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POSSIBILITY OF THE USE OF SUGAR-BEET WASHING EARTH IN THE GROWING OF SUGAR-BEET INSTEAD OF MINERAL FERTILIZERS*

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INTRODUCTION

Polish sugar refineries accumulate annually 1.0 to 1.5 million tons of washing earth (sediment) from sugar-beet which is a problem both of an economic and an ecological nature. Earlier research proved that this sediment may replace traditional mineral fertilizers especially when applied to light soils [Brandyk 1976]. However, the very high costs of sediment transportation limit its application. Therefore, the aim of the study was to establish the sediment's usefulness in fertilizing sugar-beet plantations (on medium category soils) located close to sugar refineries [Reszel, Klikocka 1992].

CONDITIONS AND METHODOLOGY OF THE INVESTIGATION

The field experiment was carried out in 1990–1992 at the farm of a sugar-beet planter in the village of Feliksówka near Zamość. The data presented in Table 1 demonstrate that the only vegetation period with favourable rainfall conditions was in 1990. The other periods (1991 and 1992) were warm and dry. The lessivé

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TABLE 1. Sums of rainfalls [mm] and temperature [°C] in the growing season and in long-term period at Zamość

Years	Months							Sum
	April	May	June	July	Aug.	Sept.	Oct.	
				Rainfalls				
1990	72	46	51	83	80	102	8	442
1991	28	89	67	76	48	64	37	409
1992	69	52	61	90	45	134	95	546
$\bar{x}$	36	47	90	74	77	62	18	404
				Mean temperature				
1990	8.2	12.9	16.4	16.5	16.8	10.8	8.3	2752
1991	6.9	10.7	15.8	18.7	17.4	14.0	7.6	2789
1992	7.3	12.4	17.3	18.7	20.8	11.8	6.3	2896
$\bar{x}$	8.2	13.3	16.0	17.8	16.7	12.3	8.0	2825

soil used in the experiment belonged to the IIIb category of very good "rye soil" (Table 2). The forecrop each time was winter wheat.

The experiment was carried out on four randomly chosen sets of plots each 17 m^2 in area. In the early spring of 1990 respective plots were fertilized with the sediment to the amount of 286, 715 and 1413 tons of dry mass per hectare (respective proportions were 10, 25 and 50% of the arable layer's dry mass). The sediment was evenly spread and left for 2 weeks to dry in the field, which was then ploughed to a depth of 30 centimetres. In order to further differentiate the vegetation conditions, half of the plots were fertilized with mineral fertilizers (N – 130 kg/ha, P_2O_5 – 80 kg/ha, K_2O – 120 kg/ha). Soil and crop cultivation as well as plant protection and herbicide application were uniform and were performed with a high standard of care.

– The granulometrical composition of the soil was determined using the Bouyoucos' method (modified by Casagrande and Prószyński).

– The organic component was determined using the Łoginow-Wiśniewski method.

– pH was measured electrometrically, and

– N content with the use of the Kjeldahl method.

The Egner-Riehm method was used to determine the content of available forms of P and K, and

– Schachtschabel's method to determine Mg content.

Another series of measurements to determine the crop's yield and its quality was performed after the harvest.

– The sugar content was measured polarimetrically,

– the ash content conductometrically,

– α-amino N calorimetrically and

– total N in the roots using the Kjeldahl method.

TABLE 2. Description of control topsoil and sediment from sugar-beet washing

Item	Control topsoil	Sediment from sugar beet washing
Per cent granulometric composition of fraction [mm]		
1 – 0.1	6	4
0.1 – 0.05	10	6
0.05 – 0.02	45	25
0.02 – 0.005	24	40
0.005 – 0.002	8	18
<0.002	7	7
Humidity [%]	36.0	56.0
Organic matter [%]	2.21	5.41
pH in H_2O	5.8	7.7
pH in KCl	5.0	7.5
Total N content [%]	0.11	0.31
Content [mg/100 g of soil]		
P	3.9	31.5
K	16.8	54.8
Mg	5.3	17.7

– The vanadium-molybdenum method was used to measure phosphorus, the photometric method to measure potassium and atomic absorption spectrometry to measure magnesium content.

The biological yield was calculated as the product of the sugar content percentage and root yield in tons per hectare. The technological crop was calculated according to the Trzebiński equation [1974]. The results of the calculations were analyzed statistically with the use of two computer programmes – Quattro Pro 3.0 and Statgraphics 5.0.

RESULTS

YIELD OF ROOTS, LEAVES AND SUGAR

The application of the smallest rate of sediment (10%) gave a 34% rise in root yield and a 45% rise in leaf yield. A 25% addition of sediment brought the above figures to 54% and 71%, respectively. The largest rate of sediment (50%) did not result in any relevant change of leaf yield and even caused a 3.6% drop in root yield compared to the yield at the level of 25% of sediment. Yields were not modified by climatic condition in different seasons.

