Electronic Journal of Polish Agricultural Universities is the very first Polish scientific journal published exclusively on the Internet, founded on January 1, 1998 by the following agricultural universities and higher schools of agriculture: University of Technology and Agriculture of Bydgoszcz, Agricultural University of Cracow, Agricultural University of Lublin, Agricultural University of Poznan, Higher School of Agriculture and Teacher Training Siedlce, Agricultural University of Szczecin, and Agricultural University of Wroclaw.

ELECTRONIC JOURNAL OF POLISH AGRICULTURAL UNIVERSITIES

1999
Volume 2
Issue 1
Series AGRONOMY

Reszel R. S., Baran S., Reszel H. 1999. CHANGES IN THE CONTENT OF PHENOLIC ACIDS IN LOOSE SAND AND BROWN SOIL FERTILISED WITH SOIL FROM SUGAR-PROCESSING PLANT SEDIMENTATION TANKS **Electronic Journal of Polish Agricultural Universities**, Agronomy, Volume 2, Issue 1.
Available Online http://www.ejpau.media.pl

CHANGES IN THE CONTENT OF PHENOLIC ACIDS IN LOOSE SAND AND BROWN SOIL FERTILISED WITH SOIL FROM SUGAR-PROCESSING PLANT SEDIMENTATION TANKS

Roman S. Reszel[1], Stanisław Baran[2], Hanna Reszel[1]
[1]*Institute of Biology and Environmental Protection, Pedagogical University, Rzeszow, Poland*
[2]*Institute of Soil Science and Development of the Natural Environment, Agricultural University, Lublin, Poland*

SUMMARY

A single dose of 10, 25 and 50% (weight percentage) of the soil collected from sugar-processing plant was added to loose sand and brown soil. A four –year - pot experiment was set where the following were cultivated, in turn:

PRINT

corn, buckwheat, spring wheat and corn. It was observed that the content of phenolic acids in soil grew proportionally to the dose of soil introduced and it was positively correlated with the contents of C-org, N-org, available P, K and Mg forms, floatable forms and sorption capacity, as well as the plant yield and its nitrogen and magnesium contents. However, the content of phenolic acids in brown soil did not show a linear dependence on the sediment dose, it correlated negatively with the amount of C fraction most susceptible to biological oxidation and with microbiological respiration activity, yet positively with the concentration of potassium available in soils, yield and its nitrogen content.

Key words: phenolic acids, soil derived from sugar-processing plant sedimentation tanks, soil fertility, brown soil, loose sand

INTRODUCTION

The soil derived from sedimentation tanks consists of soil particles mainly but also plant pieces accumulated in the sugar-processing plant sedimentation tanks, where they get along with the water used to unload and wash the sugar beets. Due to its basic reaction, high content of floatable particles and nutrients, the sediment shows a great potential as a fertiliser for arable land and for reclamation of degenerated formations. In both cases, the soil becomes richer in nutrients and organic substances and its microbiological activity increases [12,14]. However, one should remember that the plant pieces, present in the sediment, are one of the main sources of phenolic acids, compounds which can have an allelopathic effect, and whose higher concentration can have a negative effect on plant growth and yields [2-7,11]. Therefore, the present research was conducted also to examine whether introducing large doses of sugar processing plant sediment causes an accumulation of low-molecular phenolic acids in loose sand and brown soil, formations with different sorption capacity, trophic and biological characteristics as well as to define the relationship between the level of these allelo-compounds and some soil fertility indicators and the plant yield.

MATERIALS AND METHODS

The pot experiment was carried out in the years 1989-1992 in the Institute of Agricultural Sciences in Zamosc, of the Lublin Agricultural University, in loose sand sampled from the podzolic soil C layer, deposited on limestone subsoil and acid brown soil with a mean nutrient content. At the beginning of the experiment, 10, 25 and 50% (weight percentage) of soil derived from sedimentation tanks of the Klemensow sugar-processing plant was added to the formations (59% of silt, 2.2 % C_{org}, pH_{KCl} 8.0) as well as manure (the dose of 40 $Mg.ha^{-1}$). The experiment was conducted in three replications, with the following being cultivated in the successive years: corn, buckwheat, springs wheat and corn again.

