-D laws. To express the effects of both rainfall amount and rainfall intensity on the soil erosion Wischmeier and Smith (1978) developed the rainfall erosivity factor (R) as a variable of the universal soil loss equation (USLE).

In this study the climatic phenomenon and it's partitioning on the soil degradation processes is analysed in the scope of KE and erosivity factor for growing periods covering a decade (1998-2007). Rainfall events with depths greater than 10 and 12.5 mm were separated from meteorological recordings and processed with the KE-I relationships estimated by the Marshall and Palmer (1948), Wischmeier and Smith (1978), Van Dijk (2002), Coutinho and Tomás (1995) and Zanchi and Torri (1980).

Materials and methods

For purposes of this work a one minute precipitation data from the automatic rain gauges were available from the Slovak hydrometeorological institute. Measurements are representing 10 growing periods at locations Myjava and Dudince, Slovakia.

Study site

Table 1. Average monthly and annual total precipitation in mm from meteorological station Myjava

Time period	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.	Year
1961-1990	47	46	38	48	65	79	65	61	50	48	62	59	668

Table 2. Average monthly and annual total precipitation in mm from meteorological station Dudince

Time period	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year
1961-1990	37	34	40	45	56	58	59	51	48	51	55	47	584

Calculation of the rainfall kinetic energy

Rainfall intensity was calculated for each measured rain depth and transformed to KE according to KE-I relationships mentioned earlier. Total rainfall kinetic energy (E) was summed up only for days with precipitation amount greater than 10mm. Five KE-I relationships were available from literature and used in estimation of the KE (Table 3).

Table 3. Relationships between rainfall kinetic energy (KE; $J.m^{-2}.mm^{-1}$) and rainfall intensity (I; mm/h)

Equation	Author	Application	
$KE=9.81+(11.25.\log_{10}(I))$	Zanchi and Torri (1980)	Central Italy	(1)
$KE=35.9.(1-0.56.\exp(-0,034.I))$	Coutinho and Tomás (1995)	Portugal	(2)
$KE=28,3.(1-0.52.\exp(-0.042.I))$	Van Dijk (2002)	-	(3)
$KE=8.95+8.44.(\log_{10}(I))$	Marshall and Palmer (1948)	Used in Eurosem	(4)
$KE=11.87+8.73.(\log_{10}(I))$	Wischmeier-Smith (1978)	For North America	(5)

For illustration the rainfall recording consist of $3x3x10^6$ data matrix where lines comply with one minute increment and columns represent time, date and rain depth. Self made data processing Matlab application was essential in filtering whole data set with 10mm rain depth what helps us in identification of days without rain and days with potentially erosive rains.

Calculation of the rainfall erosivity factor R

According to the methodology of Wischmeier and Smith (1978) factor R is evaluated as an average annual value and calculated from records of precipitation with long-term character. Annual erosivity means the sum of particular storms, whilst not all events are considered; those of smaller precipitation sum than 0.5 inch, i.e. 12.5 mm, separated from preceding and successive rainfall events by rainless periods longer than 6 h are omitted if at least 0.25 inch (6.25 mm) of rain did not fall in the course of 15 min. Particular value of R is computed as:

$$R = E \,.\, I_{30} \quad (6)$$

where: R = average annual erosivity [$MJ.ha^{-1}.cm.h^{-1}$], E = total kinetic energy of individual rainfall [$J\,.\,m^{-2}$], I_{30} = max. 30 min. intensity of rainfall [$cm.h^{-1}$].

Results and discussion

In estimation of daily total kinetic energy the structure and length of rainfall events was not investigated in details as in previously mentioned W-S methodology. The computed values of KE for selected time period and both localities are displayed in Figure 1.

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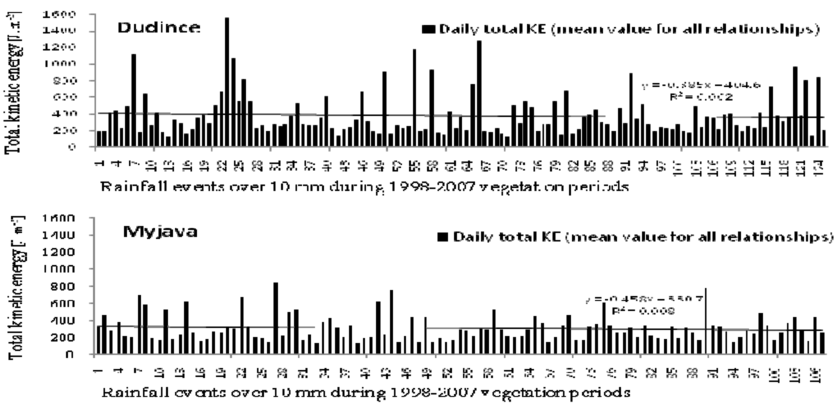

Figure 1. Trends in daily total rainfall kinetic energy for precipitatitons greater than 10 mm

The computed value of rainfall erosivity factor R for locality Dudince is 89,45 $MJ.ha^{-1}.cm.h^{-1}$ while widely used value for this locality according the Slovak erosion control methodology is 29,71 $MJ.ha^{-1}.cm.h^{-1}$. Our computed value for locality Myjava is 31,20 $MJ.ha^{-1}.cm.h^{-1}$, but widely used value for this locality is 17.5 $MJ.ha^{-1}.cm.h^{-1}$.

Conclusions

In the scope of the daily total rainfall kinetic energy no expected climate change inducted alterations to the precipitation regime were proofed for days with rainfall amounts greater than 10 mm. In both locations no significant trend was identified in investigated 10 vegetation periods. Differences between widely used values of R factor and our new computed values are fairly significant. This fact evokes a need for repeated computation of rainfall erosivity factor for the whole area of Slovak Republic.

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RELATIONSHIP BETWEEN HEAVY METALS AND CHEMICAL PARAMETERS OF DIFFERENT EXPLOITED SOIL

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Abstract: In this contribution effect of no-regularly inundation of soil by the river Laborec on soil properties of polder Beša area is shown. Research was realized in years 2007 – 2009. Six sampling sites (three experimental sites in dry polder, three reference sites in non-inundation area) were observed. Soil samples were taken from depths 0.0 – 0.6 m from each 0.1 m. Analysed soil parameters were: content of available phosphorus, potassium, humus, humic acids, fulvic acids, soil pH/KCl, soil texture, content of Cd, Pb, Ni. Variance of measured soil parameters was very large in experimental and also in reference sites, and it's indicates very high horizontal and vertical variability of soil properties. Higher contents of humus, humic acids, fulvic acids, heavy metals and lower contents of available phosphorus and potassium were determined in experimental area than in reference area. Correlations between chemical properties and heavy metals were significant untill no significant.

Keywords: chemical parameters, heavy metals, no-regularly inundation, dry polder, reference area

Introduction

Anthropogenic activities significantly effect on the stability of landscape. The dry polder Beša was constructed on the East Slovak Lowland and it is result of human activity. This object is saturated only at especial flood situations. When water-table in river Laborec is decreased, polder is discharged and after drained of soil this area is possible to cultivate. No regularly inundation of dry polder Beša area has influence on chemical soil properties and its changes. Soil parameters affects also soil management (Duffková et al., 2005).
Negative results of inundation may be the change of soil reaction or increasing of heavy metal content in the soil. From point of view of contamination, soils in polder Beša have specific role. Contamination of soil environment may be carried not only by contamination of water, but also from transport of sediments via water recipients and so various organic and inorganic contaminants are given into the soil. To these soils is important to give attention mainly from point of view of their conservation and hygiene (Várallyay, 2006). Relationship between heavy metals and plants on contaminated soils studied by Rékási and Kádár (2008) and Kádár et al. (2009).

Materials and methods

Soil properties and its changes were researched during the years 2007 – 2009. We had analyzed six sampling sites. Three of them were from the sporadic inundation area of polder Beša (experimental) and three (reference) were from non-inundation area (near by polder area). Soil samples were taken to depth of 0.0 – 0.6 m (from each 0.1 m). We had determined follows soil parameters: humus content (by Tyurin method), humic and fulvic acids content (by Kononova, Beľčikova method) soil pH/KCl, content of available phosphorus and potassium (by Mehlich III method), soil texture (by pipetting method), content of heavy metals – Cd, Pb, Ni (by atomic absorption spectrometry, after

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extraction from soil by 1 mol l^{-1} of NH_4NO_3). Methodologies used for phosphorus and potassium determination described Trávník et al. (1999), for others soil parameters Fiala et al. (1999), and for heavy metals Matúšková, Vojtáš (2005). Obtained data were analysed by a multifactorial analysis of variance and correlation analysis.

Results and discussion

Average values of observed soil parameters are presented in Table 1. Minimum and maximum values of mentioned soil parameters showed considerable spatial variability of soil properties.

Table 1. Average values of selected soil parameters

Area	Parameter	Depth [m]							Min.	Max.
		0.0-0.1	0.1-0.2	0.2-0.3	0.3-0.4	0.4-0.5	0.5-0.6	x		
Experimental area	P [mg kg^{-1}]	1.9	1.3	1.5	1.0	1.3	1.1	1,4	0.3	4.2
	K [mg kg^{-1}]	274.8	217.2	187.7	177.6	162.1	145.9	194.2	92.4	423.0
	pH/KCl	4.56	4.65	4.57	4.44	4.47	4.59	4.55	3.81	5.43
	humus [%]	6.14	4.39	3.49	2.93	2.18	1.81	3.49	1.37	9.18
	C_{HA} [%]	0.63	0.39	0.26	0.21	0.17	0.14	0.30	0.11	0.86
	C_{FA} [%]	0.57	0.49	0.44	0.35	0.31	0.23	0.40	0.17	0.74
	clay particles [%]	54.82	60.27	63.93	66.42	68.98	69.49	63.99	31.89	84.63
	Cd [mg kg^{-1}]	0.057	0.060	0.041	0.035	0.030	0.019	0.040	0.010	0.122
	Pb [mg kg^{-1}]	0.113	0.118	0.104	0.077	0.066	0.051	0.088	0.023	0.250
	Ni [mg kg^{-1}]	2.85	2.36	2.35	2.03	1.48	0.95	2.00	0.33	4.42
Reference area	P [mg kg^{-1}]	73.6	64.4	43.7	33.8	10.5	6.2	38.7	0.3	168.8
	K [mg kg^{-1}]	289.8	253.4	212.3	204.7	199.9	188.0	224.7	75.4	431.8
	pH/KCl	5.76	5.98	5.97	5.85	5.70	5.70	5.83	4.37	6.70
	humus [%]	3.07	2.71	2.26	1.91	1.52	1.41	2.15	0.30	5.26
	C_{HA} [%]	0.26	0.23	0.22	0.16	0.11	0.09	0.18	0.03	0.46
	C_{FA} [%]	0.28	0.27	0.24	0.22	0.20	0.16	0.23	0.03	0.51
	clay particles [%]	47.78	49.98	49.48	51.88	54.45	54.43	51.33	11.51	92.37
	Cd [mg kg^{-1}]	0.046	0.052	0.049	0.039	0.033	0.024	0.041	0.010	0.079
	Pb [mg kg^{-1}]	0.070	0.070	0.074	0.060	0.050	0.044	0.062	0.034	0.091
	Ni [mg kg^{-1}]	1.21	1.20	1.14	0.78	0.48	0.34	0.86	0.15	2.44

C_{HA} – carbon content of humic acids, C_{FA} – carbon content of fulvic acids

It was found, that avaluated soil parameters were significantly influenced by sampling site and depth of sampling, except content of Cd and soil reaction in experimental area (Table 2). Higher contents of humus, humic acids and fulvic acids and lower contents of available phosphorus and potassium were determined in experimental area than in reference area, which relates with the land management. Higher content of humus at minimum land use finding also Dolan et al. (2006). Soil reaction was lower in experimental area than in reference area.

Profile variability of soil properties indicates close relationship between soil depth and soil parameters, soil parameters decreased with soil depth. For the experimental area, the decrease of available potassium, humus, carbon of humic and fulvic acids in soil profile were more marked than for the reference area. For available phosphorus this picture was reversed. Decreasing of phosphorus, potassium and humus contents with depth of soil profile published also Omonode et al. (2006).

Table 2. Average values of soil parameters

Area	Parameter	Source of variability										
		Sampling sites			Depth			Year			Residual	Total
		d.f.	F	P	d.f.	F	P	d.f.	F	P	d.f.	d.f.
Experimental area	available P	2	30.80	++	5	7.86	++	2	3.83	+	203	215
	available K	2	119.97	++	5	65.39	++	2	19.40	++	203	215
	pH/KCl	2	15.51	++	5	2.13	-	2	2.90	-	203	215
	humus	2	9.46	++	5	205.13	++	2	17.04	++	203	215
	C_{HA}	2	12.90	++	5	229.27	++	2	1.61	-	203	215
	C_{FA}	2	26.17	++	5	89.61	++	2	3.39	+	203	215
	clay particles	2	99.99	++	5	21.27	++	2	25.91	++	203	215
	Cd	2	1.77	-	5	13.27	++	2	1.24	-	203	215
	Pb	2	3.85	+	5	13.59	++	2	13.70	++	203	215
	Ni	2	85.86	++	5	57.04	++	2	8.10	++	203	215
Reference area	available P	2	225.85	++	5	34.64	++	2	1.22	-	203	215
	available K	2	43.23	++	5	19.76	++	2	14.69	++	203	215
	pH/KCl	2	582.74	++	5	13.20	++	2	74.99	++	203	215
	humus	2	764.14	++	5	116.23	++	2	1.37	-	203	215
	C_{HA}	2	389.83	++	5	77.21	++	2	5.07	++	203	215
	C_{FA}	2	1017.70	++	5	48.89	++	2	11.07	++	203	215
	clay particles	2	2143.31	++	5	7.72	++	2	47.32	++	203	215
	Cd	2	18.60	++	5	17.98	++	2	1.11	-	203	215
	Pb	2	12.94	++	5	71.76	++	2	22.24	++	203	215
	Ni	2	126.49	++	5	54.32	++	2	6.68	++	203	215

$^{+}P<0.05$ $^{++}P<0.01$

d.f. – degrees of freedom, F – calculated F, P – effect of a factor significant at the level $\alpha = 0.05$ or $\alpha = 0.01$

It was found, upon the fractions of each soil separate present in a soil, that tested soils were clay-loam and clay in the experimental area and loamy sand, clay-loam and clay in reference area. Higher content of clay particles was measured in the lower parts of soil profiles.

Higher average contents of Pb and Ni were measured inside polder Beša than in reference area. The content of Ni and Pb exceeded the limit values published in Act No. 220/2004 Coll. The limit values for agricultural soils are for Ni 1.5 mg kg^{-1} and for Pb 0.1 mg kg^{-1}. Average contents of cadmium for both areas were on the same level.

The relationship between observed soil parameters was evaluated by regression analysis. It was found out, that positive correlations among humus content and C_{HA} (r = 0.96) and C_{FA} (r = 0.87) and among C_{HA} and C_{FA} (r = 0.82) were high significant. High significant positive correlations were also between clay particles and humus and humous substances (Table 3). Similar findings published Šimanský et al. (2009). Correlations among the soil chemical properties and heavy metals were mostly significant but no-significant too (Table 3). Important relationship was found between pH and content of Pb (r = -0,57) and Ni (r = -0,24) and between humus (also humous substances) and content of Cd (r = 0,34), Pb (r = 0,45) and Ni (r = 0,63).

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Table 3. Correlations among observed parameters (correlation coefficient r)

Parameter	P	K	pH/KCl	humus	C_{HA}	C_{FA}	clay particles	Cd	Pb	Ni
P	-	0.45^{++}	0.50^{++}	-0.39^{++}	-0.35^{++}	-0.47^{++}	-0.67^{++}	-0.05	-0.10	-0.12
K	0.45^{++}	-	0.17	0.28^{++}	0.34^{++}	0.22^{+}	-0.26^{++}	-0.03	0.12	0.36^{++}
pH/KCl	0.50^{++}	0.17	-	-0.45^{++}	-0.38^{++}	-0.63^{++}	-0.52^{++}	-0.01	-0.24^{+}	-0.57^{++}
humus	-0.39^{++}	0.28^{++}	-0.45^{++}	-	0.96^{++}	0.87^{++}	0.40^{++}	0.34^{++}	0.45^{++}	0.63^{++}
C_{HA}	-0.35^{++}	0.34^{++}	-0.38^{++}	0.96^{++}	-	0.82^{++}	0.30^{++}	0.30^{++}	0.44^{++}	0.63^{++}
C_{FA}	-0.47^{++}	0.22^{+}	-0.63^{++}	0.87^{++}	0.82^{++}	-	0.51^{++}	0.29^{++}	0.45^{++}	0.68^{++}
clay particl.	-0.67^{++}	-0.26^{++}	-0.52^{++}	0.40^{++}	0.30^{++}	0.51^{++}	-	0.01	-0.02	0.13
Cd	-0.05	-0.03	-0.01	0.34^{++}	0.30^{++}	0.29^{++}	0.01	-	0.59^{++}	0.00
Pb	-0.10	0.12	-0.24^{+}	0.45^{++}	0.44^{++}	0.45^{++}	-0.02	0.59^{++}	-	0.40^{++}
Ni	-0.12	0.36^{++}	-0.57^{++}	0.63^{++}	0.63^{++}	0.68^{++}	0.13	0.00	0.40^{++}	-

Conclusions

Results obtained from field survey of dry polder Beša during the years 2007 – 2009 point out high spatial heterogeneity of soil properties. Contents of observed soil parameters were significant influenced by sampling sites and depth of sampling. Higher contents of humus, humic acids, fulvic acids, heavy metals and lower contents of available phosphorus and potassium were determined in experimental area than in reference area. It was found, that tested soils inside polder Beša were clay-loam and clay and outside area were loamy sand, clay-loam and clay. Profile variability of soil properties indicates close relationship between soil depth and soil parameters, soil parameters decreased with soil depth. Correlations among chemical soil parameters were high significant untill no significant. Seeing that there was a increased content of Ni and Cd in the soil and perennial grasses are growing, there is a risk of transportation into the animals bodies and consequently into the humans bodies. For mention reason it is necessary to make a soil monitoring after inundations.

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RELOCATED SOIL MONOLITH; A RESEARCH METHOD FOR CLIMATE – SOIL – PLANT SYSTEMS

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Abstract: The basic idea of this method is to dig out identical soil monoliths and transport them to other geographic locations representing different climatic conditions, and then place them back to the soil. Growing various field crops on these monoliths the effect of the climate change can be determined, regarding alterations in productivity these crops in spatially different places. The use of a control-monolith at the original location provide possibility to measure the climatic effect on crop production and soil parameters according to the *ceteris paribus* principle. In long term it is also possible to monitor soil parameters' responses that are induced by climate change.

Keywords: climate change, relocating soil monolith, cropping

Introduction

Nowadays there is a great scientific and lay interest in global climate change (IPCC 2007). The tools of climate researches are modeling and simulation. The modeling works very well in the simple, small physical systems. But as the size and complexity is increasing (chemical, biological factors), more and more parameters should be investigated to obtain reliable results. However, the reliability of climate models is difficult to be improved by increasing the number of parameters and data volume (Bartholy and Pongrácz, 2006). The most important questions of the recent climate researches are such fundamental questions like the future average temperature and rainfall of the Earth, changes in the level of the world's oceans, etc. The effect of climate change in agriculture is also a key question, alterations within agro-ecosystems, changing yields, and possibilities of growing of certain field crops (Láng et al., 2007; Fodor, 2006; Nagy et al, 2006).
To set up an agro-climatic experiment, which follows the principle of *ceteris paribus* is very expensive in most cases. A good example for this is a phytotron and climate chambers, or manipulative field experiments (e.g. temperature, gas proportion) (Burkart, Manderscheid and Weigel, 2007). These methods are not fully suitable to measure long-term effects. Horváth (2008) developed mathematical method of future climatic conditions based on recent geographical analogy forecasting the possibilities of growing of field crops. The current results suggest that the growing zones of crops will shift to the north (in the northern hemisphere). The results of this research are promissing, however they do not provide a tool for monitoring deterioration-resilience processes. With our new method presented, it should be possible to measure the effect of climate change in a soil-plant system. Since climatic conditions can not be influenced by *in vivo* (outdoor) experimental systems, soil-plant variations are to be adjusted within that. To set up this experimental implement, there is a need for a considerably big investment, too, but the onward maintenance and operation of that should be available with moderate costs.

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Materials and methods

The basic idea of this method is that in the course of climate change the following processes have to be taken into consideration. Changes in the atmosphere will modify the plant-soil system. In longer time scale soil parameters and properties will change too. Our goal is to study the soil fertility and the productivity of the soil-plant system under such climatic conditions that are different from the original soil formation conditions. This could characterize the possible future climate.
The way of this experiment is to excavate the biggest possible sized undisturbed soil monoliths, and transport them to other place, representing other climatic properties (Figure 1.).

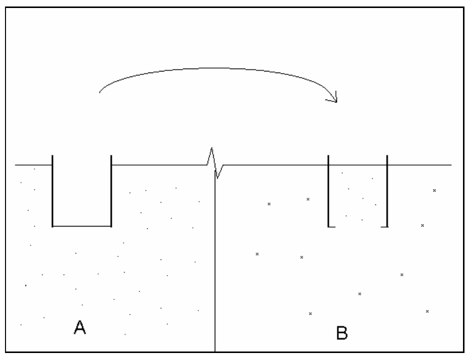

Figure 1. Translocation of a soil monolith from A to B location

The best means for transportation and store a soil monolith is a convertible bottom container. After cutting out the monolith it is possible to close the bottom for the transport, and replacing the monolith at destination with the bottom open. So this way horizontal water flow can be obstructed, but the vertical water movement is undisturbed.

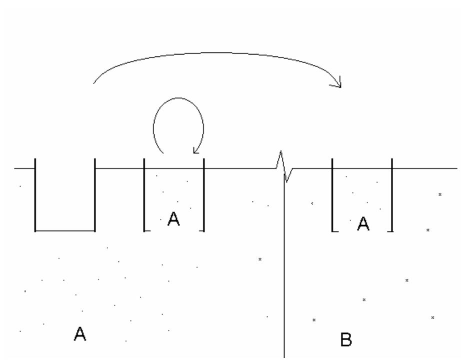

Figure 2. Translocation of a soil monolith from A to B, and a control monolith

This method is a combination of a pot experiment or a lysimeter (using containers) and a long term field experiment (outdoor). This technique eliminates the horizontal water and soil movement (also deflation and erosion) but the roots can grow downward free within the space. If we are cropping with identical way in these monoliths using a control monolith (dug out and placed back at the same place) we can measure long time and short time climatic effects according to the *ceteris paribus* principle (figure 2).
To set up this research some universities and research institutes could work together, changing soil monoliths, creating a network and a monolith-garden (figure 3) at all locations involved. The institutes can share costs, data, and results. A meteorological station is also necessary adjacent to each location measuring identical parameters.

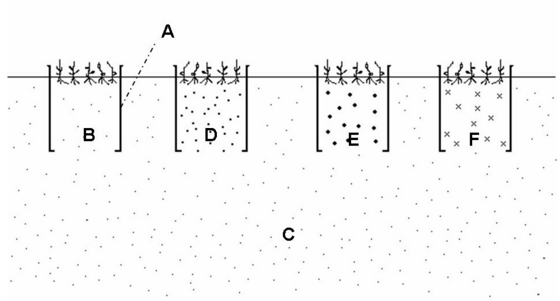

Figure 3. Monolith garden

A: open-bottom container, B: local soil replaced in monolith, C: local soil, D,E,F: alien soil monoliths

Cropping on such a monolith is possible with manual work, with the same crop, and scheduled agrotechniques. On smaller monolith units it is possible to grow crops with smaller sowing distance only, on bigger monolith units crops can be grown with regular field spacing patterns. The volume of the soil samples must be reduced to the minimum, because size of the sample is comparable with the size of the monolith.

Results and discussion

Regarding the methodology, three types of results can be forecasted according to the time horizon.

Short term results: it is possible to make soil physical tests, basically for temperature and water management in the fist year already.

Medium term results after 5-10 years: continuing the physical tests and, analyzing the result of cropping. It is possible to derive consequences about yield and plant analysis changes caused by the altered conditions.

Long term results: after 40 years or more: evaluation of the changes in the main soil parameters and the changes in the soil fertility and crop productivity can be realized.

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The worth of this experiment depends on the size, spread and accuracy of the network. There are also limits for a network size; it can be not bigger than the ecological zone of a certain crop.

This research could also make the climatic models more precise. This may also provide possibility to test the climate change scenarios, to contribute to spatial downscaling, and to make more accurate technology forecasts and strategies for the farmers. This method can help to synchronize the local models with the global models (Várallyay 2004; Várallyay 2006). Also, the method provides a tool for monitoring deterioration-resilience processes.

While implementing, special care is needed in choosing the test plots for the monolith–garden. We can easily spread all kind of pests, diseases and weeds with the soil monoliths. Phytosanitary measures are to be introduced in preventing that.

Biodiversity and ecosystems are in constant dynamic interaction (Schulze, Mooney 1993), consequently, the soil monolith method for bio-monitoring system can be one of the basic solutions.

Conclusions

The method of the relocated soil monoliths may be suitable for observing climate-soil-plant systems in long term field experiments, to calculate the impact of climate on the yield of the experimental sites and soils. The method also provides an opportunity to give regional and global comparisons of plant productivity, the phenological stage, soil physical, chemical and biological parameters in the field experiment, as well as a tool for monitoring deterioration-resilience processes.

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RESILIENCE IN THE SOIL-PLANT RELATIONSHIP ON KARSTIC AREA

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Abstract: The karstic areas are very sensitive for the effects of environment. The characteristic of the karstic soils is fundamentally determined by the amount of the pollution which comes from the surface. The buffer- and filtration capacity of the karstic soils are influenced by the pollutants which get into the karst water, which endanger the drinking water basis. These characteristics of the soils regulate the quality of the leaking water, the quantity of the available nutrients and the pollutants. In this paper we show a comparative assessment of mainly heavy metal pollution in soil and plant samples on catchment area of Béke cave in Aggtelek in Hungary.

Keywords: karstic soil, heavy metal, cadmium accumulation

Introduction

During our investigation we determine the metal content of the soils and the greenery in the catchment basin of the Béke cave in Aggtelek Karstic area. This examination is a joint research which is going on in the karst area in Aggtelek in order to survey the state of the karstic soils (mechanical compound, chemical and physical characteristics, content of the uptake able heavy metal). For example the behaviour of the heavy metals in the soil is one of the qualities which are affected by the puffer capacity of the soils. These are the pH value, content of clay mineral- and organic matter, and the quality of the clay minerals, which are very important components also in the aspect of the heavy metal mobility in the soil. If the soil has sufficient pH value and the organic matter- and clay mineral contents are high enough, it can adsorb high quantity ions hereby decreasing the mobility of the ions. The heavy metal ions which get into the soil solution are available for the greenery, and through the shallow soil layer it can get to the karstic water system which has a very important role in the drinking water system.These soil characteristics ensure resilience within certain limits. The examined area is about 10 km^2, which has very variable geology.