Mineral fertilization significantly influenced root and leaf yield only on the control plot and the 10% sediment level plot. In dry seasons, with higher levels of sediment combined with mineral fertilization there was a noted drop in root yield. The yield of leaves always increased together with increasing rate of sediment combined with mineral fertilization (Table 3).

It may be presumed that the increase in root yield from plots which were treated with both sediment and NPK resulted from creating favourable vegetation conditions. This interpretation is strongly supported by the fact that there was a 24% decrease in the number of young plants that did well in the initial stages of vegetation.

It was also observed that the sugar-beet washing sediment had a favourable influence on both the biological and technological sugar yield.

The highest yields of biological and technological sugar were achieved when combinations with 25% of sediment were used. In such cases they were higher by 43 and 35% in comparison to the control plot yield. This meant that applying the above mentioned rate of sediment resulted in a 1 ton rise in technological sugar yield per hectare compared to traditional NPK fertilization. Higher rates of sediment proved to be ineffective as they caused a 7% drop in biological yield and an 8% drop in technological yield in comparison to the 25% level of sediment. NPK application caused a significant rise in biological yield only when it was combined with the lowest level of sediment. There was no influence of mineral fertilization on technological yield (Table 3).

TABLE 3. The plant density of the sugar-beet (per m^2 average) and the yield [t/ha] (average in 1990–1992)

Sediment added to topsoil [%]	Fertilization	Plant density	Yield			
			root	leaf	of sugar	
					biological	technological
0	0	5.6	28.9	27.4	5.2	3.9
	NPK	6.1	38.6	38.3	6.9	5.2
	$\bar{x}$	5.8	33.7	32.8	6.0	4.6
10	0	6.5	42.3	41.6	7.4	5.6
	NPK	7.2	47.7	53.5	8.1	6.0
	$\bar{x}$	6.8	45.0	47.5	7.8	5.8
25	0	7.3	51.6	53.2	8.6	6.2
	NPK	7.6	52.0	59.1	8.6	6.2
	$\bar{x}$	7.4	51.8	56.2	8.6	6.2
50	0	7.1	49.4	57.4	8.0	5.7
	NPK	7.7	50.4	63.1	8.1	5.6
	$\bar{x}$	7.4	49.9	60.2	8.0	5.7
Average	0	6.6	43.0	44.9	7.3	5.4
	NPK	7.1	47.1	53.5	7.9	5.8
	$\bar{x}$	6.9	45.1	49.2	7.6	5.6
LSD*	1	0.3	3.9	5.1	0.7	0.6
	2	0.2	2.8	3.6	0.5	–

*$LSD_{0.05}$ for: 1 – sediment added, 2 – NPK

CHEMICAL COMPOSITION OF ROOTS

The technological value of roots was described as the contents of: saccharose, soluble ash and α–amino N. The above factors were considerably influenced by the percentage of sediment applied as well as by climatic conditions (Table 4). Higher rates of sediment caused a drop of dry mass and saccharose content. Dry seasons were characterized by an even bigger drop of sugar content. Analogical observations were reported by Kalinowska-Zdun, Podlaska, Polubiec [1978], Mengel, Kirkby [1983], and also Trzebiński [1974]. Sediment application facilitated the accumulation of ash and α-amino N in roots. Other sources also report this phenomenon [Byszewska-Wzorek 1978; Kalinowska-Zdun, Podlaska, Polubiec 1978].

Higher rates of sediment caused a considerable rise in N, P and Mg levels in roots. A similar tendency was also observed with regard to potassium but this has not yet been sufficiently proved. The concentration of components, with the exception of phosphorus, in roots from sediment-fertilized plots was higher than the average quoted in other sources [Jaszczołt 1989; Mengel, Kirkby 1983] and increased together with higher levels of sediment. This is an undesirable phenomenon because excessive concentration of N and K ions in sugar-beet juice renders difficult saccharose crystallization and consequently causes a decrease in technological yield (Table 3). Element absorption by roots decreased in seasons following sediment application. NPK application produced only a slight increase in N, P and K together with a decrease in Mg content (Table 4).