To define the level of phenolic acids, the soil was sampled in the autumn of the first and the last year of the experiment. Phenolic acids (from the soil solution as well as the soil solid phase were extracted, applying the method described by Hruszka [6] with a mixture of ethanol, water and acetic acid (70:28:2). Their concentration was defined with the Swain-Hillis method (in an aqueous solution with Folin-Denis reagent, with hydroquinone, as the standard).

The present research defined, as follows:

a. corn yield; plant sown in the first and last year of the research conducted;
b. content of macroelements in its straw (grain samples were not always available),
c. soil fertility indexes in the seasons analysed, defined with the methods adopted by chemical and agricultural research stations;
d. sorption capacity (defined with the Pallman method);

e. presented in an earlier paper [12] the content of organic carbon (the Tiurin method) and its fractions (the Loginow-Wisniewski method) as well as the environment metabolic activity, calculated with the amount of CO_2 educed (according to Maciak).

The results obtained were analysed statistically. Only those characteristics which showed some evidence that the changes were due to the experiment conducted were presented, and where the LSD values and correlation coefficients were significant, with the significance level not lower than 95%.

RESULTS

The sediment derived from sedimentation tanks showed a considerable content of phenolic acids (18.5 $mg.kg^{-1}$ of dry matter) and, consequently, when added, an increase in the compounds in the soils researched was observed. However the results depended mostly on the soil formation (Table 1). And so, in the first year of the sand research, with an increase in sediment doses, gradually the amount of these compounds increased (almost four-, six- and eleven-times, respectively), much more clearly than after being treated with manure. The effect of the treatment was so considerable that its results in the combinations with a 25 and 50% dose were still observed four years later. A linear dependence between the soil derived from sedimentation tanks and the level of phenolic acids in sand was observed here, independently of the dates the marks were made. The results of the pot experiment with brown soil, richer in phenolic acids than the sand, were different. In the first year, the level of these compounds increased only once the highest dose of sediment (50%) was introduced, whereas introducing the smallest dose caused a decrease in their content. However, after four years, the concentration of these phytotoxins decreased considerably and in all the combinations with the soil derived from the sedimentation tanks it was lower than in the control test (Table 1). One shall mention that the in the pots filled with sand no relationship between the level of phenolic compounds and the soil microbiological activity was observed, unlike in brown soil, where a high negative correlation between the content of phenolic acids and the environment metabolic activity, calculated with the amount of CO_2 educed ($r = -0.92$) as well as the share of carbon fraction most susceptible to microbiological oxidisation ($r = -0.75$).

Table 1. Impact of soil derived from sedimentation tanks and manure on the content of phenolic acids in sand and soil ($mg \cdot kg^{-1}$ dry matter of the soil)

Variants	Loose sand			Brown soil		
	1989	1992	Mean	1989	1992	Mean
Control test	1.25	1.18	1.22	11.9	5.82	8.88
+ manure	2.93	1.00	1.96	12.7	6.03	9.38
+ 10% of the sediment	4.58	1.48	3.03	9.52	3.58	6.55
+ 25% of the sediment	7.11	2.28	4.70	10.9	3.34	7.16
+ 50% of the sediment	13.6	3.41	8.52	13.2	4.01	8.64
Mean	5.90	1.87	3.89	11.7	4.56	8.12
$LSD_{0,05}$ for:						
variants		0.65			0.78	
years		0.36			0.45	
interactions variants x years		0.88			1.10	

PRINT

A dose of the soil derived from sedimentation tanks added caused not only an increase in the content of phenolic acids, but also in sorption capacity of the soils and their richness (Table 2). It was most clear in the pots with sand, where the level of organic carbon, total nitrogen, available P, K and Mg forms, sorption capacity and silt share were positively correlated with the content of phenolic acids. The concentration of these compounds in brown soil was related only to the content of available potassium, however less than in sand (Table 3).