On the map we can divide the area two into parts: the northern part is a non-covered karstic area, in contrast with the southern part which is covered with pannon sediments. We can observe this duality in the developed soil at parent material. In the northern part of the area you can find mainly reddish clay remained soils which are rich in clay minerals and brown forest soils. On the other hand in the covered karst area we can find bright, yellowish-brown coloured soils, which contain loam and sand (remain like terra fusca).

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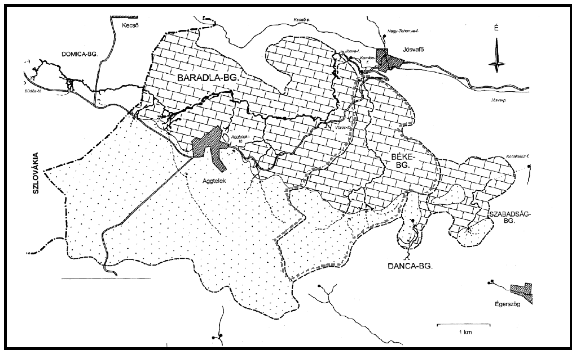

Map 1. The geological Map of Aggtelek Mountain.

From the point of view of phytogeography the catchment basin belongs to Pannonic Floraprovincial and the Floradistrict of Tornense. The vegetation of the area is very diverse. We can find a steppe-grassland (*Salvio festucetum rupicole*), a typical karst-shrub forest and extrazonal beech wood here. We can meet mainly natural forests here, but there are traces of human effects on it. In the southern part of the area we can find an impenetrable scrub built up from juniper and blackthorn. There used to be forests on that place, but after the deforestation the reforestation was not ensued because of the extreme microclimate. The microclimate became extreme because of the deforestation and as a result of this the ecological relations were changed. This led to the reduce of the natural resilience of the area. The human effects also become visible in the planted pine forests. The warm preferable cornel-oak forest (*Corno Quercetum Pubescenti Petrea*) spread on a big part of the area. For our investigation we chose plant species which are widespread in the area so that in this way we can get comparable information about the whole area. Oak, hornbeam, cornel leaves and grass were collected.

Materials and Methods

We were collecting both soil and greenery samples from each sample point during the summer of 2003. The soils samples came from two depths: one from the surface (0-10 cm) and the other came from 20-30 cm depths. We determined pH, organic matter-content, acid- and EDTA soluble heavy metal content from the soils. The acid soluble heavy metal-content was determined after digestion with acid mixture (HNO_3-H_2O_2-$HClO_4$) and the greenery metal content after digestion with HNO_3 and $HClO_4$. (Rowell, 1994). The EDTA soluble metal content was determined after shaking with 0.02M EDTA solution (pH=4.65 ± 0.05) and filtering it. (Lakanen and Erviö, 1971) The nickel, chromium, cobalt, manganese, iron, magnesium, potassium, aluminium content of the solutions which were made from the greenery and the soils were determined by ICP-AES techniques.

Results and discussion

We had chosen those sampling points by the according size of the particle, where the physical quality of the soil samples (20-30cm) were clay or loam. At several of the 4-4 sampling points we collected multifarious plant samples (in general we could collect two or three plant species on one sampling point). For the average value of all the soil types and the greenery species we took at least four sampling metal-concentrations as a basis. In the first table we correlate the metal-concentrations in the plants to the total (acid- soluble) metal-concentration in the soils. On Table 2. we took the uptake able metal concentrations and we correlate it on the element contents of tree greenery. The tables show the values in percent (hundred per cent being the acid-soluble, or rather EDTA-soluble elements concentration in the soils). The element contents of the greenery shows a similar trend on the acid-soluble and the uptake able content. In the case of the clay subsoil solution the amount of the nickel, cobalt and manganese were the highest in the oak leaves samples, the chromium, iron, and aluminium contents were the highest in the grass samples. Variance can be observed in the case of lead and potassium. This great difference can not be observed in the loam soils, we get the same sequence both solutions: in case of nickel, magnesium and potassium we can count the highest values in the cornel leaves. Grass has the highest cobalt content, the chromium, manganese and lead content is highest in the oak leaves and finally the iron and the aluminium content shows the highest value in the hornbeam leaves. In case of solutions we can observe that the examined elements are presented in higher concentrations in the loam soils greenery. It shows the resilience of the loam, as clay can bind more heavy metal hereby presenting a less resilient agent.

Table 1. Greenery metal content / Acid soluble metal concentration in percent

	Ni	Co	Cr	Mn	Pb	Fe	Al	Mg	K
oak leaves from clay	16,34	58,36	0,98	232,84	5,93	0,20	0,20	37,90	133,99
hornbeam leaves from clay	3,29	20,74	1,66	174,02	6,58	0,34	0,24	83,88	535,38
cornel leaves from clay	2,55	14,95	0,14	6,24	4,21	0,18	0,15	131,82	783,98
grass from clay	6,71	2,28	2,64	26,74	4,18	0,35	0,26	60,98	596,46
oak leaves from loam	23,78	2,98	9,53	372,38	26,06	0,43	0,04	98,96	168,68
hornbeam leaves from loam	28,20	5,09	5,71	280,48	4,00	0,68	1,44	137,60	190,97
cornel leaves from loam	37,51	4,36	1,05	13,57	2,45	0,49	0,31	264,57	1108,44
grass from loam	26,34	11,39	7,15	29,49	2,04	0,71	0,47	56,45	852,26

Conclusions

In plants the most common route of exposure is through the roots. Ions and organic molecules contact roots via the transpiration steam, diffusive transport and microbially facilitated transport. Once at the root surface, soluble contaminants have the potential to enter into the root tissue through the transpiration steam or through a range of mechanisms that are designed to facilitate nutrient uptake (Ehlers, 2003). The phytophysiologysts distinguish plants by their uptake strategy. By right of this we can find species which accumulate, exclude or indicate (Baker, 1981).

The greenery of a karstic area in Hungary was first examined by Bárány-Mezősi (1999). Based on the opinion of the authors the heavy metal content of the greenery converges to the heavy metal content maximum of the soils, and at lower soil pH the greenery has higher metal content because the lower pH can mobilize metals.

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Table 2. Greenery metal content / EDTA soluble metal concentration in percent

	Ni	Co	Cr	Mn	Pb	Fe	Al	Mg	K
oak leaves from clay	178,02	136,87	442,22	596,69	20,60	64,50	36,54	2153,90	30839,03
hornbeam leaves from clay	51,02	33,32	1867,95	473,42	13,25	130,60	50,28	9769,75	38526,85
cornel leaves from clay	35,77	28,61	24,57	14,63	8,67	72,46	33,08	11716,67	65429,22
grass from clay	120,60	84,41	2278,26	66,16	11,34	195,91	76,04	5901,85	123423,87
oak leaves from loam	291,67	22,77	9565,54	4165,71	30,09	111,09	3,96	9971,63	39453,71
hornbeam leaves from loam	234,96	39,53	3499,34	3051,33	33,83	169,20	150,84	9568,57	26925,33
cornel leaves from loam	306,78	45,96	618,11	172,42	25,57	141,47	29,71	15659,82	124291,92
grass from loam	303,33	164,27	5704,15	292,23	23,14	173,30	39,70	6105,59	117089,87

From the greenery element content - which correlate to the acid-soluble element content of the soil – we can see, that the macro- and micro element contents (potassium, magnesium, manganese) exceed the 30% which account as a normal value.

From the greenery element content - which correlates to the EDTA-soluble element content of the soil – the amount of the nickel and the chromium amount in both soil types in conspicuous.

The cumulation of the chromium in the grass is very remarkable, because this area is a National Park and it stands under protection. Among the conservation treatment, the area was used as a pasturation area which can promote the metal to accumulate into the organisms. The amount of the chromium and other non-macro nutrients in three leaves (oak and hornbeam) can raise and/or enrich the soil pollutant content. It can get into the karstic system with leaking water. In summary we can establish that the metal concentration values of the area do not exceed the threshold limit of the pollution, the characteristics of the soils can differentiate the mobilization of the metals. The resilience of soils usually protect the extreme mobilization of heavy metals, that is why the examinations are important in the conservation areas and other exploitation areas.

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RESILIENCE OF 4-6 LEAF STAGE MAIZE FOR MICROELEMENT CONTAMINATION ON A CALCAREOUS CHERNOZEM SOIL

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Abstract: A long-term field experiment on microelement contamination was set up in spring of 1991 on a calcareous chernozem loamy soil. Salts of 13 microelements ($AlCl_3$, $NaAsO_2$, $BaCl_2$, $CdSO_4$, K_2CrO_4, $CuSO_4$, $HgCl_2$, $(NH_4)_6Mo_7O_{24}$, $NiSO_4$, $Pb(NO_3)_2$, Na_2SeO_3, $SrSO_4$, $ZnSO_4$) were applied in four levels: 0, 90, 270 and 810 kg·ha^{-1}. The test plant of the experiment was maize in 1991. In the soil the mobile (1 M NH_4NO_3 soluble) and mobilisable (NH_4-acetate + EDTA soluble) element concentrations were measured. In this paper the response and resilience of 4-6 leaf stage maize and its connection to the different soil element fractions is discussed. The results showed that in case of 810 kg·ha^{-1} load compared to the control treatment, there was a 370-, 167-, 95- and 92-fold increase in the mobile fraction of Cr, Se, Hg and Cd, respectively. The mobile fraction of Ba, Cu and Sr showed the lowest increment. The sequence of the investigated elements by mobility (ratio of NH_4-acetate + EDTA and NH_4NO_3 soluble fraction) was: Zn < Ni < Cu < Cd < Hg < As < Cr < Sr = Se < Ba. The increment of each investigated element was significant in the 4-6 leaf maize shoot. In the 4-6 leaf stage the Cu, Al, Cr, Mo, Ni and Se treatments were toxic. The shoot air-dry mass diminished to 50% or less of the control value. Significant root dry mass depression could be observed in case of Cr, Mo and Ni treatments.

Keywords: soil contamination, maize, microelement

Introduction

Soil contamination can be a factor that causes a disturbance in agro-ecosystems that plants may tolerate in a different range. In agricultural soils the main source of contamination is often caused by sewage sludge application. Other sources can be the waste of industry, traffic, etc (Uzinger et al., 2009). Long-term field experiment was set up for investigating heavy metal uptake by plants in Hungary, in which the fate of the contaminants was followed along the complex soil–plant–animal–human food chain (Kádár, 1995). In this paper the response and resilience of 4-6 leaf stage maize and its connection to the different soil element fractions is discussed. The 4-6 leaf stage is important stage in the growth of maize. In this period the plant builds up nutrient pool for the elongation. Thus the element concentration in the plant tissues is basically the highest in the 4-6 leaf stage. The element composition of this phenophase is suitable for the establishment of soil nutrient and contamination status.

Materials and methods

A long-term field microelement experiment was set up in spring of 1991 on a calcareous chernozem loamy soil at the experiment station of RISSAC in Nagyhörcsök. The ploughed layer of the growing site contained around 5% $CaCO_3$ and 3% humus and was very well supplied with Ca and Mn, well supplied with Mg and Cu, moderately with N and K and poorly with P and Zn. The soil texture was loam with 40% clay + silt fraction. The pH (KCl) of the ploughed layer was 7.3. The groundwater depth was 15 m and the water balance was negative, tending to drought.

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Salts of the 13 microelements were applied once at 4 levels in spring 1991, prior to maize sowing. The 13 x 4 = 52 treatments were set up in 2 replications (104 plots) in a split-plot design. The loads were 0, 90, 270 and 810 kg·ha^{-1} for each element in the form of $AlCl_3$, $NaAsO_2$, $BaCl_2$, $CdSO_4$, K_2CrO_4, $CuSO_4$, $HgCl_2$, $(NH_4)_6Mo_7O_{24}$, $NiSO_4$, $Pb(NO_3)_2$, Na_2SeO_3, $SrSO_4$, $ZnSO_4$. Background N, P_2O_5 and K_2O fertilizers were applied each in 100 kg·ha^{-1} dose in every year (Kádár et al. 2000).
The representative plant samples were made from at least 20 subsamples collected from the 9.6 m^2 net plot area. Plant organs were washed before preparation to analysis. Determination of plant element concentrations was carried out with ICP-AES method after cc. HNO_3 + cc. H_2O_2 digestion. The 20-20 soil core samples of each plot were united to get a representative sample. The mobile (1 M NH_4NO_3 extraction, *DIN 19730, 1995*) and mobilisable element fraction of soil (0.5 M ammonium-acetate + 0.02 M EDTA extractable; Lakanen - Erviö, 1971) was determined by ICP-AES method.

Results and discussion

In the investigated soil the concentrations of Pb and Al with 1 M NH_4NO_3 extract did not reach the detection limit on any treatment level. Pb is strongly bound in most soils and Al constitutes stable complexes with soil organic matter (Filep, 1988). The mobile fraction of other elements increased as a function of treatments. In the case of As this increase was not significant. As compared to the control treatment, there was a 370-, 167-, 95- and 92-fold increase in the mobile fraction of Cr, Se, Hg and Cd, respectively. The mobile fraction of Ba, Cu and Sr showed the lowest increment (Table 1). The mobilisable element concentrations heightened also. In case of As, Cd, Cr, Hg, Mo and Se this increment was several hundred times.
The mobility of an element in soil shows how soluble is the element in the soil solution. This mobility can be defined as the ratio of different mobile fractions of the element. Calculating the ratio between LE and NH_4NO_3 soluble fractions we found that the most mobile element was Ba: 81% of the mobilizable fraction was mobile. The same value for the elements that caused the greatest depression in shoot and root dry mass were the following: Mo 50%, Se 30%, Cr 17%, Cu 1.3%, Ni 0.7%. This shows that toxicity of an element is not in direct connection with its mobility. The sequence of the investigated elements by mobility was: Zn < Ni < Cu < Cd < Hg < As < Cr < Sr = Se < Ba.
The increment of each investigated element was significant in the 4-6 leaf maize shoot (Table 2). Pb, Mo, Se and Cd showed the highest increment between the control and the highest load. The change in Cu content reached only the significance value.
In the 4-6 leaf stage the Cu, Al, Cr, Mo, Ni and Se treatments were toxic (Table 3). The shoot air-dry mass diminished to 50% or less of the control value. The root weight showed less decrease than the shoot. Significant depression can be observed in case of Cr, Mo and Ni treatments. The Al, Cu and Se treatments reduced also root dry-mass but these changes were not significant. The ratio of shoot/root decreased in Cr and Mo treatments thus the toxicity of these elements manifested in the interfering of shoot growth. The result was similar in case of Se but Cu and Ni damaged the root more. In Cr and Se treatments the plants dry matter % elevated as a result of the low water content that shows depressed physiological activity. From this aspect the root showed drastic and irreversible damages.

Table 1. Effects of treatments on the mobile element composition of the ploughed layer in 1991, mg·*kg*$^{-1}$ (Calcareous chernozem loamy soil, Nagyhörcsök) (*data of Kádár et al. 2000a)

Element	Loads in spring 1991, kg·*ha*$^{-1}$				$LSD_{5\%}$	Average
	0	90	270	810		
Mobile fraction (NH_4NO_3 extraction), mg·kg^{-1}						
Zn	<0.1	<0.1	0.1	0.4	0.3	0.1
Ni	<0.1	0.1	0.3	0.7	0.1	0.3
Hg	<0.1	0.2	0.9	4.1	0.7	1.3
Cr	<0.1	0.3	1.0	3.8	3.1	1.3
Cu	0.1	0.3	0.5	1.1	0.2	0.5
As	0.1	0.2	0.8	4.4	6.8	1.4
Cd	0.2	0.8	3.1	13.9	4.3	4.5
Se	<0.1	2.1	6.2	46.6	37.9	13.8
Mo	0.4	7.3	11.2	27.8	4.2	11.7
Sr	5.7	10.8	22.5	55.2	26.3	23.5
Ba	13.8	22.1	34.3	94.5	21.4	41.1
Mobilisable fraction (Lakanen & Erviö extraction)*, mg·kg^{-1}						
Hg	<0.1	4	49	189	13	61
Cr	<0.1	2	6	30	5	10
Mo	1	21	27	104	14	38
Se	<0.1	7	23	123	13	38
Zn	2	13	55	153	18	56
As	<0.1	7	18	66	14	23
Ni	3	15	40	74	20	33
Pb	5	29	56	158	32	62
Cu	7	24	49	110	40	47
Cd	<0.1	30	86	228	40	86
Ba	20	29	41	100	16	47
Sr	31	49	67	146	16	73
Al	67	73	87	90	8	79

Table 2. Effects of treatments on the element composition of maize in the 4-6 leaf stage in 1991 (Calcareous chernozem loamy soil, Nagyhörcsök) (data of Kádár et al, 2000b)

Element	Loads in spring 1991, kg·*ha*$^{-1}$				$LSD_{5\%}$	Average
	0	90	270	810		
Maize shoot, *mg·kg*$^{-1}$						
Al	91	114	95	198	42	124
As	0.1	0.8	1.1	1.3	1	1
Ba	4	8	22	96	12	32
Cd	0.1	1.3	3.5	12.5	2	4
Cr	0.2	0.5	2.8	2.8	1	2
Cu	18	20	21	22	4	20
Hg	0.1	2.0	2.1	3.7	1	2
Mo	0.4	107	284	781	16	294
Ni	0.8	1.3	2.1	2.4	1	2
Pb	0	1.0	2.8	5.4	1	2
Se	0.1	9	24	60	5	23
Sr	19	27	29	42	11	29
Zn	19	51	76	126	23	68

The sequence of the elements according to the increment in maize shoot (increment of element content between the control and the 810 kg·ha^{-1} load in the percentage of the

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control value) was the following: Cu < Sr < Ni < Zn < As < Cr < Ba < Hg < Cd < Se < Mo < Pb. Comparing this sequence to the element mobility sequence one can state that the low mobility of Zn, Ni and Cu may be in connection with the low plant uptake.

Table 3. Effects of treatments exhibiting toxicity (depression) in maize in the 4-6 leaf stage in 1991 (Calcareous chernozem loamy soil, Nagyhörcsök). (data of Kádár et al, 2000b)

Element	Loads in spring 1991, kg·ha^{-1}				$LSD_{5\%}$	Average
	0	90	270	810		
Air dry shoot, g·20 plants^{-1}						
Al	145	135	105	55		110
Cr	155	75	20	15		66
Cu	205	195	145	125	60	168
Mo	140	130	95	25		98
Ni	200	190	145	110		161
Se	145	140	90	75		113
Air dry root, g·20 plants^{-1}						
Al	38	35	28	21		30
Cr	34	29	13	12		22
Cu	50	47	40	37		44
Mo	38	34	20	15	20	27
Ni	54	38	41	24		39
Se	36	34	26	27		31

Conclusions

The treatments heightened the soil element concentrations in both mobile and mobilisable fractions. The increment of each investigated element was significant in the 4-6 leaf maize shoot. In the 4-6 leaf stage the Cu, Al, Cr, Mo, Ni and Se treatments were toxic. The shoot air-dry mass diminished to 50% or less of the control value. Significant root dry mass depression could be observed in case of Cr, Mo and Ni treatments.

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RESILIENCE OF DYSTRIC CAMBISOLS UNDER LIMING AND FERTILIZATION

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Abstract: Effects of liming and fertilization on improvement of soil chemical properties were studied in a field trial set up on Dystric Cambisol near Gospic, mountain part of Croatia. The two-year investigations revealed significant increases in pH value in treatment with higher rate of limestone. Treatment with higher rate of mineral fertilization and solid farmyard manure (FYM) significant improved phosphorus availability. Treatment with higher rate of NPK fertilizers and higher rate of limestone had positive influence on K_2O content in soil. Total carbon content significant increased in treatments with combinations of mineral and organic fertilizers and limestone.

Keywords: soil resilience, Dystric Cambisols, liming, fertilization

Introduction

Soil resilience can be defined as the ability of the system to recover its "functional and structural integrity" (Seybold et al., 1999). Functional integrity signifies the capacity of the soil to moderate/improve dynamic functions (e.g. fate and decay of organic compounds, microbial activity, provision and recycling of nutrients). Changes in total carbon concentrations are often used as sensitive parameter to monitor the soil recovery (Sparling et al., 2003). Soil pH, essential nutrients and clay content are soil intrinsic properties whose changes are used as indicators of soil resilience (Blanco and Lal, 2008). Liming is a major tool, along with tolerant plants, in the management of acidic soils (Conyers, 2002). Mesić (2001) studied correction of excessive soil acidity with different liming materials in Central Podravina (Croatia) on Dystric Luvisols. Hydrated lime, sugar factory waste lime, ground soft lithothamnium limestone, hard limestone and dolomite influenced the soil chemical properties on the similar way, but not equally. Lončarević et al. (2007) reported efficiency of liming and fertilization on improvement of soil chemical properties. The goal of this research was to define influence of liming and fertilization on improvement of soil dynamic functions (total carbon, nutrients content and soil pH).

Materials and methods

This study was carried out on Dystric Cambisols near Gospic, at Lika area, in mountain part of Croatia (N: 44°36' E: 15° 20'). The trial was established in 1998 with various combinations of conventional NPK fertilizers, two different limestone ($CaCO_3$) rates and one rate of solid farmyard manure (FYM) (Table 1). The experimental design was a randomized block with twelve treatments and four replications. The treatments are listed in Table1. Soil sampling was conducted after crop harvests in July 2006 and October 2009. Composite samples per parcel were taken from one depth (0-30 cm). Soil samples for physical and chemical analysis were air dried, milled, sieved and homogenized. Texture was determined by sieving and sedimentation method according to ISO 1127 (modificated). The soil pH was determined in 1:2.5 (w/v) soil suspension in 1 M KCl. Total carbon (TC) content was determined by dry combustion method (ISO 10694).

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Plant available phosphorus and potassium were extracted by ammonium lactate (AL) solution (Egner et al., 1960). This research presents results for two investigation years, when spring barley (*Hordeum vulgare* L.) and maize (*Zea mays* L) were grown in trial field. Statistical analyses for all data were performed by analysis of variance using SAS Institute 9.1. Level of $p < 0.05$ was used to test significance differences.

Table 1. Treatments and applied amounts of nutrients, limestone and solid farmyard manure

Treatment	Spring barley (2006)	Maize (2009)
Control		
$CaCO_3$ I	(10 t ha^{-1})*	(10 t ha^{-1})*
$CaCO_3$ II	(20 t ha^{-1})*	(20 t ha^{-1})*
N1P1K1	70 kg N ha^{-1} + 90 kg P ha^{-1} + 70 kg K ha^{-1}	68 kg N ha^{-1} + 80 kg P ha^{-1} + 120 kg K ha^{-1}
N2P2K2	105 kg N ha^{-1} + 135 kg P ha^{-1} + 105 kg K ha^{-1}	102 kg N ha^{-1} + 120 kg P ha^{-1} + 180 kg K ha^{-1}
FYM	(30 t ha^{-1})**	(30 t ha^{-1})**
N1P1K1 +FYM	70-90-70 kg ha^{-1} + (30 t ha^{-1})**	68-80-120 kg ha^{-1} + (30 t ha^{-1})**
N2P2K2 +FYM	105-135-105 kg ha^{-1} + (30 t ha^{-1})**	102-120-180 kg ha^{-1} + (30 t ha^{-1})**
N1P1K1 +$CaCO_3$I	70-90-70 kg ha^{-1} + (10 t ha^{-1})*	68-80-120 kg ha^{-1} + (10 t ha^{-1})*
N2P2K2 +$CaCO_3$II	105-135-105 kg ha^{-1} + (20 t ha^{-1})*	102-120-180 kg ha^{-1} + (20 t ha^{-1})*
N1P1K1 +FYM+ $CaCO_3$ I	70-90-70 kg ha^{-1} + (30 t ha^{-1})** + (10 t ha^{-1})*	68-80-120 kg ha^{-1} + (30 t ha^{-1})** + (10 t ha^{-1})*
N2P2K2 +FYM+ $CaCO_3$ II	105-135-105 kg ha^{-1} + (30 t ha^{-1})** + (20 t ha^{-1})*	102-120-180 kg ha^{-1} + (30 t ha^{-1})** + (20t ha^{-1})*

* = two rates of limestone were applied only in 1998; ** = FYM was applied in 1998 and 2006

Results and discussion

Soil texture is clay loam (Table 2). The results of soil chemical properties (soil pH, content of phosphorus, potassium and total carbon) are shown in Table 3.

Table 2. Texture of Dystric Cambisols from experimental plots*

Depth (cm)	Texture class	Particle size distribution, %			
		Coarse sand	Fine sand	Silt	Clay
0-30	Clay loam	4.4	39.8	20.6	35.2

*Average values of 12 data

Results indicate that Dystric Cambisol (control) for both investigated years was very acid (Table 3). Compared to the control treatment there was a significant increase of soil reaction for 1.4 units in treatment with higher rate of limestone (5.36 in 2006 and 5.38 in 2009). Positive and significant influence on soil reaction was also recorded in treatments with combination of limestone, mineral and organic fertilizers. Significant differences in pH values between years per each treatment were observed only for control treatment and treatment with lower rate of NPK. Soil reaction slightly decreased over the years in treatments with combination of limestone, mineral and organic fertilizers. The reason for this is probably the calcium (Ca) leaching. Mesić et al. (2007) reported that nitrogen fertilizer application significantly increased losses of Ca in drainpipe water. Application of 10 t ha^{-1} carbocalc raised pH_{KCl} value for 1.2 units in acid soils of Eastern Croatia (Rastija et al., 2008).