TABLE 4. Percentage content of dry matter, saccharose, ash content, α-amino N and elements [% of d.m.] in roots of sugar-beet (average in 1990–1992)

Sediment added to topsoil [%]	Dry matter roots	Saccharose	Ash content	α–amino N	Elements			
					total N	P	K	Mg
0	26.4	17.7	0.769	0.0188	0.58	0.10	0.79	0.21
10	25.4	17.3	0.816	0.0199	0.84	0.12	0.87	0.24
25	24.8	16.6	0.856	0.0306	0.97	0.14	1.09	0.26
50	24.0	16.2	0.881	0.0351	1.09	0.14	1.39	0.29
Average	25.2	17.0	0.830	0.0261	0.87	0.12	1.04	0.25
LSD* 1	1.0	0.7	0.040	0.0087	0.26	0.01	–	0.02

$LSD_{0.05}$ for: 1 – sediment added

SOIL COMPONENTS CONTENT

The application of sediment resulted in a considerable rise in the concentration of basic elements in the soil. Higher levels of sediment gave a higher content of total N as well as available forms of P, K and Mg (Table 5). Additional application of NPK gave a higher content of these elements with the exception of available

TABLE 5. Content of availables forms of nutrients in the soil (average in 1990–1992)

Sediment added to top-soil [%]	Total N content [%]			Phosphorus (P) [mg per 100 g of soil]			Potassium (K)			Magnesium (Mg)		
	A*	B**	$\bar{x}$	A	B	$\bar{x}$	A	B	$\bar{x}$	A	B	$\bar{x}$
0	0.10	0.10	0.10	6.7	5.7	6.2	22.8	17.3	20.0	3.6	3.3	3.4
10	0.13	0.11	0.12	12.0	9.5	10.8	24.1	17.2	20.7	4.0	3.7	3.8
25	0.13	0.12	0.13	18.4	14.6	16.5	28.9	19.9	24.4	5.2	4.6	4.9
50	0.17	0.15	0.16	29.4	22.3	25.9	35.8	23.7	29.7	8.9	7.7	8.3
Average	0.13	0.12	0.13	16.6	13.0	14.8	27.9	19.5	23.7	5.4	4.8	5.1
LSD*** 1		0.01			0.7			0.5			0.7	
2		0.01			0.5			0.4			0.5	
3		–			1.0			0.8			–	

A – before sowing, *B – after harvesting, ***$LSD_{0.05}$ for: 1 – sediment added (a), 2 – between before sowing and after harvesting (b), 3 – interaction (a x b)

Mg. In the years following sediment application there was a noted drop in the soil content of N and K and a rise in the content of P and Mg.

Absorption of elements was comparatively higher when the level of sediment was more than 10%. It may mean that sugar-beet plants were fed in an excessive way. This refers particulary to N and K. It is also possible that part of N could have been washed out by water and K could have been absorbed by soil. Such phenomena are well-known and they can be observed when there are higher content of particles < 0.02 in diameter and changes in soil acidity.

Incidence of *Heterodera schachtii* was not observed during the three-year experiment.

CONCLUSIONS

The following conclusions have been drawn on the basis of the results of the experiment:

1. The application of sediment from sugar-beet washing, which contains 5.4% of organic matter and 65% of particles < 0.02 in diameter to very good rye soil improves its fertility, which is reflected by an increase in the yield of roots and leaves as well as biological and technological sugar.

2. Higher levels of sediment, over 10% of soil's dry mass (i.e. 286 tons of sediment per hectare), makes the use of mineral fertilizers unnecessary during the first three-year period.

3. Higher levels of sediment may cause a deterioration of the technological value of sugar-beet roots.

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MOŻLIWOŚĆ ZASTĄPIENIA NAWOZÓW MINERALNYCH ZIEMIĄ SPŁAWIAKOWĄ W UPRAWIE BURAKA CUKROWEGO

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STRESZCZENIE

W latach 1990–1992 przeprowadzono badania przydatności ziemi spławiakowej do użyźniania pola przeznaczonego pod uprawę buraków cukrowych. W tym celu na glebę kompleksu żytniego bardzo dobrego nawieziono ziemię spławiakową w ilości odpowiadającej 10, 25 i 50% suchej masy jej warstwy ornej (tj. odpowiednio: 286, 715 i 1430 ton s.m. na 1 ha). Obiekt kontrolny stanowiło pole bez ziemi spławiakowej. Warunki wzrostu roślin zróżnicowano dodatkowo, wnosząc na połowę poletka nawożenie mineralne stosownie do zasobności gleby i zaleceń agrotechnicznych, które wynosiło [kg/ha]: N – 130, P_2O_5 – 80, K_2O – 120. Stwierdzono, że stosując ziemię spławiakową na tę kategorię gleb można oczekiwać poprawy jej żyzności, co wyraża się wzrostem plonu korzeni i liści buraków cukrowych, cukru biologicznego i technicznego, ale także pogorszeniem wartości technologicznych korzeni, szczególnie przy zastosowaniu najwyższej dawki ziemi spławiakowej. Ponadto wykazano, iż wnoszenie ziemi spławiakowej w dawkach wyższych niż 10% pozwala na niestosowanie nawozów mineralnych w pierwszych trzech latach po tym zabiegu.

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