Table 2. Changes in the characteristics sand and soil after the soil from sedimentation tanks and manure was added

Variants	Sorption capacity cmol (+)·kg^{-1}	C organic	Total N	Form availability (mg·kg^{-1})		
		g·kg^{-1}		P	K	Mg
Loose sand						
Sand	11.9	0.79	0.13	27	32	22
+ manure	13.4	0.87	0.15	30	49	23
+ 10% of the sediment	53.6	4.01	0.50	158	64	116
+ 25% of the sediment	56.2	6.11	0.74	194	102	200
+ 50% of the sediment	58.8	11.4	1.29	204	146	309
$LSD_{0.05}$	2.2	0.59	0.10	4	16	11
Brown soil						
Soil	14.7	9.8	0.84	38	152	50
+ manure	15.4	10.6	1.04	40	166	52
+ 10% of the sediment	53.6	11.0	1.24	180	160	97
+ 25% of the sediment	62.2	13.6	1.36	181	176	182
+ 50% of the sediment	63.5	15.6	1.74	180	208	349
$LSD_{0,05}$	1.6	0.62	0.11	6	13	17

Table 3. Values of the correlation coefficients between the content of phenolic acids in sand and soil and some soil characteristics and corn yield

Characteristics	Loose sand	Brown soil
C-org.	0.70	n.s.
Total N	0.85	n.s.

PRINT

Available P	0.51	n.s.
Available K	0.90	0.73
Available Mg	0.94	n.s.
Floatable particles	0.66	n.s.
Sorption capacity	0.64	n.s.
Corn yield	0.76	0.67
N content in straw	0.90	0.64
Mg content in straw	0.86	ns

n.s. – non-significant

Due to increased soil richness, when the soil derived from sedimentation tanks was added, the corn yield as well as the contents of nitrogen and magnesium in straw increased (Table 4). One shall mention that the plant weight as well as nitrogen concentration were positively correlated with the concentration of phenolic acids, both in sand and soil, however the amount of magnesium in straw was related to the phenolic acid level in sand only (Table 3). It is also essential that the content of available potassium in subsoil and nitrogen in plants correlated more with the content of phenolic acids in loose sand rather than in brown soil, which is seen from the significantly higher modules of the correlation coefficients.

Table 4. Impact of the soil derived from sedimentation tanks and manure on the mean corn yield and N and Mg in straw

Variants	Yield (g of dry matter/pot)		N (% of dry matter)		Mg (% of dry matter)	
	p	g	p	g	p	g
Control	25.1	79.2	0.58	0.52	0.13	0.09
+ manure	38.9	92.0	0.54	0.51	0.13	0.09
+ 10% of the sediment	59.7	101.1	0.60	0.55	0.28	0.17
+ 25% of the sediment	77.2	114.7	0.60	0.74	0.32	0.28
+ 50% of the sediment	113.5	117.0	0.78	0.95	0.40	0.32
LSD	13.9	17.1	0.03	0.05	0.02	0.02

p – loose sand; g – brown soil

DISCUSSION

An increased production of secondary metabolites, phenolic acids belong to, remains a reaction of plants to unfavourable development conditions, such as, a shortage of nutrients and water, low temperature, influence of herbicides, pest infestation, UV radiation. [3]. They accumulate on plants and enter the soil with rain, causing elution from the leaves, root secretions and decomposition of tissue remains [4,5,10]. Therefore, one can assume that an increase in the content of these allelo-compounds in soil shows the plant reaction to stress. In the present experiment no increase in the level of phenolic acids was observed in subsoil, on the contrary, after four years, their content decreased considerably (to 40% of the initial level), which shows that introducing the sediment did not make the habitat conditions any worse. However it enhanced the trophic conditions, which, consequently, made the yield higher. The same was observed in other experiments conducted on the sediment derived from sedimentation tanks [8, 14].

Obviously, the sediment from the sugar-processing plant or manure added modified physical properties, chemical analysis and microbiological potential of very poor loose sand more substantially than of the rich brown soil. A high correlation between the phenolic acid level and the sand fertility indexes is justifiable as the compounds influence solubility of numerous nutrients, they can also cause an increase in phosphate availability as they compete with them in anion sorption [7]. It is also well-known that in poor environments they create, available for plants, complexes with proteins, and, consequently, cut down N losses due to elution or nitrification [10]. It may be the reason why nitrogen content in plants cultivated on sand showed such a high positive correlation with the level of these allelo-compounds. Also in the mixtures with sand, a close relationship between phenolic acids concentration and sorption capacity was noted. The reaction in all these combinations was basic, and it is under such as well as under neutral conditions, according to Dalton et al. [as quoted in 7], phenolic acid sorption is the highest, which, in turn, enhances their polymerisation. As a result, it decreases their susceptibility to microbiological decomposition [4], which could be the reason why they show no correlation with microbiological indicators.