Table 3. Chemical properties of Dystric Cambisols per treatments

2006				2009			
pH (KCl)	AL-P_2O_5 (mg kg^{-1})	AL-K_2O (mg kg^{-1})	TC (%)	pH (KCl)	AL-P_2O_5 (mg kg^{-1})	AL-K_2O (mg kg^{-1})	TC (%)
3.89 ef	11.9 g	186.3 e	2.58 c	4.02 d	13.6 e	215.1 def	2.63 bc
4.54 bc	14.7 g	205.8 de	2.73 bc	4.66 b	14.2 e	208.8 ef	2.86 abc
5.36 a	11.7 g	183.8 e	2.67 c	5.38 a	13.5 e	194.2 f	2.62 bc
3.83 ef	55.0 de	208.3 cde	2.79 bc	4.01 d	69.0 d	232.5 cdef	2.69 abc
3.68 f	102.0 b	211.8 cde	2.70 c	3.90 d	157.7 a	263.5 abcd	2.72 abc
4.01 ed	22.9 fg	223.8 cd	2.82 bc	4.17 cd	23.3 e	232.5 cdef	2.86 abc
3.91 ef	77.8 c	240.5 bcd	3.29 a	3.97 d	115.9 b	284.5 ab	3.09 ab
3.80 ef	127.9 a	241.0 bcd	2.96 abc	4.13 d	151.7 a	258.0 bcde	2.71 abc
4.32 cd	43.8 ef	242.8 bc	2.61 c	4.52 b	69.6 d	246.2 cdef	2.45 c
4.75 b	75.6 cd	274.7 ab	2.75 bc	4.67 b	101.0 bc	310.9 a	2.74 abc
4.54 bc	92.1 bc	280.7 a	3.12 ab	4.47 bc	87.8 cd	269.0 abc	2.83 abc
5.14 a	112.9 ab	287.3 a	3.11 ab	4.77 b	105.1 bc	282.7 ab	3.15 a

*differences between values with the same letters in the same column are not significant at the 5% level

In 2006 P_2O_5 content varied from 11.7 mg kg^{-1} to 127.9 mg kg^{-1}, while in 2009 it was in range between 13.5 mg kg^{-1} and 157.7 mg kg^{-1}. In both investigated years treatment N2P2K2+FYM significantly improved phosphorus availability. Significant differences in phosphorus content between years per each treatment were observed only in treatments with combinations of NPK and limestone. Rastija et al. (2008) noted that liming also significantly increased phosphorus availability for 17.1 mg kg^{-1} in first investigation year. The highest K_2O content in 2006 (287.3 mg kg^{-1}) was recorded in treatment with combination of higher rate of NPK fertilizers, FYM and higher rate of limestone, whereas in 2009 (310.9 mg kg^{-1}) was recorded in treatment with combination of higher rate of NPK fertilizers and higher rate of limestone. Kisić et al. (2004) reported that mineral fertilization had a positive effect on the contents of phosphorus and potassium on Eutric Gleysol in Central Croatia. Total carbon (TC) content was in range between 2.58 % and 3.29 % in 2006 and between 2.45 % and 3.15 % in 2009. Significant influences on TC content were recorded in treatments with combinations of mineral and organic fertilizers and limestone. No significant differences were observed

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in potassium and carbon content between years per each treatment. Kubat and Lipavsky (1996) and Manna et al. (2006) studied the effects of fertilization, liming and manure on the carbon concentrations in soils. They found that treatment with combination of NPK and FYM increased content of organic carbon in soil.

Conclusions

Application of lower rate (10 t ha^{-1}) and higher rate (20 t ha^{-1}) of limestone significantly increased soil reaction for 0.65 units and 1.4 units, respectively for 2006 and 2009.
Mineral fertilization in combination with FYM had a positive influence on phosphorus content in soil.
Treatment with combination of NPK fertilizers, FYM and liming had significant influences on potassium availability.
Total carbon content was significantly increased in treatments with combinations of limestone, mineral and organic fertilizers.

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RESILIENCE OF SOIL IN MODIFIED CLIMATIC CONDITIONS

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Abstract: During the last decade, rapid climatic changes have occurred and through water cycle disturbance strongly affected agricultural production. Appearance of long draught intervals through vegetation periods has been detected. Annual precipitation remained at the same level, but the data indicate the increasing presence of extremely intense rainfall that cannot meet the needs of crops for water. Therefore, it is necessary to devote special attention to management of water that is available during winter time and preserving water quantities for possible draughts intervals during vegetation period. The aim of this research is to determine optimal soil tillage system that will provide sufficient water quantities for crops and increase resilience of agroecosystems. For that reason field experiment with 4 soil tillage systems was set up in Central Croatia. Tillage systems differed in implementation time of separate tillage interventions. Experiment started in 2007 and in 2008 corn was cover crop. During vegetation period soil resistance, soil moisture, bulk density, humus content and yield data were collected. Statistical data analysis showed significant differences of corn yields, hectolitre and absolute weight between treatments. Yields varied from 5.4 to 9.7 t ha^{-1} depending on tillage system.

Keywords: Climate change, corn yield, physical soil properties, soil tillage, water management.

Introduction

Knowledge of climate change is an obvious first step to maintain or improve production and land management in the future. Within this context, changing the intensity, timing, or form of tillage may be one of the management options more readily implemented to assist with adaptation to climate change (Ugalde et al., 2007). In early years of the new millennium the primary goal of tillage is to create and maintain favorable interaction between soil conservation and cropping (Birkas, 2008). Each tillage system may improve, or maintain soil aggregation however their impact on soil quality factors presumably should be different (Birkas et al., 2006). The experience so far and investigations of many years show that coincidence of adverse effects of the "year factor" and /or "tillage factor" may drastically reduce crop yields (Birkas et al., 2007; Jolonkai and Birkas, 2007; Jug et al., 2006; Kvaternjak et al., 2008). The problem is the increasing prevalence of climatically unfavorable years over the last period of time (Dabo et al., 2006). The climatic extremes that most frequently influence the ecosystems in the Carpathian Basin are low or high temperature and a deficiency or excess of rainfall (Varallyay, 2006; Mikulec and Stehlova 2006). In last decade those climatic factors also strongly affect agroecosystems in Croatia. The purpose of this research is to investigate the effects of modified climate conditions on soil parameters and corn yield (*Zea mays* L.).

Materials and methods

The experiment was set up on 4 plots of dimensions 60 m × 5 m on Stagnosol. Every plot was divided into 4 subplots. Applied tillage systems were: A – autumn ploughing, B – autumn ploughing, autumn harrowing, C – winter ploughing and D - spring ploughing. In all treatments seedbed preparation was carried out in spring. The

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experiment started in 2007, and cover crop in 2008 was corn. Spacing between rows was 70 cm and 15 cm within rows. For period 1981-2000 and years 2007 and 2008 data on temperature and precipitation were collected from nearby meteorological stations Novska and Opeke, for climate conditions description. Corn was seeded on 5^{th} of May and harvested on 22^{nd} of October. Soil resistance and water content measurements were carried out 4 times during corn vegetation to the depth of 40 cm, using cone penetrometer (Penetrologger set – Eijkelkamp-2006), and moisture meter (Theta probe instrument – Eijkelkamp-2006). Samples for bulk density and humus content determinations were taken in spring and autumn 2008. After harvest grain yield, hectolitre and absolute mass were determined on each tillage treatment. Statistical data analysis (ANOVA) was carried using collected data.

Results and discussion

Climate indicators for study region were calculated according to long-term period (1981-2000) and years 2007 and 2008. Average annual temperature for long-term period amounts 10.2 °C, and annual precipitation sum 899 mm. In 2007 average annual temperature was 12.1 °C and precipitation sum was 913 mm, while in 2008 average annual temperature was 11.9°C and precipitation sum 841 mm (Figure 1). Average annual temperatures in 2007 and 2008 were 2 °C above perennial average. Monthly temperatures in the end of 2007 were below average. In 2008 January and February were extreme warm and during vegetation period monthly temperatures were in average 1.2 °C higher than perennial average, what increased evapotranspiration rate. During long-term period distribution of precipitation has been favorable. However, in 2007 and 2008 distribution was abnormal (Figure 1). Precipitation occurred in torrential form and despite it significant amount, soil didn't receive sufficient water because of runoff. Such phenomena lead to the almost permanent state of water shortage in the soil.

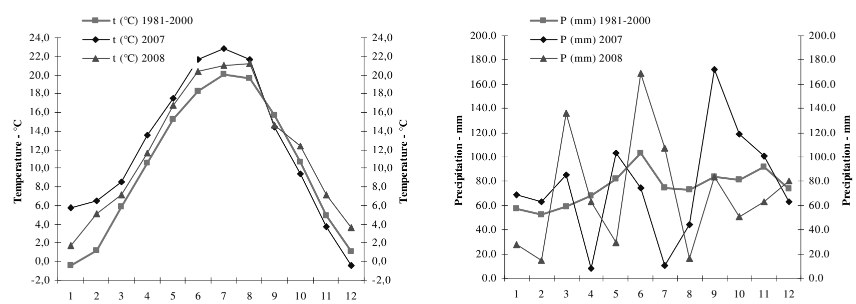

Figure 1. Monthly Temperature and Precipitation

Therefore it is necessary to take measures for mitigation of climate change impacts and to find solutions to make agroecological systems more resilient. One of the measures that can contribute in that direction, and which is presented in this paper is choosing the right soil tillage system that will provide conditions in which soil and plants can use its potentials to overcome present stress. From collected data it was determined that there were no significant differences between soil tillage systems in soil resistance and water content in soil. Depending on layer, values of soil resistance varied: 0-10 cm – 0.69-2.13 MPa, 10-20 cm – 0.92-2.27 MPa, 20-30 cm – 0.97-2.72 MPa, 30-40 cm – 1.27-3.62 MPa. Unfavorable soil resistance values over 2.50 MPa (Birkas, 2008) were recorded only at depth 20-40 cm on 30th of July, and at depth 30-40 cm on 9th of October on all tillage system treatments except on tillage treatment D. Measured values of water content in soil were: 0-10 cm – 17.0-35.8 %, 10-20 cm – 20.3-41.0 %, 20-30 cm – 24.3-42.5 %, 30-40 cm – 23.3-42.8 % (Table 1).

Table 1. Soil Resistance (MPa) and Soil Moisture (%)

Depth (cm)	Tillage system	Soil Resistance (MPa)				Soil Moisture (%)			
		21st May	1st July	30th July	9th Oct	21st May	1st July	30th July	9th Oct
0-10	A	0.98	1.64 ab	1.06	0.70	33.5	17.0	29.8	33.0
	B	0.77	2.13 a	0.99	0.69	35.8	17.8	30.7	34.5
	C	1.00	1.91 ab	0.82	0.79	29.8	18.8	33.0	31.8
	D	1.27	1.41 b	0.74	0.70	33.0	19.3	33.3	33.0
10-20	A	1.12	1.87	1.54	1.30	39.8 ab	20.3	30.0 b	33.8
	B	0.92	2.18	1.89	1.19	39.0 ab	23.3	35.7 a	33.3
	C	1.23	2.27	1.78	1.18	34.5 b	20.5	33.3 ab	32.5
	D	1.06	1.26	0.92	0.98	41.0 a	24.0	34.7 ab	34.5
20-30	A	1.28	2.24	2.72	2.41	41.0	24.5	33.0	26.3
	B	0.97	2.41	2.66	2.06	42.5	27.3	34.0	29.3
	C	1.22	2.17	2.74	1.87	41.3	25.8	32.0	24.3
	D	1.19	1.41	1.69	1.77	42.5	31.0	30.7	29.3
30-40	A	1.28	1.84 ab	2.89 ab	3.39	40.5 b	25.8	31.5	24.5
	B	1.33	2.07 a	2.61 ab	2.78	40.8 b	32.0	32.7	28.5
	C	1.50	2.15 a	3.62 a	3.07	40.3 b	30.5	26.7	23.3
	D	1.27	1.30 b	1.82 b	2.36	42.8 a	32.0	32.0	28.8

* Factor level means accompanied by various letters are significantly different with an error $p \leq 0.05$ according to Tukey's HSD test. Means without any letter point to no significant differences.

In order to monitor physical and chemical processes in soil using different tillage systems, bulk density and humus content was determined in beginning and end of corn vegetation. Bulk density in all tillage systems varied in layers: 0-15 cm – 1.31-1.52 g cm^{-3}, 15-30 cm – 1.39-1.49 g cm^{-3}, 30-45cm – 1.41-1.56 g cm^{-3}. In same layers humus content amounted: 0-15 cm – 2.2-2.7 %, 15-30 cm – 1.9-2.8 %, 30-45 cm – 1.5-2.4%. Presented data so far, showed that different timing of tillage interventions didn't affect changes in investigated physical and chemical soil properties, and therefore it is necessary to continue with research. What is the most interesting in this experiment is the fact that in first year of research significant differences in corn yield and some yield components were detected (Table 2).Treatment A with yield of 9.7 t ha^{-1} proved to be optimal tillage system for corn production in modified climatic conditions. Yield of 8.8 t ha^{-1} was recorded on treatment B, while yield on treatments C and D were significantly lower, and amounted 6.7 t ha^{-1} and 5.4 t ha^{-1}, respectively. Data from table 2 show that corn grain from treatment A also had the highest absolute weight, 332.6 g, and

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favorable hectoliter weight, 71.2 kg hL^{-1}. Based on those data it can be concluded that treatments A and B are the most appropriate tillage systems in those climatic conditions.

Table 2. Components of Yield

Component of Yield	A	B	C	D
Yield (t ha^{-1})	9.7 a	8.8 a	6.7 b	5.4 b
Hectolitre Weight (kg hL^{-1})	71.2 ab	72.5 a	71.0 ab	69.5 b
Absolute Weight (g)	332.6 a	308.0 a	307.0 a	268.5 b

* Factor level means accompanied by various letters are significantly different with an error $p \leq 0.05$ according to Tukey's HSD test. Means without any letter point to no significant differences.

It can be assumed that favorable yields on treatment A and B were result of good soil condition from aspect of water content, microbe activity and physical properties of soil in the initial stages of plant development. To confirm this finding it is necessary to continue with research and explain more detailed mechanisms of system soil – plant – atmosphere that favorably affected yields on treatments A and B.

Conclusions

Within this research it was found that implementation time of tillage interventions for spring crops affects yields and yield quality. Tillage system A - autumn ploughing and spring seed bed preparation, with the highest corn yield indicates its potential to create resilient surrounding for growing corn in modified climatic conditions. Presented data so far, showed that different timing of tillage interventions didn't affect changes in investigated physical and chemical soil properties. This research should be continued for another 4 years.

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RESILIENCE OF SOIL STRUCTURE: MAINTAINING AND AMELIORATING SOIL STRUCTURE BY ADDING DIFFERENT KINDS OF ORGANIC MATTERS

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Abstract: The effect of three different kinds of organic matter incorporation on aggregate-protected organic matter fractions: (1) Maize stem (M), (2) Wheat straw (W), and (3) Maize stem & Wheat straw (MW) on different soil organic matter fractions (SOM) was investigated on a Sandy loam soil. Quantity of carbon-protecting microaggregates and the ratio of differently protected OM forms were measured as the result of addition of different kinds of crop residues. As it was expected before, as the result of the organic matter addition, compared to the control, increasing of the mineral associated organic matter ie. intra-microaggregate POM (Heavy fraction >53µm)) fraction were detected in the Maize stem (M) > Maize stem & Wheat straw (M & W) > Wheat straw (W) order, therefore soil structural stabilizing and adaptive capacity enhancing effect of crop residues was proved.

Keywords: soil structure, soil aggregates, crop residues, SOM (soil organic matter), fractions, LF (Light Fraction), HF (Heavy Fractions)

Introduction

For human population soil acts an important role because it is the basic media of crop production (Várallyay, 2002). Therefore sustaining and ameliorating of soil properties, ie. soil structure is demanded in a high extent. Soil structure, its stability and resilience against the disrupting effects depend on soil organic matter content to a high extent. In spite of the one mentioned before tillage, crop management and irrigation (Chan et al., 2003) may cause the decrease of soil organic matter content and therefore decline of soil structure, degradation of its stability and resilience.

Soil structural stability and resilience could be improved by returning different kinds of organic matter to soil. The extent of the amelioration depends much on several factors such as quantity, quality of the used organic matters. Quality of soil organic matters is affected by their chemical build-up, which differs by their origin (i.e. plant species); and their decomposability which is affected by particle-size, protection by soil aggregates and the extent of their association to mineral surfaces. Addition of decomposable organic matter to soils may affect the total soil organic matter (SOM) content, but detailed changes for different SOM fractions are less well known. Individual SOM of the different particle sized aggregate fractions may be more sensitive indicators to the changes in soil quality and therefore resilience than soil total organic C (OC) and N content. Macroaggregates of 250-2000µm particle size are the first pool for decomposing plant debris, which results more non-mineral associated free organic matter, but this OM fraction is more sensitive to decomposition and has less soil structure stabilizing effect. Microaggregates of 53-250µm particle size contain less non-mineral associated free organic matter, but more mineral associated OM which is less sensitive to decomposition and has more pronounced soil structure stabilizing effect Six et al. (1998). Therefore we investigated the differently mineral-associated OM forms of the 3., the microaggregate fraction.

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In our paper we investigated the effect of three different kinds of organic matter incorporation on aggregate-protected organic matter fractions: (1) Maize stem (M), (2) Wheat straw (W), and (3) Maize stem & Wheat straw (MW). The investigated soil is Sandy loam. Quantity of carbon-protecting microaggregates and the ratio of differently protected OM forms in the soil affected by the addition of these different kinds of crop residues were investigated. As it was expected before, as the result of the organic matter addition, compared to the control, increasing of the mineral associated organic matter ie. intra-microaggregate POM (Heavy fraction >53μm)) fraction were detected in the Maize stem (M) > Maize stem & Wheat straw (M & W) > Wheat straw (W) order, therefore soil structural stabilizing and adaptive capacity enhancing effect of adding of crop residues was proved.

Materials and methods

Site description

The soil samples originate from the "Comparing experiment of organic and mineral fertilization" long-term field experiment (crop rotation "B") in Keszthely, Hungary. The investigated soil type is a sandy loam Eutric Cambisol (soil type FAO), Alfisol (soil type USDA). The soil of the experimental field is poor in available phosphorus, moderate in potassium, low in OM (1.7%). Soil pH_{KCl} 5.9; the content of $CaCO_3$ 0.1%; and the percentage of clay (<0.002mm fraction) 24%. In this paper addition of three different kinds of organic compounds have been investigated: (1) Maize stem (M), (2) Wheat straw (W), and (3) Maize stem and Wheat straw (MW) were mixed and compared to a not organic manure added treatment as a reference. In all four treatments 2 eqv. of NPK and 640kg of N, 360kg of P and 560 kg of K mineral fertilizers were added (pro ha). All sites have been tilled by autumn ploughing to 25cm depth. Crop residue mixing was done simultaneously with the autumn ploughing to 25cm depth every year since the set up of the experiment. Soil samples were taken from two different depth layers: the first from the depth of tillage (called upper layer: 0-20 cm) and a 10cm thick second layer under the depth of tillage (called lower layer: 20-30 cm). The experiment was set up in 1960. Crop rotation was "maize – maize – potato – winter wheat – winter wheat". Samples were taken from a fallow, which has had the same treatment as the potato field, because our aim was to investigate the organic matter addition but to exclude to the soil degrading effect of hilling planting of potato.

Method

Soil organic matter (SOM) fractions might be isolated and measured by physical fractionation of soil (Cambardella and Elliott, 1992).

Firstly, microaggregates were separated according to their particle-size with physical fractionation (i.e. wet sieving) (Six et al., 1998). Each sample was pre-treated by capillary wetting and was sieved for 2 min in an analytic sieve shaker machine with the following aperture sizes: 2 mm, 250 μm, 53 μm. Therefore 4 fractions were resulted: (1) the >2000 μm large macro-, (2) the 250-2000 μm small macro-, (3) the 53-250 μm microaggregates, and (4) the <53 μm silt and clay fraction. Secondly, the mineral-associated OM of the 3., microaggregate fraction was separated by density flotation from those OM forms that do not have any significant association with mineral particles by density flotation using 1.85 g cm^{-3} sodium polytungstate (SPT) following a procedure proposed by Six et al. (1998).

Therefore we got a Light fraction (= Fine free POM), and a Heavy fraction. Heavy fraction was dispersed with 5g/l sodium hexameta-phosphate solution and after 18hours of dispersion was sieved on a 53 µm sieve. Therefore we got the 53-250µm Heavy fraction (which contains i-POM (intra-microaggregate POM which is physically protected against the decomposition) and fine sand) and the <53µm Heavy fraction (which contains biochemical protected OM and silt & clay). Finally, we obtained five soil dry matter (DM) fractions, which contained minerals and OM. There are two fractions of unprotected OM (Coarse sand + Coarse free POM (POM: particulate OM: <53µm) and Light fraction (Fine free POM)), two fractions of protected OM (mineral-associated OM (Heavy fraction <53µm) and intra-microaggregate POM (Heavy fraction >53µm)) and a fifth fraction that contains only minerals (Silt + clay fraction). OM separation was done for all 1-3. aggregate fractions. In this paper results of the OM separation of the 3. microaggregate fraction is interpreted.

Results and discussion

Figure 1-2. show the effect of different crop residues on soil organic matter forms (SOM) for each treatment and depth layer in g fraction pro 100 g soil dimensions. Asterisk (*) indicates significant effect on the amount of SOM fractions compared to the mean of the control treatment in respective depth, and respective SOM fraction shown by ANOVA at $p<0.05$. Soil structural stability and resilience could be improved by returning organic matter to soil. The extent of the amelioration depends much on several factors such as quantity, quality of the used organic matters. Quality of soil organic matters is affected by their chemical build-up, which differs by their origin (i.e. plant species); and their decomposability is affected by particle-size, protection by soil aggregates and the extent of their association to mineral surfaces.

Since Wheat straw (W) residues consist of easily decomposable chemical compounds (mainly mono- and disaccharides) the addition of them resulted the less Light fraction (which is not associated with mineral particles), and further, Wheat residues did not cause the increasing of mineral associated organic matter ie. intra-microaggregate POM (Heavy fraction >53µm)) fraction (Fig. 1-2.). The addition of Maize stem (M) (and the usage of it with Wheat straw (W)) resulted more amount of Light fraction than the only Wheat straw (W) treatment. This could be explained by the less decomposable chemical build-up of Maize stem (S) residues, which contains more chemically stable (phenolic) compounds.

Generally could be reported that addition of any kind of crop residues decreased the amount of Heavy fraction <53 µm (biochemical protected OM, silt and clay). This could be explained by the gluing effect of decomposing organic matters, and therefore the enhancing of association to mineral particles. This phenomenon is more pronounced in the upper layer, because soil layer mixing effect of tillage results higher silt and clay content in the upper layer, in the case of the Control treatment (C), which did not get any organic matter addition (Fig. 1.). Decreasing of the Heavy fraction <53 µm as the result of the organic matter addition is less well pronounced in the lower layer because the effect of organic matter addition is concentrated mainly to the upper layer.

Summing up our results, as it was expected before, for the effect of the organic matter addition, increasing of the mineral associated organic matter ie. intra-microaggregate

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POM (Heavy fraction >53μm)) fraction was reported in the Maize stem (M) > Maize stem & Wheat straw (M & W) > Wheat straw (W) order, therefore soil structural stabilizing and adaptive capacity enhancing effect of addition of crop residues was proved.

Conclusions

Utilisation of Maize stem (M), Maize stem & Wheat straw (M & W), Wheat straw (W) residues to ameliorate soil fertility and stability was investigated. The changes of the amount of the indicator-ruled mineral associated organic matter ie. intra-microaggregate POM fraction proved the soil structural stabilizing and adaptive capacity enhancing effect of the investigates crop residues in the mentioned order. Organic matter addition enhanced the decomposing of bigger sized plant debris to smaller parts and gluing agents, and therefore the association of mineral particles to each other and building aggregates which resulted the decreasing of the single mineral particle fraction (silt and clay fraction).

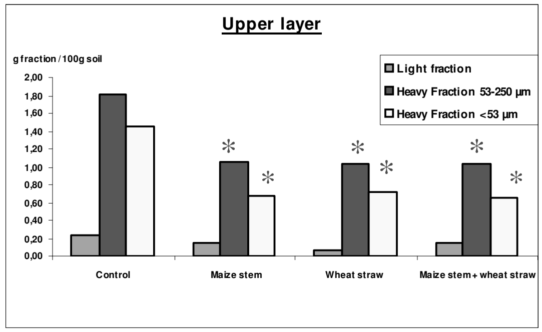

Figure 1.

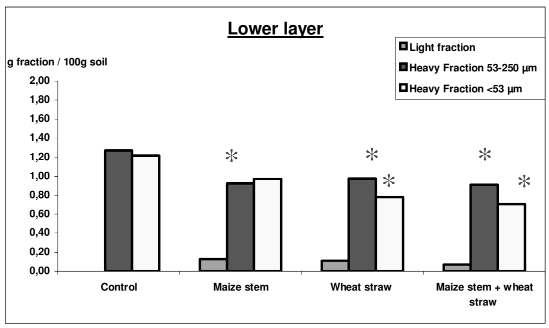

Figure 2.

Figure 1-2. Effect of different crop residues on the different SOM fractions

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RESILIENCE OF THE VEGETATION IN SALINE LAKES ON THE BASIS OF SZAPPAN - SZÉK BETWEEN THE DANUBE AND TISZA RIVERS

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Abstract: In last decades, because of the groundwater level decrease, saline lakes of sand ridges between the Danube and Tisza rivers mainly desiccated, or water disappeared from the lakes for a long time.
There were some years in the last period, when high amount of precipitation fell, therefore groundwater level increased. Vegetation adapted resiliently to the opposite changes: desiccated phytocoenosis came to the front parallel with groundwater level decrease. Afterwards, as a consequence of returned high groundwater level the vegetation showed changes toward wet conditions again.
In this paper we present changes of the vegetation in the environment of Szappan-szék between the Danube and Tisza rivers in the last twenty years. It contains aspect of the adaptation to the changing environment as well, together with risks, which reside in extreme rapid transformations.

Keywords: saline lakes, vegetation, groundwater level

Introduction

Water level of saline lakes between the Danube and Tisza rivers depends on groundwater level the most. In last decades, because of the groundwater level decrease, saline lakes of sand ridges mainly desiccated, or water disappeared from the lakes for a long time.
However there were some years in the last period, when high amount of precipitation fell, therefore groundwater level increased (Rakonczai, 2007). Vegetation adapted resiliently to the opposite changes. Desiccated phytocoenosis came to the front parallel with groundwater level decrease (Ladányi et al., 2009). As a consequence of returned high groundwater level the vegetation showed changes toward wet conditions again. Afterwards environmental changes were so fast, that the natural vegetation structure broke down on large areas.

Materials and methods

Among saline lakes of sand ridges the groundwater level and water coverage related changes of vegetation can be followed the best on the example of the vegetation of Szappan-szék. About the vegetation of Szappan-szék there were made vegetation maps at the Szeged University (Fehér, 2004; Bagi, 1988; 1989) in 1987, 1994 and 2003. The vegetation maps available became simplified from the aspect of water demand of the certain phytocoenosis with the help of Kiskunság National Park researchers. This simplification made the changes more lively.
The dataline of the groundwater wells located in the environment of the researched saline lake were provided by the Alsó-Dunavölgyi Environmental and Water Conservation Directorate and VITUKI. Among them the groundwater well no. 1387 has the longest dataline (with observation started in 1960), therefore we used the dataline of

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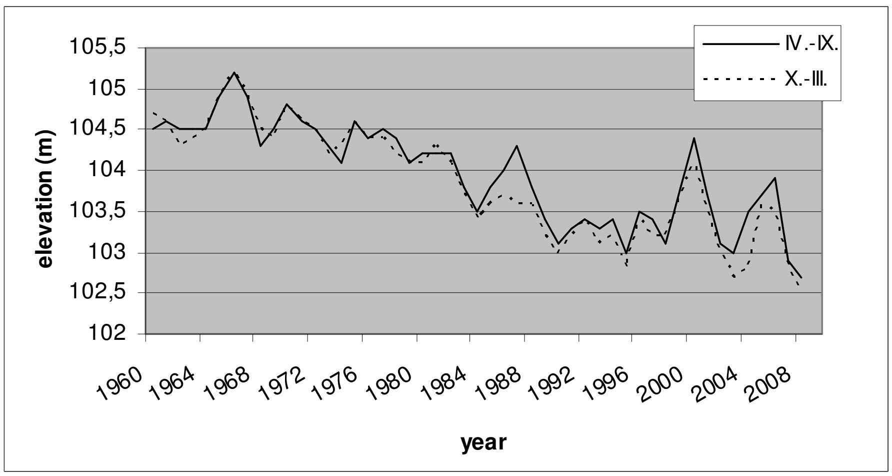
this well for presenting the groundwater level. The data were graphed with Excel charts. The meteorological data became available by the Agrometeorological Station of Kecskemét.

The simplified vegetation maps of the saline lake were compared to the groundwater level data. We evaluated the vegetation changes in the environment of Szappan-szék considering the altitude actualised with GPS measurement.

Results and discussion

In water coverage of Szappan-szék the fresh supply on surface has a dependent role. Water coverage is determined primarily by the groundwater level and its fluctuation.

The annual medium groundwater levels show dependence on the annual precipitation. The annual medium groundwater level in the last 50 years can be seen on Fig. 1.



(Source: VITUKI)

Figure 1. Annual medium groundwater level in winter and summer term (1960-2008.)

After the droughty years of the 1990's there came a precipitation peak in 1999, and considerable inland water coverage and groundwater peak in 2000. This implied that Szappan-szék filled with water and consequently its vegetation changed.

However the abundance of precipitation and water proved to be temporary and after 1999-2000, drought became dominant again with significant fluctuations in precipitation and groundwater level. Years 2004-2005 brought more precipitation than the average (with 672 mm and 610 mm annual precipitation) implying higher groundwater level again in 2006. Nevertheless this did not change the tendency of decreasing.

On vegetation maps of 1987, 1994, and 2003 there can be followed excellent the changes taken place during the 15 years (Fig. 2.). Szappan-szék was an open lake until the 1960's, then starting from the decade of 1980's it has desiccated several times due to low groundwater levels. For this reason the vegetation map of the lake basin made in 1987 already shows a rearranged state, which differs from the typical water related vegetation of saline lakes.

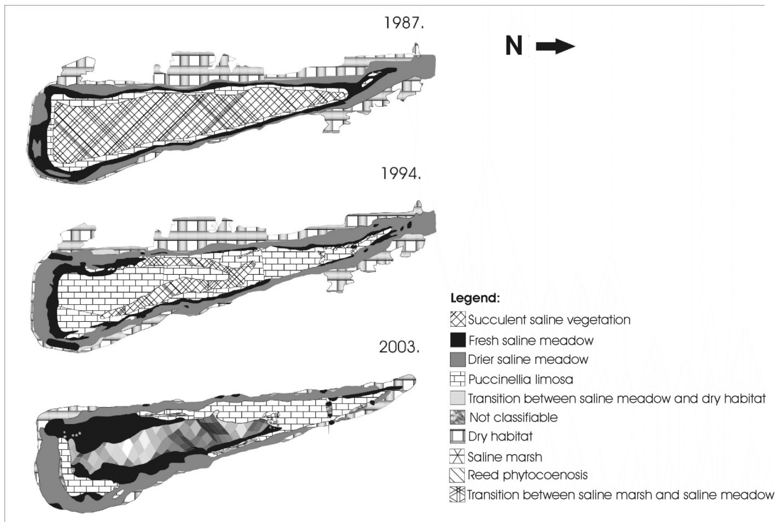


Figure 2. Vegetation map of Szappan-szék (1987, 1994, 2003.)

Vegetation zones of saline lakes change parallel with the basin depths as well as the water supply. The open water basin is bordered by saline marsh and *Bolboschocnus maritimus* with reed phytocoenosis followed by fresh saline meadow, *Puccinellia limosa, Camphorosma annua***,** *Camphorosmetum annuae* and steppe with *Artemisia santonicum* moving away from the water, in natural zonation order (Szujkó-Lacza – Kováts, 1993). In case of Szappan-szék in 1987 the lake basin was covered mostly by continental succulent saline vegetation (*Camphorosmetum annuae*), which was circled by *Puccinellietum limosae* (*Puccinellia limosa*) and saline meadow in forms of narrow zones. Accordingly by 1987 the place of the open water lake has become occupied by such vegetation that represents an environment equivalent to desiccating conditions.

Between 1987 and 1994 the desiccation of the lake continued. During this period it happened several times, that even in case of the highest annual groundwater level there were no water coverage on the surface. At the same time the low-water marks did not fall deeper than 1 m from the former lake surface. Consequently – due to the capillary effect – the phytocoenosis acquired the minimum moisture needed. At the same time the fresher type of the saline meadows decreased, and the droughty type of it increased. However the less mobile *Puccinellietum limosae* remained, which was varied by ephemeral plants during the droughty months.

The state of year 1994 presents the spread of *Puccinellia limosa* in the lake basin. This was caused primarily by the further desiccation, and partly probably by the increasing organic matter content of the lake basin.

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In 2000, following the inland water coverage in early spring, the groundwater level increased one meter compared to 1999. It implied that the open water surface returned again for a short time. The subsistence of the open water killed off the phytocoenosis that had settled in the lake basin during the past years. This lighted up the possibility that the states existed until the 1960's might return. Nevertheless the open water coverage did not prove to be lasting, and as effect of the droughty summers after 2000 (primarily year 2003) – when the groundwater went down more than 1 m compared to the lake surface – the zonation of the lake basin collapsed. During this period the vegetation adjusted itself to the environmental conditions in a way that unclassifiable phytocoenosis appeared in the former lake basin. Parts unaffected by the short-term water coverage became coated by fresher and dryer saline meadow, but the *Camphorosmetum annuae* disappeared.

Conclusions

Comparing the vegetation maps of Szappan-szék near Fülöpháza made at different times with the groundwater decrease and precipitation data. There can be discovered those changes, which have taken place on natural phytocoenosis level during the past 25 years.

In case of Szappan-szék by 1987 the place of the open water lake was occupied by such vegetation that represents an environment adequate to the desiccation conditions.

The state of 1994 showed the spread of *Puccinellia limosa* in the lake basin. It means an adaptation to the low precipitation amounts and primarily to the low groundwater levels of the seven years between 1987 and 1994.

As effect of the speedy changes in precipitation amount and groundwater level around the millennial turn, the state of 2003 presents a kind of "rearrangement" towards the wetter period of years before the 1970's. At the same time the fast, opposite changes meant such a challenge for the vegetation, that as effect of it the natural phytocoenosis structure broke down on large areas, and even unclassifiable phytocoenosis appeared.

Consequently, beside the serious adaptability of the flora it cannot be left out of account, that the rapid environment changes, including mostly the considerable fluctuation and decreasing tendency of the groundwater level, started such an alteration in the natural vegetation that probably will not be able to ensure the survival of vegetation typical of saline lakes in the future.

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SEASONAL CHANGES OF CHEMICAL AND BIOLOGICAL PARAMETERS OF LOAM ORTHIC GREYZEMS UNDER DIFFERENT TILLAGE TREATMENTS

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Abstract: Relationships between the seasonal changes in key chemical and biological soil properties were evaluated in a loam Orthic Greyzems affected by different tillage systems. The experiment was established in Vladimir region of Central Russia in 1986. Several composite disturbed soil samples were randomly collected from plots of a long-term field experiment with such soil tillage systems as: conventional ploughing to 20-22 cm, shallow tine cultivation to 6-8 cm, deep tine cultivation to 20-22 cm, shallow tine cultivation to 6-8 cm combined with deep ploughing to 28-30 cm once in 5 years, and grassland (control), Our data demonstrated that all the tillage systems significantly affected soil biological parameters. The soil microbial community had the best soil conditions for utilizing available organic C for the formation of its biomass in soil with both deep tine cultivation to 20-22 cm and shallow tine cultivation to 6-8 cm combined with deep ploughing to 28-30 cm. The worst living conditions for microorganisms were observed in the soil with conventional ploughing to 20-22 cm. N_2O emission was significantly ($p < 0{,}001$) higher from the soil with conventional ploughing to 20-22 cm than from the other three tillage systems.

Keywords: loam Orthic Greyzems, soil tillage, basal respiration, microbial biomass carbon, N_2O emission

Introduction

One of the key tools of crop management is soil tillage affecting soil physical, chemical and biological properties (Green et al, 2007). The influence of soil tillage systems on the total SOM content is detectable experimentally only after a long period of time (Janzen, 2004). In opposite, microbial activity-based indicators of soil quality may respond to disturbances on a shorter period of time than those based on physical or chemical properties. As a consequence of their essential role in soil biology and of their rapid response to changes in soil management, microbiological properties have been used as potential indicators of soil quality and productivity (Anderson and Domsch, 1990; Ulrich et al., 2006).

The objectives of our study were to: (1) evaluate the seasonal dynamics of biological and chemical properties of loam Orthic Greyzems affected by four tillage systems, and (2) estimate the importance of changes in these soil properties for N_2O production in the soil.

Materials and methods

The field experiment was carried out in Vladimir region of Central Russia (56°34'06''N, 40° 27'28''E). Long-term average air temperature and average total amount of precipitation were equal to 13.2 °C and 343 mm for growing seasons (April – September) in this region. The soil of the region was a loam Orthic Greyzems. The field experiment was established in 1986. Soil samples were collected from a depth of 0-10

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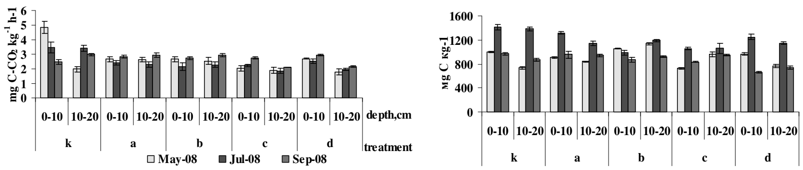
cm and 10-20 cm in May, July and September of 2008 during growing season of spring barley (*Hordeum vulgare*). 9-10 composite disturbed soil samples were randomly collected from plots with four soil tillage treatments: (a) conventional ploughing to 20-22 cm, (b) shallow tine cultivation to 6-8 cm, (c) deep tine cultivation to 20-22 cm, and (d) shallow tine cultivation to 6-8 cm combined with deep ploughing to 28-30 cm once in 5 years. A plot with native grassland (k) was used as a reference treatment. After sampling, the composite soil samples were air-dried, passed through a sieve with a diameter of openings of 2 mm, and stored for chemical and biological analyses (Chen et al., 2009). SOM content in samples was measured by a Tjurin's wet digestion method (Rastvorova et al., 1995). Mineral nitrogen (NO_3^-, NH_4^+) content was determined in soil extracts by an ion-meter equipped with relevant ion-selective electrodes. To measure a basal respiration, 4 g of the air-dried soil samples were moistened to field capacity, placed into hermetically closed 40-cm^3 glass vials, and incubated at 30 °C for 24 h (Wright et al., 2009). The CO_2 production was measured with a gas chromatograph, which was also equipped with an electron-capture detector for measuring N_2O concentrations in a headspace of glass vials with moistened soil samples. To determine the microbial biomass carbon (C_{mic}) content, measurements of substrate-induced respiration rates in soil samples were done using the gas chromatograph after adding glucose (5 mg g^{-1} soil) and their 3-h incubation in the same glass vials at 22 °C according to a method of Anderson and Domsch (1978). The results were subjected to an analysis of variance (ANOVA) for each sampling time, and the means, standart deviations (SDs) and coefficients of linear correlations between soil properties were determined at a confidence limit of up to 95%.

Results and discussion

Our data demonstrated that all the tillage systems significantly affected soil biological parameters. Warm and wet weather conditions of growing season in 2008 (average air temperature – 13.9 °C and total amount of precipitation – 472 mm) also had evident effects on the size and activity of soil microbial community. BR was significantly higher ($p < 0.001$) at the end of the growing season, and significantly decreased ($p < 0.05$) downwards-arable soil horizons in all the treatments, except for soil with the shallow tine cultivation to 6-8 cm (b), in which BR was significantly higher in the layer of 10-20 cm than in that of 0-10 cm in July and September. We observed maximum values of BR in the soil with shallow tine cultivation to 6-8 cm combined with deep ploughing to 28-30 cm once in 5 years (d), whereas minimum BR values were determined in the treatment with deep tine cultivation to 20-22 cm (c), as shown in Fig. 1. The observed differences in the tillage-induced BR values were probably induced by differences in availability and quality of SOM and its labile forms for soil microbial community (Toth et al., 2006, Dabek-Szreniawska and Balashov, 2007). Differences in C_{mic} content were also significant ($p < 0.001$) between the tillage treatments (Figure 1). Maximum C_{mic} content was observed in July and was higher in the soil with conventional ploughing to 20-22 cm (a) and with shallow tine cultivation to 6-8 cm combined with deep ploughing to 28-30 cm once in 5 years (d).



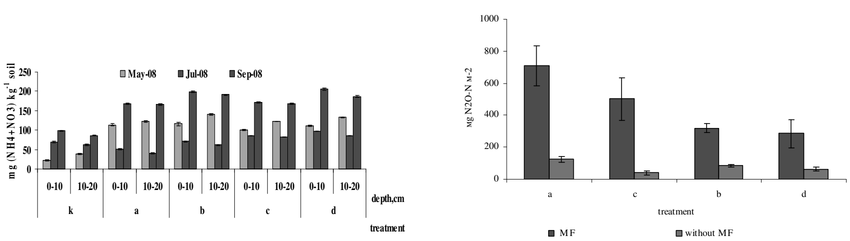
I II

Figure 1. Dynamics of BR (I) and C_{mic} content (II) in a loam Orthic Greyzems under different tillage: (a) conventional ploughing to 20-22 cm, (b) shallow tine cultivation to 6-8 cm, (c) deep tine cultivation to 20-22 cm, and (d) shallow tine cultivation to 6-8 cm combined with deep ploughing to 28-30 cm once in 5 years, (k) – native grassland, growing period of 2008.

The increase in C_{mic} content in July can be attributed to increasing soil temperature and amount of easily available organic matter originated from root and plant residues (Böhme et al., 2005). Air temperature was equal to +22/+28°C in July. After reaching its maximum values in the middle of growing season, C_{mic} content decreased to its previous spring level by autumn. C_{mic} content significantly correlated with SOM ($r = 0.76$, $p < 0.001$) and mineral N content ($r = 0.75$, $p < 0.001$).

Our data on seasonal changes in qCO_2 showed that soil microbial community could suffer a higher physiological stress at the end of growing season in all the tillage treatments as also supported by Sabo et al. (2007). The microbial community had the best living conditions for utilizing available organic C in the soil with the shallow tine cultivation to 6-8 cm and with shallow tine cultivation to 6-8 cm combined with deep ploughing to 28-30 cm once in 5 years. However, the worst conditions for soil microorganisms, in terms of qCO_2, were observed in the soil with deep tine cultivation to 20-22 cm, which could result in the highest decrease in availability and quality of available SOM (Anderson, Domsch, 1990; Böhme et al., 2005).

Soil mineral N concentrations were higher in the soil of the tillage treatments than in the reference soil, and demonstrated mostly significant changes during the growing season. Seasonal dynamics of soil mineral N concentration showed its decrease in July, probably as result of highest immobilization of mineral N by soil microorganisms strongly utilizing easily available organic carbon for the formation of their biomass in this period of time (Figure 2).



I II

Figure 2. Dynamics of mineral N (I) and cumulative N_2O emission (II) from a loam Orthic Greyzems under different tillage, growing period of 2008.

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If all the four different tillage systems were compared together, the lowest cumulative N_2O fluxes were measured from the soil with shallow tine cultivation to 6-8 cm (284±88 mg N_2O-N m^{-2}) and with shallow tine cultivation to 6-8 cm combined with deep ploughing to 28-30 cm once in 5 years (310±61 mg N_2O-N m^{-2}), as shown in Fig. 2. Two other tillage treatments resulted in higher cumulative N_2O fluxes from soils probably as a result of: (1) degradation of soil structure, and (2) subsequent increase in soil bulk density. If it is necessary to select an environmentally rational soil tillage system in this region, it is better to avoid that one leading to an increase in soil bulk density of the topsoil or in degradation of soil structure.

Conclusions

The results of our studies showed that among the studied tillage systems, both shallow tine cultivation to 6-8 cm and shallow tine cultivation to 6-8 cm combined with deep ploughing to 28-30 cm once in 5 years contributed to a formation of the best living conditions for soil microbial community in a loam Orthic Greyzems. Significant increase ($p < 0.001$) in C_{mic} content was observed in the middle of growing period in all the tillage treatments. In terms of N_2O emission, both shallow tine cultivation to 6-8 cm and shallow tine cultivation to 6-8 cm combined with deep ploughing to 28-30 cm once in 5 years were the best tillage systems from an agro-ecological point of view.

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SOIL CONDITION AND YIELD STUDIES IN AN INTERNATIONAL FERTILISATION EXPERIMENT

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Abstract: Different stress factors and stability changes in the structure can induce soil compaction. Already developed compaction changes the relationship between soil elements, pore size and quantity. Cultivation failures in plant growing trials reduce yield through limiting moisture household and fertilizer efficiency in dry years. Yield loss is higher in treatments where root zone is half or one third shallower because of compaction. We found a very close correlation (R = 0.98) between the moisture content and the resistance to penetration. Moisture content determined the resistance at 96 %. We could show significant difference (0.1 %) between the layers determined by the penetrogram, no matter which layer we compared

Keywords: soil condition, compaction, soil moisture

Introduction

Different stress factors and stability changes in structure can induce soil compaction. Already developed compaction changes the relationship between soil elements, pore size and quantity as a result the field capacity reduces. The soil cultivation ability decreases through the changed relationship between the soil elements. Soil structure in the compacted layer becomes lamellar and roots are not able or can hardly get through this layer and as a result water and nutrient uptake decrease and roots develop poorly. The soil can become airless, which limits aerobe processes. All these factors lead to the deterioration of soil quality, to yield depression and make the way for different processes of degradation. Developed compaction can considerably change soil structure, as a result pore volume decreases (Pagliai et al., 2003). Soil cultivation changes the ratio of pore volume responsible for water retention and water non-retention, so soil cultivation is of great importance. Soil cultivation shall be used for controlling soil structural features so that most rainfall leave the soil through the plant and soil transpiration always remains at minimal level. Soil cultivation methods like deep or deepening tillage that assist water uptake create favourable soil physical conditions through loosening the compact upper compacted layer or the one with poor water draining ability (Birkás, 1987, 2002; Ruzsányi and Lesznyák Mné, 2003; Schmidt et al., 1998/a). On compacted soil yield is closely connected with the coverage and function of roots. Most models take root growth into consideration when evaluating penetration resistance and moisture level in soils. The critical value of soil resistance can be estimated which inhibits root growth (Dexter, 1987; Diggle, 1988; Bengough and Mullins, 1990; Schmidt et al., 1998/b). This critical value can change in relation to soil texture, macro-porosity depth and plant variety (Glinski et Lipiec, 1990; Pabin et al., 1998; Schmidt et al., 2000).

Materials and methods

Measurements were carried out during long lasting International Organic and artificial Fertilization Experiments (IOSDV) maintained by Pannon University Georgikon Faculty (2003, 2004). The experiment was launched in split-plot design with three

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replications in 1983. Maize, winter wheat, winter barley and oil seed rape (after winter barley as stubble crop) were grown there. The plot size was 48 m^2. Stem residues and straw were incorporated into the soil completed by the application of organic and green manure as well as artificial fertilizers in different doses. The trial plot was set on a field with sandy loam of Ramann-type brown forest soil, poor in organic matter, with available low P_2O_5 and moderate K_2O content. The soil profile showed an initial compact layer in a depth of 0.25-0.30 m. There was lack of rainfall in the years of testing: 174.4 mm in 2003 and 63.9 mm in 2004 respectively. Measurements were carried out with a 3T system penetrometer in 20 replications per treatment until the depth of 0.50 m. The equipment contains an electronicmeasuring cell, wich gives the value of penetration resistance in kPa and the soil water content as the rate of field capacity expressed in the percentage of soil moisture (pF 2.5). The penetrometer stores the measured data in an electronic module. The data are processed by Microsoft Excel and prepared for statistical analysis. Statistical evaluation was done by MS Excell and Statistica. Single factor analysis of variance was used to evaluate the yield results. Analysis of regression was used to evaluate the effect of measured moisture content on penetration resistance. Analysis of variance was used to evaluate the mechanical resistance of layers determined on the basis of penetrograms.

Results and discussion

In October 2003 (Fig. 1) the resistance to penetration reaches the critical value of 3.5 M Pa at 0.20 m. A tillage pan layer can be observed in depths of 0.20-0.37 m, where the value of resistance is about 6 MPa. In layers at 0.38-0.50 m the mechanical resistance is continuously increasing due to settlement as well as natural compaction of soil. We can observe seedbed preparation failures in the upper 0.05 m deep soil layers too. As the soil was wet at the time of measurement (Fig. 1) the measured values of resistance to penetration reflected probably the real soil condition. The maximum value of soil moisture and the site of tillage pan layer were to observe at the same depth. The compact layer delayed the wetting of the profile, which can explain this fact. With the use of quadratic equation ($Y' = -0.2903 + 0.3220x + -0.0040x^2$) we calculated a moderate close correlation between the soil moisture content and the resistance to penetration ($R = 0.5235$). The effect of moisture on determining compaction reflects 27 %. The quadratic effect is significant at 5 %. The layer analysis proved a difference of 0.1 % between five layers. The difference between the layers of 0.01-0.10 m and 0.11-0.15 m is tendentious. The resistance values of layers at 0.11-0.15 m and 0.16-0.25 m differ at a significant level of 0.1 % with $LSD_{5\%} = 1.02$. The difference between the layers of 0.16-0.25 m and 0.26-0.35 m can be confirmed at significant level of 1 % with $LSD_{5\%} = 0.83$. We found significant difference of 0.1 % between the layers of 0.26-0.35 and 0.36-0.50 m with $LSD_{5\%} = 0.76$ (Table 1).

Table 1. IOSDV experiment with analysis of variance per layer, in maize of Oct.2003, 2004

Layers 2003	$LSD_{5\%}$	Level	Layers 2004	$LSD_{5\%}$	Level
0.01-0.10m és 0.11-0.15m	1.02	NS	0.01-0.10m és 0.11-0.20m	0.49	***
0.11-0.15m és 0.16-0.25m	1.02	***	0.11-0.20m és 0.21-0.30m	0.49	***
0.16-0.25m és 0.26-0.35m	0.83	**	0.21-0.30m és 0.31-0.50m	0.42	***
0.26-0.35m és 0.36-0.50m	0.76	***			

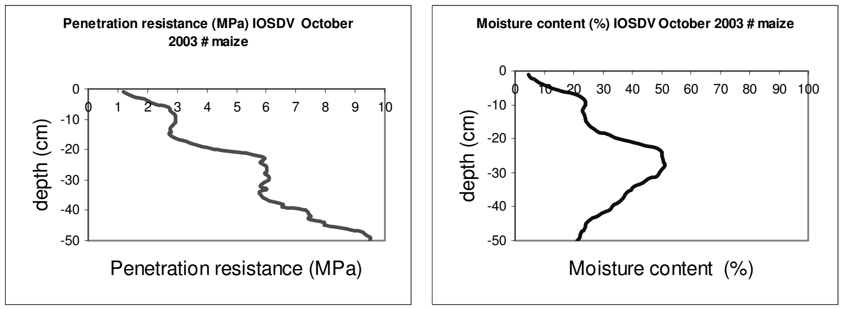

Figure 1. Penetration resistance and moisture content in Oct. 2003

In October 2004 penetration reaches the critical level in layers deeper than 0.20 m. In depth of 0.25-0.40 m we could observe the maximum value, which is as high as measured in the year before followed by a decrease in values (Fig. 2). The development of the penetrogram like this can be explained by the fact that the soil was drenched with rain. The moisture measurement results refer to the fact that the soil was drenched through until the tested layer and similar to the maize monoculture experiment (Fig. 2). We evaluated the measurement results with statistical methods and found a very close correlation (R = 0.98) between the moisture content and the resistance to penetration ($Y' = 0.2076 + 0.0311x + 0.0001x^2$). Moisture content determined the resistance at 96 %. We could show significant difference (0.1 %) between the layers determined by the penetrogram, no matter which layer we compared (Table 1).

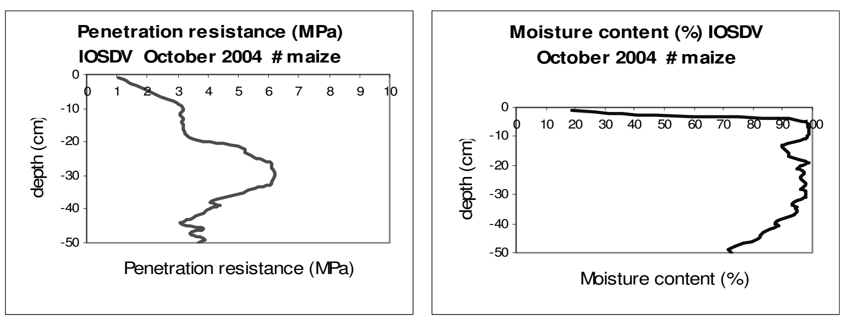

Figure 2. Penetration resistance and moisture content in Oct. 2004

The following table shows the yields of maize kernels (t ha^{-1}) and the doses of manure in the IOSDV long term experiments:
Where: I.: fertilizer, II.: artificial and organic manure, III.: artificial manure, straw incorporation and green manure treatment are compared.There were significant differences between the yields both in draughty or average years. Highest yields were produced if we applied a combination of artificial and organic manure. The lowest yields were produced on plots, where only artificial fertilizer was applied. In 2004, which can be considered as an average year, maize yield was 50 % higher than in the

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draughty year of 2003. The yields and penetration resistance values show the effect of the relevant year as well.