Faster degradation of phenolic acids in brown soil, as compared with loose sand, can have been due to a greater activity of the micro-organisms living there which used these compounds as a source of carbon [1, 3, 4]. It is confirmed by the negative correlation of the concentration of these phytotoxins and the intensity of microbiological respiration as well as the content of the carbon fraction most susceptible to biological oxidation, observed in all the pots with brown soil.

CONCLUSIONS

1. Introducing the soil derived from sedimentation tanks into soil-less formations as well as the brown soil arable layer, one shall expect an increase in phenolic acids, which, in turn, does not necessary brings about a decrease in yield.
2. The changes in the concentration of phenolic acids in loose sand and brown soil fertilised with the soil derived from the sedimentation tanks depend both on the dose as well as the kind of formation it was put into.

REFERENCES

1. Blum U., Shafer S.R., 1988. Microbial populations and phenolic acids in soil. Soil Biol. Biochem., 20 (6), 793-800.
2. Blum U., 1996. Allelopathic interaction involving phenolic acids. Journal of Nemetology, 28 (3), 259-267.
3. Einhellig F.A., 1996. Interactions involving allelopathy in cropping systems. Agron. J. 88, 886-893.
4. Hartley R.D., Whitehead D.C., 1985. Phenolic acids in soils and their influence on plant growth and soil microbial processes. Developments in Pant and Soil Sciences, 16, 109-149.
5. Hennequin J.-R., Juste C., 1967. Présence d'acides phénols libres dans le sol. Étude de leur influence sur la germination et la croissance des végétaux. Ann. Agron., 18 (5), 545-569.
6. Hruszka M., 1982. Studia nad toksycznoscia zwiazkow fenolowych w uprawach monokulturo-wych. Acta Univ. Agric. (Brno), Fac. agron. XXX, (3), 79-85.
7. Inderjit, 1996. Plant Phenolics in allelopathy. The Botanical Review 62 (2), 186-202.
8. Klikocka H., 1997. Wplyw uzyzniania gleby plowej ziemia z osadnikow cukrowni na plonowanie roslin. Cz.II. Plony roslin i ich jakosc. Ann. Univ. Mariae Curie-Sklodowska, s. E, 52, 139-148.
9. Maciak F., Harms H., 1987. Content of phenolic acids in low peat soils depending on their agricultural utilisation. Roczn Glebozn. 38 (2), 45-60.
10. Northup R., Yu Z., Danhlgren R., Vogt K., 1995. Polyphenol control of nitrogen release from pine litter. Nature, 377, 227-229.
11. Oleszek W., 1996. Allelopatia - rys historyczny, definicje nazewnictwo. IUNG Pulawy, seria K (10).
12. Reszel R.S., Baran S., Flis-Bujak M., Reszel H., 1994. The influence of sugar beet washing earth on organic matter and biological activity of the soil and yield of plants. Roczn. Gleb., XLV, 109-117.
13. Reszel R.S., Baran S., Reszel H., 1996. Przydatnosc ziemi z osadnikow cukrowni do rekultywacji gleb. Zesz. Probl. Post. Nauk Roln., 437, 311-316.
14. Reszel R.S., Reszel H., Klikocka H., 1997. Wplyw uzyzniania gleby plowej ziemia z osadnikow cukrowni na plonowanie roslin. Cz.I. Niektore wlasciwosci i zasobnosc gleby. Ann. Univ. Mariae Curie-Sklodowska, s. E, 52, 133-138.

Submited:

Roman S. Reszel, Hanna Reszel
Institute of Biology and Environmental Protection, Pedagogical University in Rzeszow
Rejtana 16C, 35-310 Rzeszow, Poland
tel. (017) 62-56-28
E-mail: reszelro@univ.rzeszow.pl

Stanisław Baran
Institute of Soil Science and Development of the Natural Environment
Agricultural University in Lublin