Table 2. Kernel yields of maize, and the doses of manure IOSDV

Year	I	II	III	$LSD_{5\%}$
2003	3..579	4.463	4.146	0..27
Soil condition	At 0-20cm good, deeper compacted			
2004	7.731	8..578	8..203	0..96
Soil condition	At 0-20cm good, deeper compacted			
I	II	III		
P_2O_5: 100 kg ha^{-1} K_2O: 100kg ha^{-1}				
N0: 0 kg ha^{-1}	N0: 0 kg ha^{-1}	N0: 0 kg ha^{-1}		
N1: 70 kg ha^{-1}	N1: 70 kg ha^{-1}	N1: 70 kg ha^{-1}		
N2: 140 kg ha^{-1}	N2: 140 kg ha^{-1}	N2: 140 kg ha^{-1}		
N3: 210 kg ha^{-1}	N3: 210 kg ha^{-1}	N3: 210 kg ha^{-1}		
N4: 280 kg ha^{-1}	N4: 280 kg ha^{-1}	N4: 280 kg ha^{-1}		
	#: 31.250 t ha^{-1}	straw, green manure		

Conclusions

Compaction failures can develop and extend at a higher rate than usual due basic cultivation failure after late harvest. In dry years soil resistance values are generally higher due to lower moisture content therefore the featuring differences in soil condition are minor. Cultivation failures in plant growing experiments can reduce yield through limiting moisture household and fertilizer efficiency. Yield decrease is always higher in treatments, where the root zone is twice or thrice as shallow as the normal because of the damage.

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SOIL MANAGEMENT SYSTEMS INFLUENCING SOIL CARBON DIOXIDE EMISSION IN A PEACH PLANTATION

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Abstract: The aim of this work was to analyze our newly developed method for determining soil carbon-dioxide emission from large undisturbed soil cores under controlled laboratory conditions. The soil samples were taken from a peach plantation, where two management practices were carried out: undisturbed, grass-cover rows alternated with oft-times (every second-third week) disked rows. The samples were incubated in a climatic room. Soil CO2 efflux was determined using a gas chromatograph. Management-induced differences in soil CO_2 emission were evaluated at different soil water content and water potential values. Significant differences between soil CO2 efflux values, measured in different treatments were found for almost all the measurement dates. Our results indicate that undisturbed soil samples has to be used when comparing the effects of soil treatments, influencing soil structural status on soil carbon dioxide emission.

Keywords: carbon-dioxide emission, climatic room, soil water potential, large undisturbed soil cores

Introduction

Carbon dioxide is recognized as a significant contributor to climatic change, accounting for 60% of total greenhouse effect on global warming of earth's climate. Hence, there is a growing interest in quantifying the significant sources and sinks of this trace gas (Barcza et al., 2009). The influence of various land use and soil management systems on soil carbon storage and greenhouse gas emission are being examined worldwide for implementing carbon sequestering practices (Kersebaum et al., 2009; Smith et al., 2009). The primary sources of soil carbon dioxide efflux are root and microbiological respiration. Their rate highly depends (Smith et al. 2003) on soil temperature, soil organic matter content and soil water content (Szili-Kovács et al., 2009). Soil temperature and water content were found to be the major factors influencing temporal variation of carbon dioxide emission, because they directly affect roots and microbial functioning (Smith et al., 2003; Szili-Kovács, 2004).

Processes standing behind soil respiration and microbial activity have strong soil- and site-specific nature (Birkás, 2009) and – due to their complexity – the timing (just after soil disturbance or much later; with or without vegetation cover, etc.) and conditions of measurements (soil temperature and water content and their stability during the incubation, etc.) have strong influence on the outcome.

Uncontrolled changes in soil temperature and water content during in situ incubations make evaluation of field measurements complicated. Thus, the effect of various factors on soil carbon dioxide efflux can hardly be distinguished.

Our newly developed measuring technique at RISSAC is designed for measuring soil carbon dioxide emission from undisturbed soil samples under controlled laboratory conditions at a range of soil water potential values. Measurements carried out at similar soil water content values calculated on mass base make difficult to compare the results, obtained for soils belonging to different textural classes, because the same mass-based soil water content value in e.g. sandy and clay soils reflects totally different energetic

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status of water in soil. The new measurement approach makes possible to account for the effect of soil structural status and soil water potential on soil CO_2 emission. Our objectives were to test the new experimental set up and to analyse the effect of tillage-induced soil structural properties on soil CO_2 efflux under controlled circumstances.

Materials and methods

As soil respiration concerns topsoil where soil microbial activity is the most intensive (Agbeko and Kita, 2007), soil samples for laboratory analyses were collected from the upper 10 cm layer. The samples were taken in a peach plantation, located in Vác, from two management practices: from i) undisturbed, grass-covered rows and ii) oft-times (every second-third week) disked rows. Twenty-three undisturbed samples per treatment were collected in PVC tubes (20 cm long; 10.5 cm i.d.); twenty for laboratory incubations and three for determining initial conditions. In addition, three undisturbed soil samples of 100 cm^3 volume were taken from each of the treatments and analysed for bulk density and soil water retention characteristics at water potentials of -1, -2.5, -10, -32, -100, -200; -500, -2500 and -15850 hPa (Várallyay, 1973). Disturbed soil samples were analysed for soil physical, chemical and biological properties (Table 1).

The large soil cores were placed in a climatic room and watered from the top to obtain different soil water potential values inside the columns. The amount of water added to the samples was calculated (Tóth et al., 2009) from i) the average initial soil water contents and ii) the average water retention curves, characteristic for the particular treatment in the upper 10 cm layer. The columns remained undisturbed during the whole measurement procedure and their mass was determined at each air sampling time.

Soil carbon dioxide emission measurements were carried out 12 times in a climatic room at constant humidity, light conditions and air temperature of 21°C. After nine measurement dates samples were watered back to their initial mass.

On each sampling day two air samples – in the beginning and after three hours of incubation - were collected into evacuated vials (Exetainer tube, Labco Limited, UK). The CO_2 concentration was analysed using a gas chromatograph. Soil CO_2 fluxes were calculated from detected changes in carbon dioxide concentration.

Differences in soil CO_2 fluxes and bulk density values, attributed to various treatments were analysed by ANOVA using the STATISTICA software (StatSoft Inc 2001).

Results and discussion

Effect of treatments on soil properties influencing soil CO_2 efflux

We found considerable differences in almost all the examined properties between the two treatments (Table 1), especially in those indicating microbiological activity (water extractable organic carbon (WEOC) and nitrogen (WEON) contents, microbial biomass carbon and nitrogen contents). Despite WEOC and WEON represent a small part of soil organic matter; they appear to be involved in many soil processes. Nevertheless, it is now recognized that those molecules do influence soil biological activity. On the basis of chemical soil properties it is well seen that undisturbed, grass-covered rows are richer in all nutrients and soil life. Microbiological soil life is more intensive under grass.

Statistically significant differences between bulk density values of the 0-5 cm layer were found in the two treatments (Table 2). This can be explained with the loosening effect of grass-roots, which have the highest density in the topsoil.

Table 1. Soil chemical, biological and hydraulic properties measured in the different rows

Soil properties	grass-covered row		disked row	
	0-5cm	5-10cm	0-5cm	5-10cm
pH (KCl)	7.76	7.96	7.3	7.29
pH (H2O)	7.12	7.21	8.15	8.13
Total N [mg/kg]	1805		1298	
K_2O [mg/kg]	387		244	
P_2O_5 [mg/kg]	382		337	
WEOC [µg C/g soil]	138.10	93.90	41.56	41.11
WEON [µg C/g soil]	10.58	7.01	1.48	3.16
Microbial biomass C	234.5	87.0	52.0	32.9
Microbial biomass N	50.0	17.0	9.1	8.8
Organic carbon %	1.32		0.98	
Humus %	2.28		1.69	
Bulk density [gr/cm^3]	1.18	1.43	1.35	1.47
Water content at saturation [v%]	57.3	48.1	51.3	47.6
Field capacity [v%]	38.1	33.2	31.2	32.5
Wilting point [v%]	10.3	10.4	9.7	10.6
Plant-available water content [v%]	27.8	22.8	21.5	21.9

Effect of treatments on soil carbon-dioxide emission

Significantly higher CO_2 emission values were measured in the grass-covered row compared to the disking treatment in almost all the measurement times (Table 2) and at various soil water content status (Figure 1). These results indicate that although tillage results in oxygen-rich state in the topsoil, regular soil disturbance destroys soil microbiological life, thus, reduces soil microbial activity.

Table 2. Mean values and standard deviations (SD) of soil CO_2 fluxes- measured in different times- as well as of bulk density (bd) values in different treatments

Time	Treatment	n	Mean*	SD	Time	Treatment	n	Mean*	SD
1	Disking	20	1.23 a*	0.49	7	Disking	19	1.81 a	1.24
	Grass	20	4.92 b	2.89		Grass	20	4.08 b	2.66
2	Disking	20	4.18 a	4.26	8	Disking	15	1.54 a	1.45
	Grass	20	15.56 b	6.18		Grass	20	2.17 a	1.37
3	Disking	20	5.71 a	4.36	9	Disking	20	5.72 a	3.60
	Grass	20	19.40 b	9.86		Grass	19	18.71 b	6.84
4	Disking	20	4.50 a	3.33	10	Disking	16	1.09 a	1.11
	Grass	20	11.92 b	7.15		Grass	20	1.89 a	1.63
5	Disking	20	6.87 a	4.10	11	Disking	11	0.49 a	0.50
	Grass	20	17.11 b	10.60		Grass	18	0.98 a	0.96
6	Disking	19	2.82 a	2.17	12	Disking	12	0.29 a	0.18
	Grass	19	6.33 b	4.80		Grass	20	1.10 b	1.03
Bd	Disking	20	1.19 a	0.13	Total	Disking	212	3.31 a	3.53
	Grass	20	1.07 b	0.11		Grass	236	8.71 b	8.98

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**Mean values are significantly different at a probability level P < 0.05, if the same letters do not follow them.*

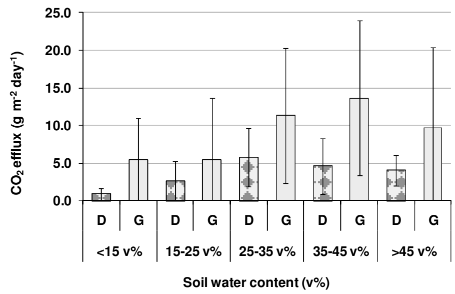

Figure 1. Soil CO_2 efflux measured in grass (G) and disking (D) treatments under various moisture conditions

These results are in accordance with those (Table 1), indicating higher microbial activity in the undisturbed treatment.

Conclusions

We compared soil biological properties and CO_2 emission in undisturbed grass and regularly disked rows of a peach plantation. Significantly higher CO2 fluxes were measured in the grass in a wide range of soil water contents at almost all the measurement times. Our results indicate that besides the favorable effect of soil tillage on soil aeration, regular soil disturbance reduces soil microbial activity.

Acknowledgements

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SOIL MICROBIOLOGICAL STATUS AND SOIL RESILIENSE WITH ZN AND CR CONTAINING SEWAGE SLUDGE DOSES

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Abstract: Some soil-quality parameters of four representative Hungarian soils were assessed following the alternative organic treatments with communal and industrial sewage sludge doses (0, 2.5, 5, 10 and 20 g kg^{-1}, as 0, 7.5, 15, 30 and 60 kg ha^{-1}) in a "long-term" pot-experiment. At the 3rd year (representing 12 years of field application) the colonization of arbuscular mycorrhiza (AM) fungi and among others coliforms as microbe of food-safety importance were assessed in the rhizosphere of green-pea (*Pisum sativum*). Soil-resilience, measured as the available nutrients (N, P) and the soil (rhizo-) microbiological status were found to be improved by the increasing doses of sewage sludge, more particularly at the sandy type of soils. After the repeated application, however, colonization value of the beneficial AM fungi was decreasing; the abundance of coliforms was increasing concomitant with the accumulation of toxic heavy metals, more particularly the Zn content. Care should be given for the acidic forest soils with its high elimination potential on the resilience-important biofertilizer-type of mycorrhiza fungi..

Keywords: soil fertility, biofertilizer, microbes of food-safety importance, soil quality, heavy metals.

Introduction

Stabilized, digested and/or composted, pathogen-free communal sewage sludge can be a resource in the agriculture, by replacing alternatively the farmyard manure and the fertilizer applications (Biró et al., 2004). Soil-resilience can be highly improved with those amendments (Franco et al., 2004). The use of sewage sludge has several advantages, as the improvement of water-holding capacity, soil-plasticity, nutrient availability and also the microbial, soil-biological properties. The land deposition is encouraged by the European Community, beside the fact, that heavy metals (toxic elements) and organic micro-pollutants are accumulating in the soils by the frequent application, reducing the soil resilience in general. Care should be given more particularly for the long-term applications, and monitoring tools must be developed in the soil-plant-animal-human food chain (Biró et al., 2004; 2008; Gregory et al., 2009). According to the literary data different soil-biological parameters, such as the N_2-fixing microsymbionts, the soil algae, or the other soil-biological properties can be highly affected by the heavy metals and/or the sludge applications (Biró et al., 2005). Beside those investigations the elimination of microbes of food-safety importance should be a key issue. Simultaneously the abundance and functioning of beneficial microbes (biofertilizer bacteria and fungi) could be maintained long for improving the soil quality and fertility. Those specific microbes are used to show the degradation level of soils (Franco et al., 2004). For safe soil resilience assessment the use of soil-biological and the more usual soil-physical-chemical features are suggested (Kuan et al., 2007). But which microbiological tools can indicate properly those characteristics? Beside the yield elements of crops, changes of soil(rhizo)microbiological status are suggested to consider. Microsymbionts supply the plants with macro- and microelements, their abundance are in connection with the plant growth, soil fertility and resilience.

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Microbiological status of four Hungarian soils were investigated at the increasing doses of two sewage sludge types, in a pot-experiment after 3 years of regular applications.

Materials and methods

The effect of increasing sewage sludge doses (0, 2.5, 5, 10 and 20 g kg^{-1} soil, as 0, 7.5, 15, 30 and 60 t ha^{-1} ratio) for the growth and metal uptake of green pea (*Pisum sativum* L.) was investigated in a long term pot experiment (10 kg dry soil/pot), in four representative Hungarian soil types, ((calcareous- chernozem (CC), calcareous sand (CS), acidic- forest (AF), acidic sand (AS)) in 4 consecutive years. The pots were treated once a year with the relevant doses of sewage sludges one communal (Com) with high Zn content (6157 $mg.kg^{-1}$ d.w.), and one industrial (Ind) sludge with high Cr content (5226 $mg.kg^{-1}$ d.w.). Beside the yield elements of pea and the ICP analysis of element-contents, the colonization of arbuscular mycorrhizal fungi (AMF) was assessed according to Trouvelot et al. (1986). The abundance of coliforms, having food safety importance was investigated by the MSZ 3640/18-79. Colonization of AMF was arcsin-transformed; the abundance of coliforms was log10-transformed preceding the statistical analysis. Standard deviations (SD) or the least significant differences ($LSD_{5\%}$) are labeled.

Results and discussion

Table 1 shows the nitrogen (N), phosphorous (P) and heavy metal (Zn or Cr) concentrations in the four Hungarian soils treated with the two different sewage sludges. The values of the increasing sludge doses are summarized and average values for the two different sludge-types are shown. The final macro-element content in the soils resulted by the sludge-addition was highly influenced by the soil-types. Available P content increased significantly in the acidic soils (AC, AF), the N-content was greater in the calcareous soils (CS, CC). The treatments with sewage sludge result in a considerable increase in the available nutrient content of the soils. However, simultaneously the amount of heavy metals, the Zn at the communal sewage sludge application, or the Cr at the industrial sludge application was found also to be increasing. The soil types did not differ very much in this respect, however, the acidic forest (AF) seemed to accumulate Zn (but not the Cr) at a higher rate, than the other soils. After 3 years of application the average available content of the Zn and Cr in the soils, independently from its types, was not reaching the limits of permission, in spite of the fact that it was representing a 12 years of application in the model experiment.

Care should be given, however for the increasing doses of sewage sludge. In case of macro elements (N, P), the content can be 4-7-times greater at the highest sludge doses. Concomitant with the nutrient improvement of soils, the availability of heavy metals on the other hands are also increasing, as a function of the sewage sludge doses and the application time periods. This fact was shown also on the microbial colonization data (Figures 1 and 2).

The colonization of the beneficial arbuscular mycorrhiza fungi (AMF) was found to be decreasing with the applied doses in case of both types of sewage sludge (Figure 1).

Table 1. Nitrogen (N) as NH_4NO_3 (mg kg^{-1}), phosphorous (P, in ppm) and Zn or Cr (ppm) content of the four Hungarian representative soils (CC, CS, AF, AS) treated with communal (Com) or industrial (Ind) sewage sludge doses after 3 years of application, in 2001. Mean and SD of 4 replicates.

CC		CS		AF		AS		Sludge-
Mean	SD.	Mean	SD.	Mean	SD.	Mean	SD.	elements
30.1	2.6	18.7	9.6	28.8	6.6	9.5	1.4	Com-N
402.6	4.5	390.6	24.9	1245.3	63.3	662.5	77.5	Com-P
107.4	16.4	84.2	7.3	170.1	9.2	94.6	9.1	Com-Zn
28.7	4.5	19.6	9.9	13.7	4.0	14.2	4.3	Ind-N
110.8	3.6	142.0	1.6	482.5	17.2	138.3	6.7	Ind-P
8.3	0.2	7.1	0.6	7.7	3.8	24.9	0.6	Ind-Cr

The abundance of food safety important microbes was showing an opposite tendency with the mycorrhiza fungi. There were an increasing number of coliform bacteria found in the soils with the increasing sludge doses. The reason of increase in coliform counts comes also from the better availability of nutrients for the microbes (as Gregory et al. 2009 also found), and they are possibly less sensitive to the Cr and Zn metals at this level, too (Figure 1). In case of industrial sludge, the increase in the number of sulphite reducing clostridia was also noticed, indicating the anaerobic conditions created by the sludge, compared to the communal sludge. Considering all investigated microbes of food safety importance, the type of soil was more determinative in their abundance, being the acidic soil more favorable, than the calcareous; and also the communal sewage sludge supported the growth better, than the industrial one (Figure 2).

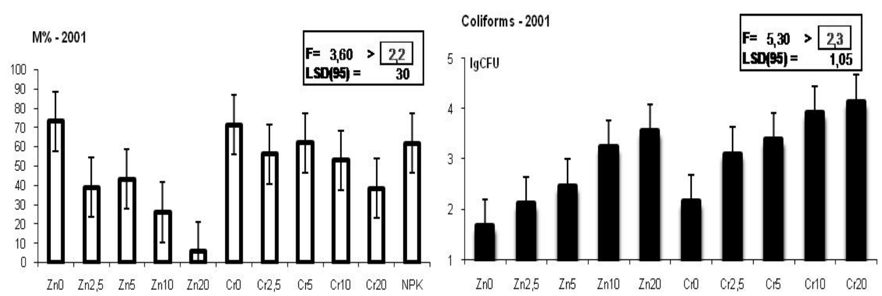

Figure 1. Colonization (M%) of beneficial arbuscular mycorrhiza fungi and abundance (lgCFU) of countable food safety important coliform bacteria in the rhizosphere of green-pea at the increasing doses (0, 2.5, 5, 10, 20 g.kg^{-1}) of Zn-containing communal or Cr-containing industrial sewage sludge types (n=4).

Nevertheless, care should be given to the appropriate treatment of sewage sludges, not to have high microbial load, and no pathogens at all (GAP – good agricultural practice) – to ensure food safety also at the beginning of the food chain. The importance of optimal sewage sludge application can be highlighted also, when considering the colonization of AM fungi. An elimination of those biofertilizer microbes, with key-importance of soil resilience was found at the increasing doses of sludges. See the opposite tendency of colonization of two microbial groups in Figure 1. The type of soil is crucial in the microbial colonization (Kuan et al., 2007). Figure 2 shows, that in the

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acidic forest soil (AF) the lowest mycorrhiza colonization and the highest coliform numbers was found. The risk, caused by the food safety important microbes is increasing; the beneficial effect of biofertilizer microbes is decreasing on the acidic soils.

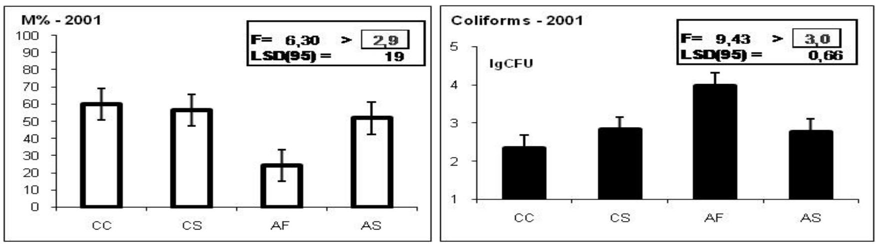

Figure 2. Colonization (M%) of arbuscular mycorrhiza fungi and abundance (lgCFU) of countable food safety important coliform bacteria in the rhizosphere of green-pea in sewage-sludge treated four Hungarian representative soil types (CC, CS, AF, AS) after the 3rd years of "long-term" application (n=4).

Conclusions

Care should be given when applying the sewage sludge doses as potential treatments of the improved soil-resilience. The key importance of sludge types and doses and also the opposite colonization capacity of microsymbionts and coliforms in the acidic forest soils are highlighted from the study.

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SOIL NUTRIENT SUPPLY, YIELD AND MINERAL ELEMENT COMPOSITION OF GRASS

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Abstract: The effects of different N, P and K supply levels and water supply on the yield, mineral element content and nutrient yield of an established all-grass sward were examined from 2001, i.e. the 28th year of a long-term fertilization experiment set up on a calcareous chernozem soil. The soil of the growing site contained 3% humus, 5% $CaCO_3$, 20-22% clay in the ploughed layer and was originally moderately well supplied with available K, Mg, Mn and Cu and poorly supplied with P and Zn. The trial included 4Nx4Px4K=64 treatments in 2 replications, giving 128 plots. The area was prone to drought. The grass was established with seed mixture of eight species in September 2000. In a favourable wet year (700 mm precipitation during the total vegetation period) in 2001 NPK fertilization increased the air-dried hay yield from 3 t ha^{-1} to 13 t ha^{-1} (1st+2nd cuts together). While the grass herbage yield was determined by the NxP supply levels, the nutritional values were influenced by the NxK interactions. As a function of N-fertilization the mineral macro-, microelement content of the 1st cut hay usually increased.

Keywords: NPK fertilization, established all-grass, hay yield, mineral element content

Introduction

As Voisin (1965) stated: "Mineral fertilizers are one of the most important of the discoveries of modern chemistry. Well applied they maintain and even raise soil fertility, increase crop yields, and improve the feeding value of agricultural produce. If unwisely used, however, this marvellous tool can destroy soil fertility, reduce yields and impair the feeding value of agricultural products, seriously and adversely affecting both animal and human health".

The long-term effect of N, P and K fertilizers on soil and crop is still not well understood. As a consequence of dressings of P fertilizers available Zn "disappears" from the soil. The effect is marked when the soil is relatively low in available Zn and the crop is susceptible to Zn deficiency. This effect of P is cumulative. In traditional maize-growing regions Zn deficiency is becoming more frequent following decades of heavy and often excessive application of P (Kádár, 1992; Kádár et al., 2000).

The antagonistic effect of K on the uptake of Ca, Mg, Na, B etc. elements has been recognized for many decades. The synergetic effects of N on the element uptake of the main major nutrients are also well known (Finck, 1982; Geisler, 1988).

Fertilization can reduce the diversity of grasslands, but farmyard manure application may improve it (Szemán, 2009). The present work aimed to evaluate the effect of different N, P and K supply levels and their combinations on the development, yield and mineral composition of an established all-grass sward in the 28th year of a long-term fertilization trial set up on a calcareous chernozem soil.

Materials and methods

The calcareous chernozem soil of the growing site in Nagyhörcsök in the Mezőföld region of Hungary contained around 3% humus, 3–5% $CaCO_3$, 20–22% clay in the ploughed layer and was originally supplied moderately well with available K, Mg, Mn,

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Cu and poorly with P and Zn. The trial included 4N×4P×4K= 64 treatments in 2 replications, giving a total of 128 plots. The applied fertilizers were Ca-ammonium nitrate, superphosphate and potassium chloride. The area was drought sensitive with yearly precipitation of 590 mm (622 mm in 2001), groundwater table at a depth of 13–15 m and negative water balance of about 100 mm yr^{-1}. The grass was established on 21st September 2000. Treatments and soluble PK contents of the soil's ploughed layer are given in Table 1.

Table 1. Treatments and their effects on the soluble PK content in the ploughed layer of the calcareous chernozem soil

Fertilization and soil analysis	Treatments or fertilization levels				$LSD_{5\%}$	Mean
	0	1	2	3		
Applied amount of fertilizer						
N kg ha^{-1} yr^{-1}	0	100	200	300	–	150
N kg ha^{-1} 30 yrs^{-1}	0	3000	6000	9000	–	4500
P_2O_5 kg ha^{-1} 30 yrs^{-1}	0	1500	3000	4500	–	2250
K_2O kg ha^{-1} 30 yrs^{-1}	0	2500	5000	7500	–	3750
Ammonium lactate soluble P and K content of soil (Egnér et al., 1960)						
AL-P_2O_5, mg kg^{-1}	66	153	333	542	42	274
AL-K_2O, mg kg^{-1}	135	193	279	390	32	249

During the thirty years of the experiment 0–9000 kg N, 0–4500 kg P_2O_5 and 0–7500 kg K_2O nutrients were applied per hectare. N doses were divided into two halves, one was applied in autumn and the other in spring. The experimental plots represent low, moderate, high and very high supply levels and all of their combinations, which may possibly be found elsewhere in arable fields or are probable to develop in the future. Until 2000 several arable crops, from 2001 grass was grown. The mixture of 8 grass species: Meadow fescue *(Festuca pratensis)*, Tall fescue *(Festuca arundinacea)*, Perennial ryegrass *(Lolium perenne)*, Agropyron *(Agropyron cristatum)*, Red fescue *(Festuca rubra)*, Timothy *(Phleum pratense)*, Reed canarygrass *(Phalaris arundinacea)*, Cocksfoot *(Dactylis glomerata)* was sown in autumn 2000. The dominant species was the meadow fescue with a 25% application rate.
Plant samples were dried, milled and analyzed for 20–25 elements with cc. HNO_3 + cc. H_2O_2 digestion. After drying and milling of the soil samples, NH_4-acetate+EDTA soluble element contents were determined with the Lakanen and Erviö (1971) method, as well as their NH_4-lactate soluble PK content according to Egner et al. (1960). The layout and method of the trial was published elsewhere (Kádár, 2005*)*.

Results and discussion

The 1st cut took place on 23 May, 2001. The effect of N was moderate in the 1st cut, giving around 2 t ha^{-1} hay surpluses on the average, and the maximum yield responses were obtained in the N_1 (100 kg N ha^{-1} yr^{-1}) treatment. The yield of the 2nd cut (9 October, 2001) showed increased N responses, the yields were basically determined only by N fertilization. The highest hay surpluses were obtained in the N_3 (300 kg N ha^{-1} yr^{-1}) treatment, making out about 3 t ha^{-1}. There was a 4-fold increment in hay yield due to the applied N (Table 2).

Table 2. Effect of NxP supply levels on the air-dry hay yield in 2001, t ha^{-1}

AL-P_2O_5	Yearly N-fertilization rates, kg N ha^{-1} yr^{-1}				$LSD_{5\%}$	Mean
mg kg^{-1}	0	100	200	300		
1st cut (23 May)						
66	3.3	3.9	3.8	4.8		4.0
153	5.5	7.2	7.6	6.9	1.0	6.8
333	5.8	7.9	7.4	7.4		7.1
542	4.9	8.1	7.9	8.1		7.2
Mean	4.9	6.8	6.7	6.8	0.5	6.3
2nd cut (9 October)						
66	1.4	2.7	3.5	3.6		2.8
153	0.8	2.1	3.5	4.0	0.4	2.6
333	1.0	2.3	3.4	4.0		2.7
542	0.9	2.1	3.4	3.9		2.7
Mean	1.0	2.3	3.4	3.9	0.2	2.7

The „moderate" supply levels (135 mg kg^{-1} AL-K_2O and 153 mg kg^{-1} AL-P_2O_5) basically satisfied the P and K demands of grass. An increasing trend was observable, however, in yields with the higher P supply levels. Without a satisfactory P supply the efficiency of N fertilization was much lower and vice versa. N, P or K over-fertilization did not cause a significant depression, though the higher P levels reduced yield on the N control plots in both cuts. There were no P responses at the 2nd cut (Table 2).

The optimum N content in the hay, leading to maximum yield, amounted to 2% and 2.5–3.0% in the 1st and 2nd cut. Due to the applied N the air-dry content decreased from 33% to 31% in the 1st cut, and from 27% to 21% in the 2nd. In the 1st cut hay the optimum K content was around 2% and more, where the highest hay yields were obtained. These optima may be valid for only similar conditions, and for the 1st cut hay.

As a function of N fertilization the element content of hay in the 1st cut usually increased, except for Al and Mo, which showed dilution effects. The rise in element concentration was 25–50% for K, Ca, Mg, Mn, P, Sr, B and Ni; 60–70% for S and Co, two-fold for N and Cu; 5-fold for NO_3-N and Na as compared to N control (Table 3).

Table 3. Effect of N fertilization on the mineral element content of the air-dry hay on 23 May 2001

Measured elements and units		N-fertilization, N kg ha^{-1} yr^{-1}				$LSD_{5\%}$	Mean
		0	100	200	300		
K	%	1.86	2.37	2.26	2.38	0.09	2.22
N	%	1.10	1.87	2.09	2.39	0.16	1.86
Ca	%	0.48	0.56	0.58	0.62	0.03	0.56
S	%	0.15	0.25	0.26	0.26	0.01	0.23
P	%	0.17	0.22	0.22	0.23	0.01	0.21
Mg	%	0.12	0.17	0.18	0.18	0.01	0.16
NO_3-N	%	0.06	0.10	0.22	0.34	0.03	0.18
Na	mg kg^{-1}	109	488	574	535	62	426
Mn	mg kg^{-1}	83	106	114	118	5	105
Al	mg kg^{-1}	102	93	80	78	23	88
Sr	mg kg^{-1}	13	16	16	17	1	15
B	mg kg^{-1}	4.4	5.4	5.3	5.4	0.4	5.1
Cu	mg kg^{-1}	2.1	3.8	4.4	4.7	0.3	3.8
Ni	mg kg^{-1}	0.90	1.01	1.10	1.12	0.16	1.03
Mo	mg kg^{-1}	0.21	0.20	0.18	0.16	0.02	0.19
Co	mg kg^{-1}	0.05	0.07	0.07	0.08	0.02	0.07

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Note: As, Hg, Cd, Pb and Se are below the 0.1 mg kg^{-1} detection limit. Data are means of PK-treatments

P fertilization stimulated the uptake of Mn and Mg by 10–20%; S, NO_3-N and Co by 40-50%, Na and Sr by 60–70%, P by 90%; while it inhibited the uptake of Zn and Co by 20–40%, Al and Fe by 50–60%, Mo by 70% in comparison to the P control. The reduced Fe content has no considerable effect on grass quality, but the decline in Zn content in fodder may cause disturbances in some protein synthesis. The optimal P/Zn rate is assumed to be between 50 and 150 (Kádár, 1992). The P/Zn ratio in the P control soil showed optimal values of 118, while in the soil with high P supply this ratio was 278, indicating Zn deficiency.

K fertilization had a marked effect on the mineral element composition of the 1st cut. So, due to the rising K levels K, Ba and N increased in the hay, while the uptake of all other measured elements was depressed. It is worth mentioning that not only the uptake of metal cations was hindered, but also that of B and Mo, which are generally in anion form in the soil solution

Conclusions

Long-term fertilization can drastically (in some cases with an order of magnitude) change the concentrations and ratios of elements built in hay through synergetic or antagonistic effects. In the hay of the 1st cut, for example, the minima–maxima contents of measured elements varied in air-dry hay as follows: N 0.90–3.02, Ca 0.4–0.7, S 0.14–0.32, P 0.12–0.30, Mg 0.10–0.24%; Na 70–700, Fe 100–288, Al 45–250, Mn 71–130, Sr 10–22, Zn 7–14, Ba 6–11, B 3.6–8.1, Ni 0.3–1.6, Cr 0.1–0.4, Mo 0.04–0.44, Co 0.04–0.12 mg kg^{-1}.

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SPOIL HEAPS AFTER OPEN-CAST COAL MINING: RESILIENCE OF PLANT COMMUNITIES

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Abstract: A study into vegetation spontaneously developing in spoil heaps, i.e. on the dump sites with the material removed in the process of open-cast coal mining, which are characterized by conditions unsuitable for plant growth and development. The characteristics of some significant plant communities, usually determined by edification species, more or less at the initial stages of dump-site vegetation; there are mostly depleted derivatives of the described communities, very often with predominance of weed and ruderal plants. These communities increase the stability, adaptation and resilience of the composition of vegetation on the surface of spoil heaps. In this period, the succession of plants is important; one of the commonly present types in the spoil heaps of the region is mentioned. The succession of plant communities in the spoil heaps is linked to the considerable flexibility and adaptation of the taxa to the conditions on the surfaces of dump sites with extreme conditions for plant growth and development.

Keywords: waste dump, vegetation, communities, succession

Introduction

Through systematic and long-term disposal of soil from the overlaying layers removed in the process of open-cast coal mining, areas referred to as spoil heaps are formed. They are anthropogenic formations consisting mainly of unstable, weathering, gradually subsiding sand and clay with extremely overheated surface and with the absence of a humus layer. Seeds and other reproductive parts of various species of plants get on the surface of the spoil heaps in various ways. Primarily the most resistant ones, mainly ruderal plants and weeds, are capable of surviving and reproducing even under these unfavourable conditions. Over time, the vegetation of the spoil heaps goes through a succession-based development; however, usually sooner or later, man intervenes in this development process with reclamation, mainly of the forestry type in recent times.

Materials and methods

The subject matter of the research consists of non-reclaimed spoil heaps of various ages, which are formed by disposal of waste rock excavated in the process of open-cast coal mining and which are found in the northern region of the Czech Republic. They consist mainly of materials of tertiary origin; sand and white-grey illitic-kaolinic clay with a coal admixture. These soils are very poor in nutrients, with unfavourable water regimen, soil grain size and chemical characteristics. The vegetation of the spoil heaps has been studied by means of standard floristic and phytocoenological methods (for example, Novak et al., 2008). For morphological distinguishing carried out by means of a diacritical method, analysis of the taxonomic features or the scope of their variability – identification and nomenclature – see (Kubat et al., 2002). Lists of species of higher plants have been made for individual localities. The presence of species was evaluated semi-quantitatively by means of a five-degree scale. The vegetation was systematically

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examined in the years 1995-2008; it was examined with regard to the R-C-S strategies in the years 2001-2008. Strategies were classified based on an evaluation criterion – limitation of the generation of biomass as a consequence of the effect and the combination of factors, specifically disturbance, stress and competition (Grime, 2001).

Results and discussion

The plants in spoil heaps are characterized by uneven adaptability, i.e. essentially by various capabilities of growth, development, reproduction and propagation. Adaptation to a certain biotope is considered to be a manifestation and consequence of the strategy of species. There are three types of primary strategies, represented by the relevant taxa, identified as ruderal, competitive and stress-tolerant strategies (the concept of R-C-S strategies). In the extreme environment of the spoil heaps, special, usually simple communities, mostly at the initial stages of development, come into being, with the predominance of ruderal and weed plants. Some dominant communities are described, with an example of ecological succession being stated. The identified communities, that is, the derivatives of weed and ruderal communities are usually identified as communities with a predominant edification species. Woody plants usually appear in the later stage of succession-based development.

Community of *Calamagrostis epigejos* – this species is very widespread, especially in the older spoil heaps; in terms of competition, the dominant species is very strong; it limits dustiness, the extremeness of the habitats and erosion but it prevents other species from taking hold. It forms vegetation with a low number of species or even monocoenosis. The more frequent accompanying species are, for example, *Cirsium arvense*, *Tussilago farfara* and *Epilobium angustifolium*; from among species of other types, the accompanying species are *Carduus acanthoides*, *Linaria vulgaris*, *Hypericum perforatum*, etc.

Community of *Cirsium arvense* – on the monitored dump sites, the only edification species was *Cirsium arvense*; a more frequent accompanying species was only *Tripleurospermum inodorum*; sometimes the species *Sysimbrium altissimum*, *Elytrigia repens*, *Chenopodium album*, *Atriplex* sp. and the like were seen. *Cirsium arvense* is a typical geophyte with root buds; it regenerates from the fragments of root systems in the soil and gets control of a free area quite quickly. It reproduces mainly from the supplies of these generative diaspores in the layered substrate of spoil heaps.

Community of *Tussilago farfara* – it is mostly present in the younger spoil heaps. With a low dominance, this species is often accompanied by *Cirsium arvense*, *Calamagrostis epigejos*, sometimes even by other species (*Artemisia vulgaris*, *Tanacetum vulgare*, *Poa pratensis*, etc.). Polycormons of *Tussilago farfara* often open the succession on a denudation surface. It is a hygromesophytic anti-erosion type of community, which is present on almost all dump sites, in spoil heaps of various age (Pecharova and Hejny, 1998) with a high competitive capability. It suppresses other plants; it can also be dangerous in the cultures of cultivated crops (Mikulka, 2005).

Community of *Atriplex sagittata* – its dominant species is *Atriplex sagittata*, forming vegetation with cover rate of nearly 100 %. The more frequent accompanying species are *Senecio viscosus*, *Cirsium arvense*, *Tripleurospermum inodorum*, *Carduus acanthoides*; sometimes even *Sinapis arvensis*, *Rumex crispus*, *Elytrigia repens*, *Lolium* *perenne*, etc. *Atriplex sagittata* is a distinctly heliophyte species and with its large size and high competitive ability, it overshadows and suppresses other species (Mikulka, 2005); in spoil heaps, it is often the initial community.

Community of *Artemisia vulgaris* – the species *Artemisia vulgaris* has high dominance; it is usually supplemented, to a more significant extent, by *Calamagrostis epigejos* and *Poa palustris*; sometimes *Epilobium angustifolium*, *Tanacetum vulgare*, *Cirsium vulgare*, *Tussilago farfara* and other species are present. It is a highly widespread ruderal community of perennial plants; often poor in the number of species. In the spoil heaps, it most often evolves from a community of *Tussilago farfara* or from a community of *Cirsium arvense*.

Community of *Cirsium arvense-Rumex crispus* – these dominant species are very often regularly supplemented by *Elytrigia repens*; on phytocoenological relevés, *Atriplex sagittata*, *Urtica dioica*, *Chenopodium album*, *Carduus acanthoides* and *Tripleurospermum inodorum* were also identified. It is a community with high stability; it often starts succession on the slopes of spoil heaps with a drying sandy soil.

Community of *Elytrigia repens* – one of the most stable communities growing even on substrates very poor in nutrients. The ediphicator of the community, *Elytrigia repens*, often remains sterile in the spoil heaps; it is usually accompanied by *Cirsium arvense*, *Calamagrostis epigejos*; sometimes *Daucus carota*, *Coronilla varia*, *Convolvulus arvensis* and other species are also present. *Elytrigia repens* is extraordinarily vital; it opens succession on denudation and variously harmed soils; during the succession, it consolidates its position with its high competitive capability and wide coenological amplitude over a number of years. It also grows in habitats with unstable surface, in erosion furrow, in slope landslide formations, etc.

Community of *Epilobium angustifolium* – with the dominance of *Epilobium angustifolium*, the species *Calamagrostis epigejos* and *Salix caprea* quite often thrive in this community. The community is present in areas with better soil conditions and is usually regarded as pre-forest stage formation.

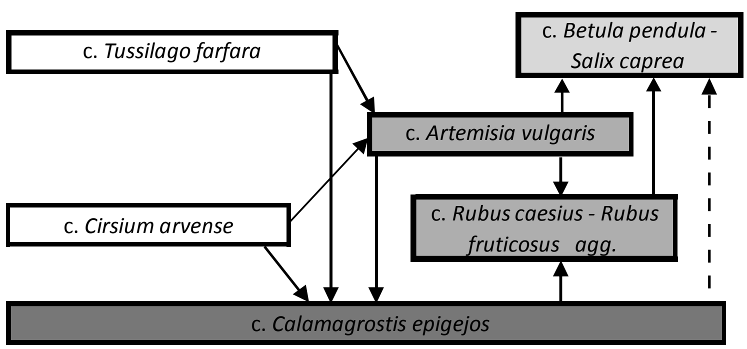

Figure 1. Example of vegetation development in spoil heaps (natural succession).

Community of *Arrhenatherum elatius* – the community of older spoil heaps; besides the dominant species of *Arrhenatherum elatius*, the species *Poa palustris* subsp. *xerotica*, *Calamagrostis epigejos* and *Elytrigia repens* are more frequently present; sometimes

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Dactylis glomerata, *Poa pratensis*, *Vicia angustifolia*, *Epilobium angustifolium*, etc. are also present. In the monitored spoil heaps, the dominant species *Arrhenatherum elatius* did not form a continuous gramineous cover but it formed a sparsely tufty cover with a highly variable vegetation cover.
Community of *Sinapis arvensis* – the only dominant species of this community is *Sinapis arvensis*; loosely involved vegetation of this kind develops as early as in the first year after the soil is dumped. The supply of germinative diaspores of this species is decisive; their numbers often reach very high levels in the removed topsoil. This community reproduces mainly from the supply of diaspores originating from the topsoil of former fields; it is a species typical of the soil stripping. With a somewhat higher regularity and lower dominance, the species *Carduus acanthoides*, *Lactuca serriola*, *Atriplex sagittata* are present in this community; other species, such as *Tussilago farfara*, *Polygonum lapathifolium*, *Senecio viscosus*, etc. are rarely present. Long-term monitoring of succession in waste rock disposal areas was carried out by (Volf, 1994), for example, Fig. 1.

Conclusions

The spontaneously developing vegetation in spoil heaps, anthropogenic formations created by heaping removed material (waste rock) in the process of open-cast coal mining, consists of simple plant communities. Basically, the communities are usually poorer derivatives of the already known communities, often with predominance of weed and mainly ruderal plants. This is why the identified communities are identified as communities with a predominant edification species; the most important ones are mentioned and briefly described. In this period, the spontaneous succession of the plants is important, which takes place in various ways – an example of one of the most common types of succession-based development is presented.

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STUDIES ON THE AGRONOMIC AND ENVIRONMENTAL ASPECTS OF LOW TO HIGH LEVEL ORGANIC AND MINERAL FERTILIZATION IN LONG-TERM FIELD AND MODEL POT EXPERIMENTS

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Abstract: The objectives of this research were: 1/ to investigate the long-term effect of increasing doses of farm-yard manure (FYM; 35, 70, 105 t ha^{-1} 5 yrs^{-1}) or equivalent NPK fertilizers (eqv.) and their combinations with high NPK doses (640, 360 and 660 kg N, P_2O_5, K_2O ha^{-1} 5 yrs^{-1}, respectively) with or without recycling by-products on the grain yield of winter wheat in a 44-year field fertilization trial set up in Keszthely on Ramann-type brown forest soil, 2/ to study the dry matter production and N accumulation in the grains and vegetative parts of maize and CO_2 production in the soil in a pot experiment, in which pots were filled with the soil of the above field experiment. Both types of the experiments proved the advantage of eqv. mineral fertilization over FYM. The highest yields could be achieved with high NPK doses with or without FYM or ploughing in crop residues. The different treatments continuously increased the CO_2 concentration of the soil air in the first half of the vegetation period then the gas evolution declined. On the average of treatments of high NPK doses combined or not with organic fertilization, the cumulative CO_2 concentration was 19.8 % higher as compared to the unfertilized control.

Keywords: field and pot experiments, organic and mineral fertilization, wheat, maize, yield, CO_2 in soil air

Introduction

One of the future challenges for agriculture is to develop fertilization strategies that have the least undesirable impact on the environment. Sustainable agriculture implies the utilization of biological resources. FYM and ploughing in crop residues have an important role in maintaining soil fertility. This is why more attention had to be given to organic matter recycling (Németh, 2004). Fertilization with high N doses without easily available carbon sources can result in an increased microbial degradation of the humus materials in the soil, and recycled organic matter can cause increased CO_2 release (Huang et al., 2004). The emission of the greenhouse gas CO_2 from cultivated soils is of great importance from environmental point of view.

Materials and methods

In 1963 a long-term organic-mineral fertilizer experiment was set up on Ramann type brown forest soil (Eutric Cambisol) at Keszthely (Hungary) with two crop rotations and different doses of FYM or equivalent NPK fertilizer and combined treatments of NPK fertilizer and FYM or straw manuring. Both rotations contained 15 treatments. The trials were set up on plots of 98 m^2 in randomized block design, in 4 replications. For more information see Hoffmann et al. (2008). For the present study, ten of the treatments have been selected from the two rotations (Table 1). The original fertility of this neutral sandy loam was poor for organic matter and phosphorus, medium for potassium content. Mean annual temperature and precipitation (in years 1951-2000)

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were 10.4 C° and 654 mm, respectively. Model pot experiment was set up with maize (*Zea Mays* L.) in the closed section of a greenhouse in 2008. Large pots (40x40 cm) were filled with 45 kg (absolute dry) soil taken from the field plots of the above selected treatments. Gas traps of 1.8 dm^3 volume were laid at a depth of 20 cm into the soil. Four plants per pots were grown until full maturity. The experiment was set up with 3 replications in a randomized block design. The plants were watered, maintaining the optimal water supplying capacity of the soil during the whole experimental period. The trapped soil air was sampled at intervals shown in Table 2 and analyzed by gas chromatography. In the present study, winter wheat yields in the field experiment in 2008, dry matter production and N accumulation in the grains and vegetative parts of maize as well as CO_2 production in the soil air in the pot experiment are discussed.

Table 1. Selected treatments of the long-term experiment

Treatment no.	FYM	eqv.	Supplementary mineral fertilization (kg N,P_2O_5,K_2O ha^{-1} 5 yrs^{-1})	Total N, P_2O_5, K_2O (kg ha^{-1} yr^{-1})	Maize stalk or wheat straw incorporation
1	-	-	-	-	-
2	1 FYM(5)	-	-	44, 38, 49	-
3	2 FYM(5)	-	-	88, 76, 98	-
4	3 FYM(5)	-	-	132, 114, 147	-
5	-	1 eqv.	-	44, 38, 49	-
6	-	2 eqv.	-	88, 76, 98	-
7	-	3 eqv.	-	132, 114, 147	-
8	1 FYM(1)	-	640, 360, 660	172, 110, 181	-
9	-	1 eqv.	640, 360, 660	172, 110, 181	-
10	-	1 eqv.	640, 360, 660	172, 110, 181	+

Legends: 1 FYM(5) = 35 t ha^{-1} farmyard manure in 5 years, distributed in the first and third years; 1 FYM(1) = 35 t ha^{-1} farmyard manure in 1 year, distributed in one dose; 1 eqv. = mineral NPK equivalent to 35 t ha^{-1} FYM in 5 years, distributed yearly.

Table 2. Date of soil air samplings

Sampling no.	1	2	3	4	5	6	7	8	9
Sampling dates	13 May	21 May	04 Jun.	18 Jun.	03 Jul.	16 Jul.	28 Jul.	13 Aug.	03 Sept.

Results and discussion

In the 44^{th} year of the field experiment, the applied fertilizer treatments resulted in significant grain yield increases as compared to the control except for the FYM doses (Table 3). Winter wheat yield has risen nearly twofold in treatments 8-10 including high NPK doses. In the pot experiment, every treatment significantly increased the dry matter accumulation of the grains and vegetative parts of maize as compared to the unfertilized control. Both grains and total above ground plant accumulated significantly higher dry matter amounts in the eqv. NPK treatments compared to FYM doses. Similarly to the field experiment, the high NPK treatments proved to be the most effective. As regards N content of both the grains and the total above ground plant, similar treatment effects could be detected. The high mineral fertilizer dose combined with organic matter recycling (treatment 10) proved to be the most effective in this case as well: It resulted in 8.4 and 4.3 times higher N content in the grains and total above ground plant, respectively, than no fertilization.

Table 3. Dry matter and nitrogen yields (2008)

Treatment no.	Field experiment, winter wheat		Pot experiment, maize			
			Grain		Total above ground plant	
	Grain yield ($t\ ha^{-1}$)	Yield increase (%)	Dry matter weight ($g\ pot^{-1}$)	Nitrogen content ($mg\ N\ pot^{-1}$)	Dry matter weight ($g\ pot^{-1}$)	Nitrogen content ($mg\ N\ pot^{-1}$)
1	3.59		26	273	135	904
2	3.67	2.23	51	475	173	1093
3	3.91	8.91	59	585	183	1237
4	4.13	15.04	75	754	199	1335
5	4.25	18.38	115	1053	266	1806
6	5.87	63.51	159	1530	371	2572
7	6.13	70.75	173	1629	431	2728
8	6.99	94.71	173	1809	411	2925
9	7.03	95.82	216	2019	492	3252
10	7.08	97.21	227	2304	542	3920
$LSD_{5\%}$	0.64		22	221	37	314

Table 4. CO_2 concentrations in the soil air ($mg\ l^{-1}$)

Treatment no.	Days from sowing (08 May)									Cumulative amounts
	6	14	28	42	57	70	82	98	119	
1	3.2	3.2	10.0	16.9	21.6	15.8	21.5	29.4	7.3	128.9
2	3.0	3.3	11.9	14.1	27.1	19.0	26.9	25.7	8.1	139.1
3	3.2	3.2	11.2	16.1	22.5	16.9	24.3	26.2	7.5	131.1
4	3.5	3.3	12.6	17.0	28.9	21.4	29.8	26.6	7.3	150.4
5	3.0	2.9	11.9	18.7	24.9	16.5	25.3	9.8	4.5	117.5
6	3.0	3.0	14.2	20.4	36.0	27.2	21.7	10.4	5.7	141.6
7	2.8	2.9	13.4	19.7	34.0	20.6	24.5	16.2	8.7	142.8
8	3.3	4.0	17.0	23.0	27.3	24.8	32.5	16.7	7.4	156.0
9	3.5	3.8	16.7	23.6	26.7	21.9	39.5	13.8	8.1	157.6
10	3.4	3.6	16.9	21.3	28.9	21.1	28.1	14.3	12.0	149.6
$LSD_{5\%}$	n. s.	0.6	2.4	3.4	8.0	3.6	9.3	11.0	n. s.	n. s.

After a lag phase, the CO_2 content of the soil air showed a continuous increase from the 2nd sampling in the first half of the vegetation period then it decreased with smaller or higher fluctuations (Table 4). The CO_2 production could be well described by linear regression in the first, continuously ascending part of the curves describing the gas formation (samplings 2-5). The analysis of variance of the regression coefficients in the linear regression equations showed significant differences only as an effect of the eqv. NPK treatments (6th and 7th) of higher dose as compared to the control (Table 5), i.e. in

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case of these mineral fertilizer treatments, CO_2 production was of significantly higher rate and degree. In most samplings, treatments with high NPK doses significantly increased the CO_2 content of the soil air as compared to the control (*Table 4*). Between the cumulative amounts, however, no significant differences could be detected on the bases of the one-year results.

Table 5. Regression analysis results (y = a + bx, n=12)

Treatment no.	a	b	r
1	-2.546	6.196	+0.998
2	-4.262	7.351	+0.952
3	-2.483	6.281	+0.992
4	-4.882	8.130	+0.984
5	-3.819	7.301	+0.995
6	-7.895	10.506	+0.985
7	-7.368	9.943	+0.982
8	-3.427	7.591	+0.948
9	-3.500	7.553	+0.950
10	-2.404	8.030	+0.975
$LSD_{5\%}$		2.334	

Conclusions

- In the field experiment FYM treatments did not, but all eqv. mineral fertilizer doses resulted in a significant grain yield increase as compared to the unfertilized control. Treatments including high mineral NPK doses with or without organic matter recycling gave a further significant yield increase. Similarly to the field experiment, treatments including high NPK doses proved to be the most beneficial both with regard to the total above ground dry matter production and to the N yield in the pot experiment as well.
- The different organic and/or mineral fertilizer treatments gradually increased the CO_2 concentration in the soil air in the first half of the vegetation period then the CO_2 formation decreased. Compared to the control, treatments of high NPK doses combined or not with organic fertilization increased the cumulative CO_2 concentration by 19.8% on the average. However, the differences between the effects of the different ways of nutrient supply could not be statistically proved.

Acknowledgements

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THE DUMP OF METALLURGICAL WASTE – LÚŽENEC AND ITS IMPACT OF THE LANDSCAPE AT SEREĎ IN SLOVAK REPUBLIC

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Abstract: The dump of lúženec is situated to the south of Sereď on the Váh floodplain in the northern border area of the Danube plain. The biggest length of the dump is 750 m and the width is 550 m. Its relative hight is about 30 m in the south and in the west, in the east and the northeast approximately 22 m and in the north it is about 5 - 14 m. The dump area covers around 50 ha. Volume of the dump is in present days 5.5 - 6.5 mil. t and in 1993 it was about 9 mil. t. The dump of lúženec formed during 30 years of manufacturing process, which was stopped due to the economic and ecological reasons in 1993. The pollution of base rocks, underground waters, soils and air pollution was noticed during Nickel smelting plant operation and continues up to the present days.

Keywords: metalurgical waste, polymetallic dust, contamination, Sereď

Introduction

The area of the Danube plain near Sereď is built by fluvial sediments (Pleistocene, Holocene). Regarding the anthropogenic sediments there is a significant dump of metalurgical waste – lúženec. It is a homogenuos formation from the petrographic point of view. Lúženec is granulometric very fine material (97 % faction is smaller then 0.1 mm), black colour, originated by grinding and washing Albanian laterite iron-nickel ore. The penetrantion of this mass is very high, so the rainfalls can reach its bottom layers very quickly. The dump is classified as an industrial, fireproof, surface, convex, accumulating form (Zapletal, 1969, 1976; Lacika, 1999), antropogenic terraced plateau with wide surface and steep slopes (declination of slopes 10° - 45°). The dump is the subject of recent fast natural erosive geomorphologic and anthropogenic processes as well (rain wash, creep, deflation, mining). Deflation occurs on the dry and vegetation free dump body, mostly on the places, where the dump plain is destroyed by mining procesess. The investigated area is warm and dry with very mild winter and a rainfall shortage from 100 to 150 mm per year. The region belongs to the Váh river basin with rich collectors of the underground waters (in the depth of 2 - 3.5 m under the surface). The vegetation (metahemerobic, with minimal biogeneous processes, Jurko, 1990) and soils (Anthropo-Skeletic Leptosols on anthropogenic substrates of technogenous origin, Šály, 2000) of the dump are very specific. Animals are concentrated on recultivated part of the dump.

Materials and methods

Methodology is oriented towards the research of the primary geoecological structure of the dump. Secondary landscape structure according to the corresponding categories of land use, were identified by using the interpretation of high-resolution orthophoto from 2009. Digitalization of spatial data were processed manually by method „on screen“

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using software ArcView GIS 3.1 The identified landscape elements were consequently categorized into the purposefully arranged legend according to their content characteristics. The obtained results were verified in the terrain research.

Results and discussion

The presented contribution was focused on the character of the primary landscape structure and secondary landscape structure and especially on the impact of the dump to environment. The attention was given to floristic composition of plants communities on the lúženec dump. Physical and chemical characteristics of lúženec preconditioned inception of a very specific ecosystem, which cannot be found in any natural landscape. The dump vegetation presents completely new specific type. Its variety composition is not similar to any overgrown occuring at the similar stands of another dumps. The highest number of plant species grows from its foothill to the height approximately 2 metres. Vegetation, concentrated into scraggles, is covered sporadically the upper parts of the slopes, which are formed by pure Fe-concentrate. Vegetation can be seen in the small cavities mostly in the oldest dump parts. Regardingthe area, they occur only in very little places as species monotonous incoherent. More than a half of the dump is covered by herbaceous-grass formations, monocenosis of *Calamagrostis epigejos* and *Artemisia absinthum.* The trees vegetation is presented mostly by *Populus canenscens.* About 40 % of the dump area is uncovered by vegetation (Fig. 1).

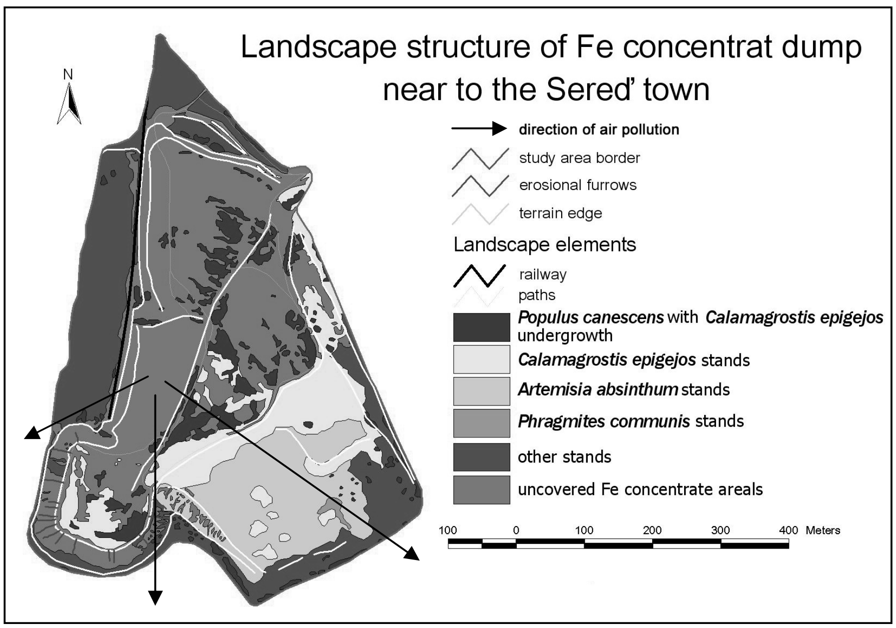

Figure 1. Landscape structure of the Fe-concentrate dump in 2009.

The area of dump is strongly degradated. According to the environmental regionalization of the Slovak Republic by the Department of the Environment (2008) the territory after the investigation belongs to strongly disturbed environs according to the environmental quality. The situation is more important as it concerns the region with the oldest settlement of the lowland landscape in Slovakia with the most productive, highly and very productive soils. Production of Nickel smelting plant per year was 3000 t of Ni, 60 t of Co and 300 000 t of waste (lúženec). The waste of nickel production – lúženec shows high content of various metal oxides and other substances. The highest is content of iron - Fe (Fig. 2). It is a medium rich Fe - concentrate (Kalebáč, Souček, Had, 1987). Despite of this, its use in matallurgy is higly limited. Compsumption of chemicals per year at process was very high (Fig. 3).

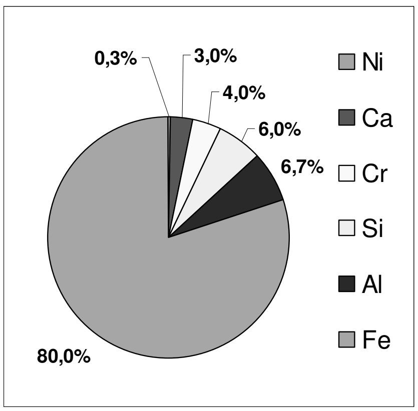

Figure 2. Composition of waste-luženec

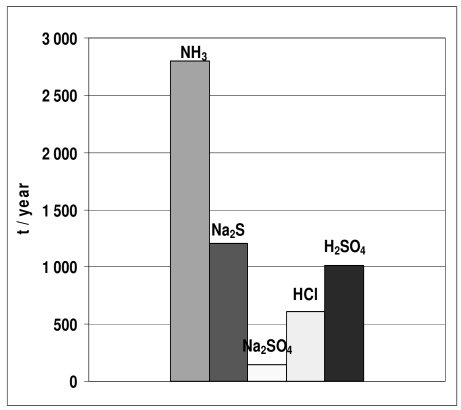

Figure 3. Year Consumption of Chemicals

From the aspect of negative impact of the dump on environment in present days we identified these: In a lowland scenery the dump, with its physiognomic shape, represents a significant allochthonous, barrier element. Its integration in to the landscape, mainly regarding the length of a human life, could be considered as incontrovertible phenomenon. According to the present mining rate and export of lúženec it is possible to liquidate the dump in approximately 600 years.From the beginning of its depositing in 1963 till the present days the dump of lúženec has been the source polymetalic dust, which escapes in to the landscape (air, waters, soils, vegatation cover, athropogenic teracces) to the distance of 50 km. There is no monitoring station of the air pollution and therefore the data concerning dustiness polllution and another emissions are missing. According to the long-lasting observations of the state observing system the worst water quality is measured on the Váh river near Sereď. Water contamination was caused by technological water release until the cessation of manufacturing process in 1993, without any cleaning the realease was directed to the inundation area of the Váh river and directly into the river. The river pollution influenced the underground water quality, where the increased contents of heavy metals, nitrogen, chloride and disulphate compounds were measured. High

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concentration exceeded border limit of the state standards. On the basis of micropollutants content the water on this part of the river belongs to the IV.th class of quality (extremely polluted). Nickel is considered for risk element of soils. The dump of lúženec and area of former Nickel smalting plant represents anthropogenic Ni sources. This is evident in the floodplain of the Váh river, where Ni has been dispersed from this technogene sources by air transport (dust) and migration of underground waters to the distance of 40 to 50 km (about 1500 ha of agricultural soils contains Ni – risk element). In soils of these areas Ni is concentraded in organic matter and in secondary Fe oxides (Čurlík, Šefčík, Vojtek 1999). Regional median values of Ni content is from 35 mg to 40 mg. kg $^{-1}$ of soil (Šefčík, 2006). The risk of the contamination of plant production with heavy metals is so high, that it is recommended only for permanent grassland areas.

Conclusion

There were several solutions of lúženec dump liquidation at Sereď: its use as a material for Cor-Ten steel production, for production of oxide pellets, for direct batch into the blast furnace, the dump recultivation, building of green polyfunctional zone in its vicinity, using Fe-concentrate in cement factories, for brown coal washing process. Project documentation was elaborated for each of these lúženec removal forms, but most these suggestions remained on the level of projects and the pollution elimination, mainly of underground and surface waters, was left to the self-cleaning ability of natural structure. The pollution continues up to the present days. The environment devastation of the region is the key problem for foreigen investors and it is an obstruction for modern trends in agriculture development.

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THE EFFECT OF DIFFERENT CLIMATES ON THE SOIL MECHANICAL PROPERTIES OF AGRICULTURAL SOILS

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Abstract: The climate strongly influences the behavior of the soils by evapotranspiration, leaching and temperature. The soils and also the vegetation and land use tend to show strong geographical correlation with climate. We investigated with standard soil mechanical testing methods two common clayey agricultural soils which has the same characteristics in soil mechanical view but originated from different climatic area. The aim of the measurements was to determine and compare the plastic (compaction) and elastic behavior of the different soils, which behaviors are effects to the method of the land cultivation and the plant production. We have found differences in the compaction and elastic behavior of the investigated soils. The results suggest that the cause of the difference is in the mineral composition and mainly the amount of the amorphous content. The quantities of these materials are stongly climate dependent. The presentation also summarizes the first measurements results, the quantitative and qualitative analysis of mineral composition and shows the importance of amorphous materials and the effect of climate in soil mechanical view.

Keywords: elastic behavior, compaction, amorphous content, X-ray powder diffraction, climate

Introduction

The investigation of the deformation of soil structure and compaction is a key issue for the sustainable land use. The compaction basically determines the soils behavior, effects to the porosity, permeability, saturation distribution and the development of the vegetation. The climate influences the mineralogical composition and the structure of the soils, which properties basically determine the harmful effects of cultivation. The agricultural vehicles increases vertical loads, the effective stresses increasing in the soil, occurs significant compaction and elastic deformations. To reduce the harmful antropogenous effects we have to get more information about the elastic and plastic behavior of the agricultural soils.

Materials and methods

The loose, agricultural soil samples at different moisture contents were investigated (dry and medium state). To characterize the mechanical behavior of clayey agricultural soils we performed triaxial tests to simulate and understand the naturally occurring stresses and deformations. During the triaxial measurements a cylindrical soil sample- in rubber membrane- tested in the triaxial cell filled with de-aired water. The measurements were done using the SHD serial hydrostatic deviatory stress paths. The hydrostatic phase is homogenizes the sample and we get the elastic parameters of the soil and with a following deviatory phase the sample reach the critical state and we can measure the failure conditions of the sample. Mineralogical composition of investigated samples was determined by X-ray Powder Diffraction (XPD) on a Bruker D8 Advance diffractometer (Department of Mineralogy and Petrology, University of Miskolc) in

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Bragg-Brentano geometry (Cu-Kα radiation). The whole-soil samples were obtained by air drying the soils and taking representative quantities, which than were grinded to ~1μm grain size. These samples were analyzed in the angular range of 2 - 65˚2θ in step-scanning mode with step size of 0,004˚ 2θ and collecting time of 4 sec/step. Clay minerals were identified by regularly applied investigation procedures. Clay fraction (<2 μm fraction) was obtained by gravitational sedimentation in water column using distilled water. The mounts were then investigated in the angular range of 2 - 30˚2θ, with step size of 0.004˚2θ and collecting time of 3sec/step. Data was collected on air-dried, ethylene-glycol saturated, 350˚C and 560˚C heated specimens. The X-ray amorphous content was determined by the addition of α-Al_2O_3 as internal standard.

Results and discussion

During the triaxial tests the change of the void ratio measured, and after the tests the elastic parameters were determined on the basis of the CSSM theory. The elastic parameters (κ) are related to the slopes of the loops on the obtained curves. Figure 1 and Table 1 shows, that in case of dry clay samples Cranfield clay (CRF) was more compactable and Taktaharkány clay (TH) soil had higher elasticity. But at medium moisture content Cranfield clay becomes more elastic then the Hungarian clayey soil.

Table 1. Results of triaxial tests- comparison of the elastic parameters (κ values) at different moisture content

Soil type	W [%]	e^0 [-]	κ_1	κ_2	κ_3	κ_4	κ_5	κ_6	κ_7	κ_8
TH	15	1.05	-0.014	-0.019	-0.022	-0.024	-0.026	-0.029	-0.032	-0.034
CRF	14	1.04	-0.013	-0.017	-0.02	-0.023	-0.025	-0.028	-0.032	-0.034
TH	24	0.89	-0.009	-0.018	-0.022	-0.024	-0.025	-0.028	-0.03	-0.032
CRF	24	0.89	-0.011	-0.019	-0.023	-0.025	-0.027	-0.029	-0.033	-0.035

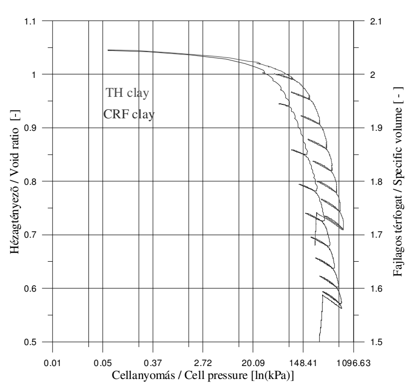

Figure 1. The comparison of compaction and elastic behavior during triaxial tests

The mineralogical composition of whole-soil samples were obtained by FPM pattern fitting based on PDF files of identified minerals (Table 2.). The composition is dominated by quartz and feldspars, with different amounts of clay minerals.

Table 2. The mineralogycal composition of the investigated soils

Concentrations	Taktaharkány clay	Concentrations	Cranfield clay
4.40%	Albite, ordered	10.70%	Illite-2M1 (NR)
11.90%	Illite-2M1 (NR)	5.10%	Kaolinite 2M
6.40%	Kaolinite 2M	12.20%	Labradorite
5.80%	Microcline intermediate	22.30%	Microcline, intermediate
21.50%	Muscovite-2M1	9.80%	Muscovite-2M1
1.10%	Nontronite-15A	0.90%	Nontronite-15A
47.40%	Quartz, syn	37.80%	Quartz, syn
1.60%	Vermiculite 2M	1.30%	Vermiculite 2M

The illite has the same ratio in both samples, but the muscovite is found to be more abundant in TH soil. CRF soil has more total feldspar content, while in TH quartz has higher contribution. For a good identification of clay minerals, the oriented mounts were also investigated before quantification (Figure 2). Figure 3 shows the amount of mineral composition in soil mechanical view. The blue color is related to the quantity of the materials which have good elastic behavior, green shows the amount of minerals with semi-elastic properties and magenta shows the composition with non elastic properties at medium moisture content in the investigated soils. X-ray amorphous contribution was found higher in CRF sample (~14 weight %) than is TH sample (~6 weight %).

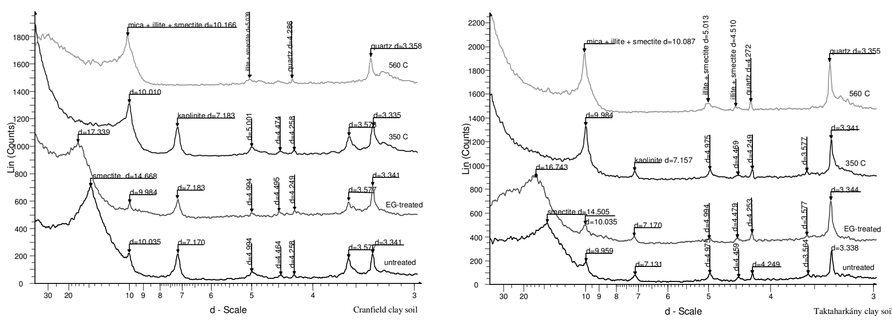

Figure 2. The diffractograms of the clay fraction of the investigated soils

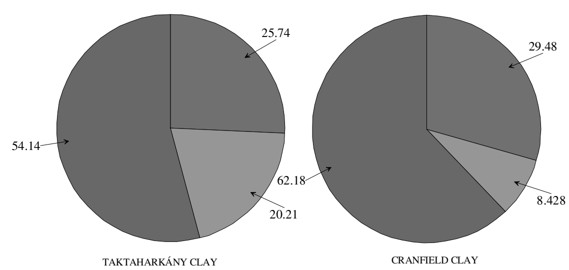

Figure 3. Amount of the minerals with different water adsorbing capacity

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Conclusions

Summarizing XPD results, the main differences were found in the total X-ray amorphous content, the ratios of clay minerals and crystalline degree of smectites. The reason of the difference is in the origin of the soils to be found. X-ray amorphous materials are primarily amorphous aluminosilicate gels (allophane), organic matter, Al and Fe hydroxides. The agricultural soils contains clays and X-ray amorphous materials of various types and origins, depends on the climate, vegetation, land use and mother rock.

Hungary has continental climate, the decomposition of minerals are slowly, leaching is not dominant process because of the frost at winter and the lack of precipitation at summer. The soils are mainly acid. Taktaharkány clay samples originated from sedimentary clay deposits, created from clay minerals which suspended in the Tisza-river and accumulated in the flood plains. UK has oceanic climate, with cooler and humid conditions. Cranfield clay samples are from residual clay deposits. The weathering of minerals are very fast because of the low pH of the soil and the lot of precipitation. The main process is the leaching. The hard decomposition and the acid soil occurs Fe- and Al- cations releases, which metal cations hydrated and became amorphous gel. The results of the triaxial measurements support the fact, that the amorphous gels are increases the elasticity of the soil due to the fast reactions between the large reaction surface of amorphous materials and water, but in dry state the minerals with non or low water adsorbing capacity determines the elastic and plastic behavior of the clay soils.

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THE EFFECT OF POTASSIUM ENRICHED MUNICIPAL SEWAGE SLUDGE COMPOST ON THE YIELD OF MAIZE PLANTS

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Abstract: In Hungary, like everywhere in the world municipal sewage sludge is produced in great quantities. Due to its chemical composition municipal sewage sludge contains valuable nutrients. Municipal sewage sludge produced in the town Győr has a low content of toxic elements therefore it can be utilized by composting. The low potassium content of municipal sewage sludge could not ensure a balanced nutrient supply on the sandy soil of the experimental field. The soil was poorly supplied with potassium, phosphorous and humus. To increase the organic matter content of the soil the sewage sludge proved to be the right source. To replace potassium we used the ash of sunflower seed husk of high potassium content, which we mixed into the sewage sludge during the composting process. In the experiments we compared the yield of the absolute control plots with those treated with synthetic fertilizer (N= 120 kg/ha, P_2O= 110 kg/ha, K_2O= 176 kg/ha), sewage sludge compost (50 t/ha) and sewage sludge compost + ash of sunflower seed husk (50 t/ha + 357 kg/ha). Soil treatments increased the kernel yield of maize compared to the control. The highest yield increase (1.65t/ha compared to the control) was produced by the treatment with sewage sludge compost + ash of sunflower seed husk.

Keywords: sewage sludge compost, ash of sunflower seed husk, humus, potassium, yield, maize

Introduction

Due to urbanisation a great amount of wastes are produced in the form of gas, liquid and solids. In Hungary some 70 million tons of wastes are produced yearly. There are among them a high amount of agricultural wastes, mostly composed of plant residues. About 15 million tons of liquid municipal wastes are also produced, which contains about 150 thousand tonnes of dry matter a year. The toxic matter content of sludge quantities deriving from municipal sewage treatment works is below the threshold value and can be used again in agriculture (Németh et al., 1996; Tomcsik et al., 2008; Kovács and Füleky, 2007). Application of synthetic fertilizers cannot maintain the natural retaining and organic puffer material and humus content of soil. Even smaller and smaller parts of plant residues are recycled into the soil in the natural material cycle due to large scale agricultural product processes, urbanisation and energetic utilization of plant bio mass etc (Kárpáti, 2002). The use of sewage sludge compost offers an excellent possibility for the replacement of humus materials (Guevas et al., 2003; Vermes, 1998). In Hungary vinasses, a by-product of distillery has been used to raise the organic matter content of soil for several decades. Ill-application of vinasses makes the soil saline due to its high sodium content (Barkóczi et al., 2007). Sewage sludge compost can successfully be used on soils with poor water household, low adsorption, shallow tilth, low biological activity and with poor organic matter content. If incorporated into the soil sewage sludge composts raise the organic matter, the humus content, fertility and nutrient supply ability as well as its microbiological activity (Loncaric et al., 2009; Vermes, 1998). Sewage sludge composts contain nitrogen, phosphorous in considerable quantities, and are excellent sources of nutrients for plants.

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The favourable effects of sewage sludge compost application on soils were confirmed in different plant cultivars. The high nitrogen content of composts increase the raw protein content and the yield of maize (Simon and Szente, 2000; Kádár and Morvai, 2008). Barkóczi et al., 2008; and Kovacevic et al., 2009 report considerable yield increase as a result of potassium replacement on soils with poor potassium supply.

Material and method

Potassium is needed to supply plants harmonically. Compost was prepared with the ash of sunflower seed husk of high potassium content and was applied on sandy soil in maize. To apply sewage sludge - produced by the Municipal Co. in Győr - in the experiments we reduced its water content below 50%. Aerobe putrefaction was conducted with the addition of wood shavings in chambers for 170 hours. After riddling it on a cylinder riddle we divided the raw compost into two parts. We mixed ash of sunflower seed husk of high potassium content into one part of the compost. Both compost parts were let ripen for further 6 months. These types of composts were used in the field experiments. In 2006 we launched our experiments on maize plots of $20m^2$ in random block design on sandy soil with four replications in Győrszentiván. The composts were applied in spring and were ploughed into the soil. Table 1 shows the soil composition.

Table 1. Soil analysis results, Győrszentiván, Hungary

pH		K_A	$CaCO_3$ %	Humus %	AL-soluble			Mg	EDTA-soluble			
H_2O	KCl				P_2O_5	K_2O	Na		Zn	Cu	Mn	Fe
					$mgkg^{-1}$							
7.65	7.44	38.0	3.2	0.8	94.0	96.0	41.0	58.0	1.1	1.2	38.0	32.4

As a result of long year research we observed that the application of 50t/ha sewage sludge compost produced the best results therefore we launched our experiments with this quantity.

Table 2. Composition of sewage sludge compost and ash of sunflower seed husk

Material	pH	Dry matter content w%	Organic matter content w%	N w%	P w%	K w%
Sewage sludge compost	6.87	51	47.8	2.1	0.3	0.15
Ash of sunflower seed husk	12.4	97	0.3	0.0	4.1	21

+

The composition of sandy soil revealed that it was poorly supplied with potassium (K_2O=96 mg/kg). 140 kg-potassium containing compound (176kg K_2O) was needed per hectare to satisfy the potassium demand of maize. With the application of 50t/ha sewage sludge we supplied the soil with 65kg potassium per hectare (Table 2). 75kg potassium, as a difference, was replaced by mixing 375kg ash of sunflower seed husk to the compost.

We applied four treatments in our experiments:

1. control (without nutrient supply)
2. fertilizer treatment (N= 120 kg/ha, P_2O_5= 110 kg/ha, K_2O=176 kg/ha).
3. sewage sludge compost (50 t/ha).
4. sewage sludge compost + ash of sunflower seed husk (50 t/ha + 357 kg/ha).

Results and discussion

Figure 1 shows the kernel yield of the harvested samples. Based on the results of analysis we can state that compared to the control every treatment produced yield increase. Synthetic fertilizer applications raised yields by more than one ton. In this treatment the yield increase was not significant, but compared to the control and as a result of the treatments the plants grew much higher.

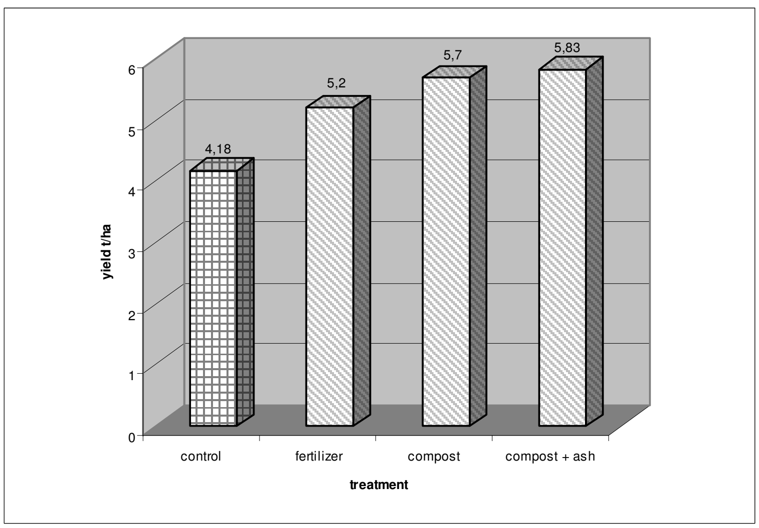

Figure 1. Changes in maize yields due to potassium replacement

The dry matter content of the maize plant decreased considerably if compared to the control. Compost treatment induced a much higher yield increase. Due to the compost treatments we measured the highest values for plant height in this treatment. We received the lowest values for dry matter in this treatment as well, which explains the positive effect of the compost on the soil structure and water household. Compost treatment produced a yield increase by 1.52t/ha compared to the control, which could be confirmed ($LSD_{5\%}$= 1.12) mathematically. Compared to the compost treatment we

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observed further increase in yields, though a little bit lower, after the treatment with the ash of sunflower seed husk. Compared to the control the yield increase was 1.65t/ha showing significant results. In the compost treatment enriched with plant ash the yield increase was not only enhanced by the high potassium content of the ash, but the high other macro- and microelement content had an influence on it, too. Sunflower seed husk also contains a high amount of sulphur, boron and magnesium. The highest yield increase was induced by the positive macro-, and microelement content of the compost, but its positive effect on the soil structure and water household. The values for plant height due to potassium were only lower if compared to the compost, but they still remained higher than in the treatments with synthetic fertilizers.

Conclusion

We replaced potassium and organic matter on soils poorly supplied with potassium and humus. We raised the low potassium content of municipal sewage sludge compost by adding some ash of sunflower seed husk to the compost. We carried out comparative analyses with the application of synthetic fertilizers. As a result of the experiments we proved a yield increase of higher than 20% due to nutrients supplied by fertilizers. The sewage sludge compost treatment raised the kernel yield of maize more than the fertilizer application. In this range of experiments yield increase was higher than 33% compared to the control. The highest yield increase was reached if the ash of sunflower seed husk and sewage sludge compost were applied together. This resulted in a yield increase of about 40%. Due to the treatments of sewage sludge compost and sewage sludge compost + ash of sunflower seed husk the kernel yield of maize increased significantly.

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THE ROLE OF SOIL RESILIENCE IN SUSTAINABLE DEVELOPMENT

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Abstract: Soils and ecosystems are worldwide subjected to increasing degrees of natural and/or human-induced physical, chemical and biological stresses. Up to a certain limit soils can survive (tolerate, buffer, moderate) these stresses because of their unique characteristic, *resilience:* the ability to recover after various disturbances. Theoretically most of the soil processes (both the formation and degradation processes) are reversible. This reversibility is the basis of resilience and of the fact that *soils are conditionally renewable natural resources.* Ensuring the conditions of resilience and renewal by rational land use and soil management the desirable *multifunctionality and fertility of soil are sustainable* and can be maintained for a long time.

Keywords: soil resilience,soil as conditionally renewable natural resource,sustainability,multifunctionality.

Introduction

The satisfaction of the rapidly increasing demand of the ever-growing world's population and the ensuring them acceptable (or at least tolerable) living conditions (enough quantity of good-quality, healthy food; clean water; pleasant environment) formulate the imperative task: more efficient and sustainable use of natural resources, without undesirable environmental consequences. *Water and soil are conditionally renewable natural resources.* They do not "disappear" or their "quality", desirable multifunctionality are not necessarily lost or reduced considerably and irreversibly during their rational use. But the renewal is not "automatic" and has strict preconditions: rational land use and *sustainable soil management.*

Soil resilience

Soil resilience gives reality for the *renewal* of soil fertility (Várallyay, 2007). During history there were two main concepts of *soil resilience* (Eswaran, 1994; Greenland & Szabolcs, 1994; Lal, 1994; Posters, 1992; Szabolcs, 1994):

(1) *Resistance of soils to various changes* or the ability not to respond to impressed forces. E.g. the sensitivity/susceptibility of soils to various environmental (climatic, hydrological) extremes, soil degradation processes, or natural and human-induced stresses.

(2) *Ability of soil to recover after any disturbance:* to return to the original state or to a new dynamic equilibrium.

Later the two concepts were separated as *"vulnerability"* and *"resilience"*.

The present concept of soil resilience can be applied to the

- *Structure* of the soil system: thickness and arrangement of soil horizons, proportion of the main soil components and other *long-term* changes (Arnold et al., 1990).
- *Performance* of the soil system: functional and more rapidly changing soil components and most of the soil functions, including fertility and biomass productivity.

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Resilience is not a general property of soil, and can be evaluated and interpreted only as a function of the character and intensity of the disturbance; and/or the soil type and characteristics: ability of the system to return to a (near) original state.
The resilience of various soils are very different depending on their physical, chemical and biological properties and soil processes. The *specific resilience* determines the rate of degradation under various stresses and the rate of recovery after the "stress stop". Consequently, the quantified and specified soil resilience may contribute to the prevention or reduction of the risk and stresses as degradation processes, pollution, extreme hydrological events, etc.

Stresses and soil resilience

The main groups of stresses determining, influencing or modifying soil formation and soil processes (mass, energy and water regimes, abiotic and biotic transport and transformation) are as follows (Greenland and Szabolcs, 1994; Lal, 1994; Várallyay, 2006):

- Irrational land use practices (improper cropping pattern and agrotechnics).
- Soil degradation processes: water and wind erosion; acidification; salinisation/ sodification; aggregate destruction and compaction; biological degradation; unfavourable changes in the biogeochemical cycle of elements.
- Soil pollution from point, "quasi-point" or diffuse pollutant sources.
- Extreme hydrological events: floods, waterlogging, over-moistening versus drought.
- Stresses of urban and rural development (infrastructure, industry, mining, traffic, agriculture, etc.).

The reason of these stresses can be natural factors and human activities. *Soil degradation and restoration processes and anthropogenic interventions* are schematically summarized in Figure 1.

Soil resilience and sustainable development

The maintenance of soil fertility/productivity necessitates the permanent satisfaction of the strict preconditions of "renewal" and utilization of soil resilience with the control of soil processes. This is the basis for *sustainable land use and soil management.* The scientifically based, efficient control of soil processes requires the consecutive steps shown in Figure 2.

For the *sustainable maintenance of soil resilience* the the following steps are required (Blum and Aguilar Santelises, 1994; Greenland and Szabolcs, 1994; Várallyay, 1994, 2003):

- exact definition, quantitative description and characterization of the existing processes and their mechanisms with special attention to their reversibility;
- determination of influencing factors, their relationships, partial and integral impacts;

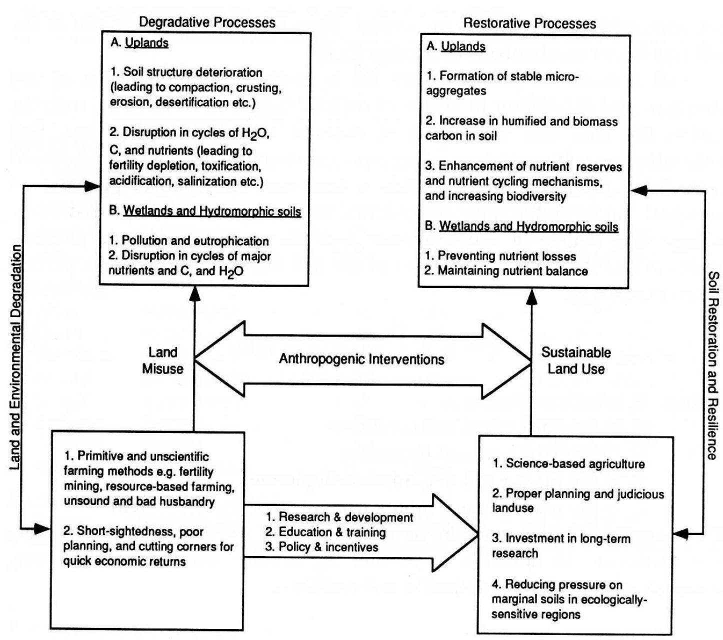

Figure 1. Soil degradation and restorative processes and anthropogenic interventions

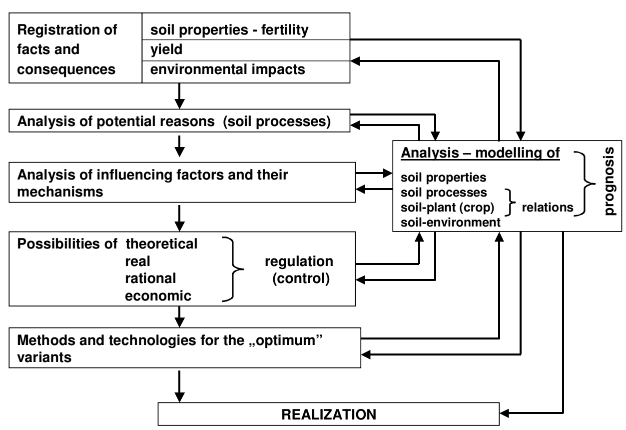

Figure 2. Control of soil processes

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– definition of the thresholds of various stresses (extreme moisture regime, extreme soil reaction, nutrient deficiency, pollution, toxicity, etc.), which can be tolerated by the soil without irreversible, non- or hardly correctable changes: harmful deterioration in the soil or in the ecosystem ("limit values of soil resilience");
– determination of the possibilities and elaboration of proper technologies for efficient soil process control and for the maintenance or increase of the desirable multifunctionality, utilizing soil resilience.

Conclusions

Soils are conditionally renewable natural resources because they have a unique property, *soil resilience:* the ability to recover after various disturbances, increasing natural and human induced stresses. Ensuring the preconditions of resilience by rational land use and soil management, the desirable multifunctionality and fertility of soils are sustainable.

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TILLAGE AND RESIDUE MANAGEMENT EFFECTS ON SOIL CARBON SEQUESTRATION AND BASAL RESPIRATION IN A PEAS PHASE OF CROP ROTATION

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Abstract: An eight year field study was conducted in south-western Slovakia to investigate the effects of different soil tillage intensities and residue management on soil carbon sequestration and soil basal respiration under peas for grain growing after cereal forecrops. The soil type is Orthic Luvisol with a loamy texture and a pH of 5.7. There were conventional and reduced tillage treatments and treatments with whole residues incorporation, removed residues, treatments with and without mineral fertilization. The experimental design was a split-plot with four replicates. There was a significantly increase in basal respiration after reduced tillage - twice shallow loosening to a depth of 0.1 m (2.82 mg CO_2-C $100g^{-1}$ day^{-1}) and smaller after ploughing treatment to a depth of 0.22m (2.35 mg CO_2-C $100g^{-1}$ day^{-1}). The basal respiration had a seasonal pattern mainly due to cropping of peas. The reduced tillage also creates better condition for soil carbon accumulation (32.6 t ha^{-1}) with comparison to mouldboard ploughing (31.4 t ha^{-1}) in 0.2 soil layer. Resilience of crop rotation pattern through improved management practices and threshold limits for C sequestration are discussed.

Keywords: sequestration, tillage, fertilization, soil respiration

Introduction

Sequestration of carbon from plant biomass into organic matter is a key sequestration pathway in agriculture. The net change in soil organic carbon (SOC) depends not only on the C loss as CO_2 emission but also on the C input and tillage intensity (Lacko-Bartošová, 2006; Birkás et al., 2008; Molnárová and Žembery, 2009). To promote carbon sequestration research and human activity needs to maximise the inputs and minimise the outputs to increase sustainability and resilience of agroecosystem in particular crop rotation pattern (Lacko-Bartošová and Korczyk-Sabo, 2008; Berzsenyi, 2009). There is also a verified link between inputs of mineral fertilizers and SOC sequestration via biomass production (Kováčik et al., 2006; Fogarassy et al., 2008). Organic matter stock and microbial respiration are recommended indicators for evaluation of soil in EÚ (Michéli et al., 2008). Land use changes and soil and crop management practices with potential for SOC sequestration include conservation tillage methods, use of crop residues, diverse crop rotations, erosion control (Singh and Lal, 2005) and judicious use of fertilizers and manures (Kováčik, 2007; Kováčik et al., 2009).The objective of this study was to investigate the effects of different soil tillage intensities and fertilization on soil carbon sequestration and soil basal respiration under peas for grain.

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Materials and methods

Field trials were conducted from 1996 through 2003 at the SAU in Nitra in south-western Slovakia. The average annual/growing season rainfall is 561/327 mm. The mean annual/growing season temperature is 9.7°C/16.2°C. The soil type is Orthic Luvisol with a loamy texture and a pH of 5.7. The experimental design was a split-plot with four replicates. The tillage was the main plot factor; the fertilization was the subplot factor. The subplots were 3 m wide by 10 m long and plots were subjected to primary soil tillage treatments as follows: mouldboard ploughing (CT) to a depth of 0.22 m (conventional tillage), twice shallow loosening (R) to a depth of 0.1 m (reduced tillage). Three fertilization treatments as follows: 0–without organic and inorganic fertilization, PH–mineral fertilizers calculated to the 3 t yield level, PR–incorporation of all above-ground plant material supplemented with mineral fertilizer to the balance equilibrium level. Common pea (*Pisum sativum* L.) was growing after cereal forecrop (spring barley since 2001 – winter wheat). The soil samples were collected from the 0.25 m (for total respiration) and 0.075m (for seasonal dynamics) topsoil layer three times (spring, summer and autumn samples). The soil samples were incubated at 28 ºC and soil basal respiration was measured 17-18 days. CO_2 captured was indirectly determined after addition of saturated $BaCl_2$ to the NaOH solution, followed by the titration of the NaOH with HCl. SOC content was determined by the Tjurin method. For organic matter stock (kg ha^{-1}) calculation for 0.2m soil layer, the soil bulk density was determined by soil core sampling kit.

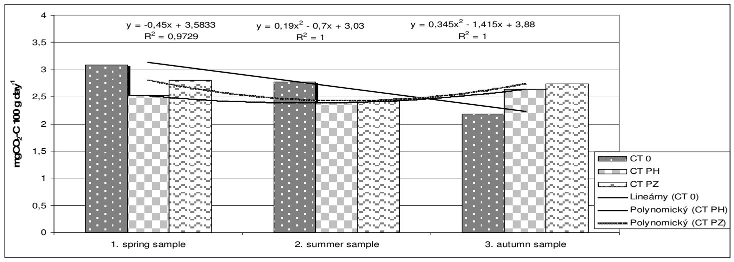
Results and discussion

It can be seen from Table 1 that average daily soil basal respiration is grater in reduced tillage treatments (twice shallow loosening) with comparison to conventional mouldboard ploughing. In this specific site condition the fertilization treatments has been insignificant source of variability.

Table 1. Soil respiration in mg CO_2-C 100g day^{-1} in each tillage and fertilization treatments. The means within tillage (bold) and fertilization treatments followed by the same letter are not significant at $P<0.05$ or $P<0.01$ probability level

Source of variability	Treatments	Soil respiration
Tillage	conventional	2.35**a**
	reduced	2.82**b**
Fertilization	0-without fertilizers	2.52a
	PH-mineral fertilizers	2.64a
	PZ-organic and mineral fertilizers	2.61a

For ilustration the seasonal dynamics of soil basal respiration under conventional tillage can be seen from Figures 1. Concordance with Mielnick et al., (2000) soil CO_2-C flux has a seasonal pattern in field condition. The autumn samples, both conventional and reduced soil tillage treatments reflect the influence of crop residues and soil preconditions for mineralization processes (Franchini et al., 2007). The differences in CO_2 were identified after the addition of crop residues to the soil, stimulating microbial activity and resulting in stronger decomposition in both soil management systems. The seasonal dynamics of particular fertilization treatments was described by linear and polynomic equation.



Figue 1. Seasonal dynamics of soil basal respiration in conventional tillage under different fertilization treatments from 2001-2003

Temporal change was evaluated as absolute and net change (Table 2). Absolute change in stored C from first year of field trial was strongly decline from 36.6 t ha^{-1} (1994) to 32 t ha^{-1} (1996-2003). Net change of SOM between tillage treatments revealed significantly higher C sequestration in reduced tillage system.

Table 2. *S*oil carbon stocked in equivalent soil mass (t ha^{-1}) in each tillage and fertilization treatments. The means between years followed by the same letter are not significant at $P<0.05$ or $P<0.01$ probability level

Tillage/fertilization	1996	1999	2000	2001	2002	2003	1996-2003
CT-0	33.0	33.7	31.00	31.0	27.7	28.9	30.9
CT-PH	33.3	34.2	31.3	31.9	30.7	28.9	31.2
CT-PZ	33.6	32.0	32.7	30.8	31.2	32.4	32.1
R-0	30.3	34.2	33.0	29.4	31.8	34.2	32.2
R-PH	31.8	33.5	33.8	32.1	32.3	34.2	33.0
R-PZ	31.8	33.2	35.3	30.0	29.5	35.7	32.6
Average	31.8b	33.5d	32.9c	30.9a	30.5a	32.4c	32.0

The most efficient method of accumulating carbon in soil must be by direct decomposition of plant material, but declination of SOM revealed insufficient input of above ground plant material without cattle manure compensation. Regarding two tillage systems, the average net change in SOC was higher in reduced tillage treatments with comparison to conventional one (Table 3).

Table 3. Soil carbon stocked in equivalent soil mass (t ha^{-1}). influenced by tillage and fertilization treatments. The means within tillage (bold) and fertilization treatments followed by the same letter are not significant at $P<0.05$ or $P<0.01$ probability level

Source of variability	Treatments	Soil organic carbon
Tillage	conventional	31.4**a**
	reduced	32.6**b**
Fertilization	0-without fertilizers	31.5a
	PH-mineral fertilizers	32.1b
	PZ-organic and mineral fertilizers	32.4b

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Differences between the samples with application of mineral fertilizers (PH) or organic and mineral fertilizers (PZ) are associated with the decomposition of common peas residues or great amount of biomass production (roots, exudates and post harvest residues).

Conclusions

The fertilization treatments do not revealed the significant differences in soil basal respiration in an average, but strong seasonal dynamics was recognised. These changes are potentially useful as responsive indicator of the effects of crop and soil management. Higher soil basal respiration and more CO_2 was realised from reduced-till compared to conventional tillage despite there being increased levels of soil carbon. Suitable soil tillage systems may play an important role in improving the soil fertility and reducing global warming by providing a greater sink for CO_2.

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USE OF BIOGAS RESIDUES AS FERTILIZERS – EFFECTS ON PLANT AND SOIL PARAMETERS

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Abstract: Biogas generation does not only provide renewable energy it also leaves residues which contain all important plant nutrients and thus can be used as fertilizers in crop production. Compared to input substrates used in biogas plants, the residues are altered concerning nutrient availability and organic matter content. The effect of fertilization with biogas residues on plant and soil parameters was studied in a pot experiment. Dry matter yield and plant available P (Olsen-P) content increased when the biogas residues were applied compared to the unfermented input substrate. On the contrary soil respiration and dehydrogenase activity decreased after application of the fermented residues.

Keywords: biogas residues, P availability, soil respiration, dehydrogenase activity

Introduction

Biogas generation plays an important role in renewable energy production from biomass. In the agricultural practice the most commonly used substrates for biogas plants are slurries, fodder- and plant residues or energy crops. After fermentation, the residues still contain all relevant plant nutrients like nitrogen (N), phosphorus (P), potassium (K) and organic matter, and thus can be used as fertilizer in crop production. This is especially important for the element P, because the natural P resources are declining. Therefore, the use of alternative P sources and the recycling of P in agriculture becomes more and more important. The fermentation process influences nutrient availability and organic matter composition of the substrates used. Especially the content of NH_4-N, which is easily available for plants, has been shown to be higher in the fermented residue compared to untreated slurries (Pötsch et al., 2004). This is mainly due to the decomposition of organic matter during anaerobic digestion by which organically bound nutrients became mineralized (Loria and Sawyer, 2005). On the other hand, as a consequence of the decomposition of easily degradable organic substances, only hardly degradable compounds like lignin remain in the fermented residue (Roschke, 2003). This has effects on plant P nutrition, soil P cycle and biological soil parameters. The aim of this work was to (I) analyse the effects of the fermentation process on the composition of the output substrate of biogas plants and (II) the effects of unfermented and fermented substrate on plant P uptake, P availability in the soil and soil microbial activity.

Materials and methods

The substrates (15 m³ dairy slurry + 1 t maize silage + 0.2 t wheat-corn) were analysed before and after 28 days of fermentation regarding their nutrient and organic matter content. Samples were dried in the oven at 105 °C to determine dry matter content

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(DM). Dry material was ground and organic matter content (OM) was determined after ashing at 550 °C. For total P, K and Mg content the ash was digested in 20 % hydrochloric acid. Total P and Mg contents in the filtrate were determined photometrically. Total K content was analysed using flame spectrometry. Kjeldahl method was used to analyse total N and NH_4-N content in the fresh substrates. Both substrates were used as fertilizers in a pot experiment. Six kg of a P-poor loamy sand (double lactate P content: 3.6 mg 100 g^{-1}, pH 5.6) were weighted into Mitcherlich pots. The unfermented substrate (US) and the fermented substrate (FS) was applied to the soil corresponding to 0.2 (low) and to 0.4 (high) g of P per pot, and immediately mixed into the soil to avoid NH_4-N losses. As a control a mineral fertilization without P (NK) and a treatment with Triplesuperphosphate as easily available P source (NPK) were established. The amount of mineral N, P and K added in these treatments was adjusted to the total amount of nutrients applied with the biogas substrates. Maize *(Zea mays)* was cultivated as a test crop. All treatments were established in four replicates. Pots were randomized and placed outside in a cage, exposed to natural weather conditions. Destilled water was used for irrigation according to plants needs. Plants were harvested eight weeks after germination. Soil samples were taken immediately and stored at -18 °C for microbial and chemical analysis. Dry matter yield was determined after drying the harvested biomass at 60 °C to constant weight. Total P content in plant tissue was determined as described above for the biogas substrates. Plant available P content in soil was determined in 0.5 *M* $NaHCO_3$ solution (Page, 1982). Soil Respiration was analysed as described by Isermeyer (1952). Dehydrogenase activity was determined photometrically after incubating 1 g of soil for 24 hours in a 0.8 % Triphenyl-tetrazoliumchloride solution (Thalmann, 1968). Univariate analysis of variance was used to investigate the effect of the fertilizer treatment on plant and soil parameters. If significant effects were found, the Duncan test was used to compare means at $p \leq 0.05$. Significantly different means were indicated by using different characters.

Results and discussion

Dry matter content as well as organic matter content was considerably reduced during the fermentation process. Especially organic matter content decreased for about 43.8 %, which is due to the decomposition of organic compounds during the fermentation process by methane producing bacteria.

Table 1. Composition of the biogas substrates before and after 28 days of fermentation (in % of fresh weight).

	unfermented substrate	fermented substrate
DM	12.11	7.63
OM	10.5	5.9
N	0.47	0.49
NH4-N	0.19	0.25
P	0.07	0.07
K	0.20	0.24
Mg	0.08	0.07
pH	7.5	8.6

The total nutrient content wasn't influenced by the fermentation process, but the content of NH_4-N increased for 31.6 % during the fermentation process, accounting 51.0 % of total N in the biogas residue (Table 1). The pH value of the substrates increased as well after fermentation for about one unit. Because total P content remained constant during the fermentation process, the same amount of fermented and unfermented substrate was applied to the soil, which resulted on the other hand in a considerable variation of organic matter and NH_4-N supply.

Dry matter yield of maize increased significantly when the biogas residue was applied compared to the control without P supply. The effect of the biogas residue on the yield was almost comparable with a high soluble mineral P source, while the fertilization with the unfermented substrate resulted in significantly lower yields. The higher fertilizer dosage did not increase yields in comparison to the low dosage, but confirmed the positive effect of fermentation residue on maize yields compared to the unfermented substrate (Table 2). This can be due to a higher P availability but also due to the higher NH_4-N content after the fermentation. Compared to the control, the P uptake almost doubled when P fertilizers were applied (low dosage), no matter if a mineral or an organic P source was used. Between the fermented and unfermented fertilizers no differences in the P fertilizing efficiency were found. This indicates that the difference in the yield between both substrates is more attributed to the higher supply of mineral N with the biogas residue than to a better P availability (Table 2).

Table 2. Effect of unfermented and fermented biogas substrates on maize yield and P uptake of maize in a 8 week pot experiment (l=low dosage, h=high dosage)

Treatment	Yield mg per pot		P uptake mg per pot	
	Mean	SD.	Mean	SD.
NK_l	47.78 a	3.45	66.00 a	3.18
NPK_l	84.88 d	3.07	111.92 b	2.97
US_l	56.08 b	3.17	98.72 b	7.87
FS_l	71.88 c	5.60	114.03 bc	3.90
NPK_h	69.60 c	8.44	149.48 e	16.94
US_h	56.33 b	9.40	128.84 cd	18.74
FS_h	69.10 c	5.95	135.70 de	17.42

Although, there was no difference in P uptake between fermented and unfermented substrate, the plant available P content in the soil differed significantly. Especially at the low dosage, plant available P content was lowest in the treatment fertilized with the unfermented substrate and in the control without P supply, and increased significantly when the biogas residue or mineral P was applied (Table 3). This confirms the assumption of a higher P availability after fermentation process.

On the contrary to plant and chemical soil parameters, biogas residue application tended to decrease soil microbial activity. At the high dosage, a decline of soil respiration for about 24 % was observed when the fermented residue was applied compared to the unfermented substrate. The same effect was shown by dehydrogenase activity, which was highest when the unfermented substrate was used as fertilizer and significantly decreased when the biogas residue was applied, no matter if low or high dosage of the fertilizers was used (Table 3). A decline in microbial activity after fertilization with biogas residues compared to untreated slurries was also described by Ernst et al. (2008).

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Furthermore, in a field experiment Kautz and Rauber (2007) found no effect of biogas residue application on β-Glucosidase activity compared to mineral fertilized soils, indicating that biogas residues may not be a suitable carbon source for microorganisms.

Table 3. Effect of unfermented and fermented biogas substrates on chemical and biological soil parameters in a 8 week pot experiment (l=low dosage, h=high dosage)

Treatment	Olsen-P mg kg^{-1} DM		Soil Respiration mg CO_2 $100g^{-1}$ DM 7 d^{-1}		Dehydrogenase activity µg TPF g^{-1} DM 24 h^{-1}	
	Mean	SD.	Mean	SD.	Mean	SD.
NK_l	46.04 a	3.27	33.67	10.98	34.8 a	8.02
NPK_l	55.39 b	3.33	37.27	10.27	87.57 b	25.41
US_l	45.58 a	4.48	46.47	13.98	130.07 c	27.51
FS_l	54.96 b	5.14	47.54	11.43	94.26 b	17.76
NPKh	64.91 c	6.21	42.62	4.33	45.39 a	7.25
USh	58.41 bc	2.47	50.19	4.12	192.56 d	14.77
FSh	61.10 bc	1.77	38.28	5.73	94.49 b	7.54

Conclusions

The biogas fermentation process improves the N and the P solubility in the substrates which may result in a positive effect on yields and on the P availability in soils. On the other hand the results indicate, that biogas residues are not a suitable energy and carbon source for microorganisms and additional measures may be necessary to maintain the microbial activity in soils continuously fertilized with biogas residues.

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