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POSSIBILITIES OF THE AGRICULTURAL USE OF DECOCTIONS FROM THE ALCOHOL-DISTILLING INDUSTRY

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Abstract: The fertilizing value of rye, potato and molasses decoctions was evaluated in a microplot experiment, in which maize and turnip were used as testing plants. Based on the analysis of chemical composition of decoctions it was found that these decoctions used as fertilizing material were unbalanced with respect to their N, P and K contents. The potato decoction is characterized by the most favourable N:K ratio from the point of view of the nutritional requirements of plants. The rye decoction contains too little potassium and that from molasses - too much of this element in relation to N content. The use of the molasses decoction in fertilizing is possible after its correction with phosphorus. The rye decoction requires correction with potassium for appropriate use in fertilization.
In addition, application of the decoctions studied caused an increase in the organic C and total N contents in soil and improvements in the sorption properties of soil. The molasses decoction caused a decrease in the available forms of P in soil. The decoctions applied in experiments considerably increased yields and nutrient content in plants studied, both in the direct and after- effect.

Key words: rye decoction, potato decoction, molasses decoction, fertilization, soil properties, maize, turnip

INTRODUCTION

Decoction is a process generating a number of by-products in the alcohol-distilling industry. It is used during the transformation of starch-containing raw materials, such as potatoes, cereals or molasses into alcohol. Traditionally, the alcohol-distilling decoctions are mainly used for forage (Jarosz, Łączyński 1985). However, the decoction is a troublesome by-product, especially in areas with a limited animal population. It is estimated that every fifth alcohol distillery in Poland discharges decoctions directly to surface waters or to drainage ditches in agricultural land. The organic loading of alcohol-distilling decoction, expressed as BOD, amounts to 50000-70000 mg $O_2 \cdot l^{-1}$. For this reason the decoction constitutes an important potential hazard to the environment (Singh et al. 2007, Jain et al. 2005). Consequently, alcohol-distilleries are forced to look for new applications of decoctions. The utilization of decoction with fertilizing purposes may be a useful alternative. Earlier studies, concerning the use of decoction for fertilization, considered, first of all, the decoction of molasses, of lower forage value (Mahimairaja and Bolan 2004, Pathak et al. 1999, Ramana et al. 2002, Sobczak, Kropisz 1990). Results of studies prove that molasses decoction is a good organic manure, suitable for fertilization of field crops, but only if applied before sowing (Alexander et al. 2006, Debruck, Lewicki 1985; Mercik, Stępień 1992).

The aim of this paper is to estimate the possible use of three alcohol-distilling decoctions (rye, potatoes and molasses) as possible fertilizers.

MATERIALS AND METHODS

The evaluation of fertilizing value of alcohol-distilling decoctions was conducted on the basis of a microplot experiment carried out at the Experimental Station of Warsaw University of Life Sciences in Skierniewice. The experiment was established in four replications with a random blocks method. The microplots were comprised of stoneware pipes (diameter 40 cm; depth 120 cm), sunk into the ground, and filled with soil, having the same whole profile as the experimental field. The upper layer (0-30 cm) was composed of heavy loamy sand, with a slightly acid reaction and with medium availability of macro- and micronutrients. The layer 30-45 cm was comprised of light loamy sand. The pipes were filled with light loam to a depth greater than 45 cm. This experiment included control objects and objects to which three kinds of decoctions were applied.
The doses were established on the basis of nitrogen content, to be comparable with respect to the total quantity of nitrogen. The doses of decoctions, after conversion for 1 ha, were as follows:

- for rye decoction: I - 2.65 t; II – 5.31 t; III – 10.62 t
- for potato decoction: I – 1.92 t; II – 3.84 t; III – 7.68 t
- for molasses decoction: I – 2.38 t; II – 4.76 t; III – 9.52 t.

The experiment investigated the direct effect of decoctions, applied before sowing, in maize (harvested at milk-wax maturity), and the after-effect. The turnip was planted in the second year of the experiment. Turnip was the test plant used for estimation of the after-effect of decoctions.
The soil samples for analysis were collected after harvesting the crops. After drying in laboratory and sieving to 1 mm, the following characteristics were measured in soil:

- total nitrogen content, measured using the Kjeldahl method with a VAPODEST 30 apparatus (produced by Gerhardt , Königswinter, Germany),
- organic carbon content, determined directly with a C-MAT 5500 apparatus (produced by Strohlein),
- pH in KCl (1 mol · dm^{-3}) with a potentiometric method,
- exchangeable cations, after extraction with CH_3COONH_4 (1 mol · dm^{-3}), using ASA method, with an AAS- 3300 Atomic Absorption Spectrometer produced by Perkin Elmer,
- available P and K, with the Egner-Riehm method (Egner et al. 1960),
- micronutrients content, after extraction with HCl (1 mol · dm^{-3}), using ASA method, with AAS-PERKIN_ELMER 3300 Atomic Absorption Spectrometer produced by Perkin Elmer.

The samples of plant materials and decoctions were dried at 55°C, milled mechanically and then used to determine the following parameters:

- total nitrogen content, measured using the Kjeldahl method with VAPODEST 30 apparatus (produced by Gerhardt-Germany),
- total Ca, Mg and K content, after mineralization in a mixture of HNO_3 and $HClO_4$ acids (3:1), using ASA method, with AAS-PERKIN_ELMER 3300 Atomic Absorption Spectrometer produced by Perkin Elmer,
- total P content using a colorimetric, molybdenum-vanadium method (Allen et al. 1976),
- total content of Cu, Zn, Mn and Fe after mineralization in a mixture of HNO_3 and $HClO_4$ acids (3:1), using ASA method, with AAS-PERKIN_ELMER 3300 Atomic Absorption Spectrometer produced by Perkin Elmer.

The results of chemical analyses were subjected to statistical elaboration using analysis of variance.

The significance of differences between the means characterizing particular factors was estimated by Tuckey's test at significance level p=0.05. The calculations were performed with STATISTICA 5,0PL.

RESULTS AND DISCUSSION

The decoctions analysed varied in respect of dry matter, macro- and micronutrients content (tab. 1). All decoctions studied were characterized by a relatively low dry matter content especially in the case of rye and potato decoctions. This was also noticed in the studies of Jarosz and Łączyński (1985), Łabętowicz et al. (1999), Kotarska et.al. (1998). The molasses decoction was characterized by the largest dry matter content of all wastes studied, and also it contained the largest amounts of nitrogen, potassium and calcium. However, the N:P:K ratio indicates excessive potassium content in relation to nutritional requirements of crops. The most favourable N:K ratio, from the point of view of plant nutrition, was shown by the potato decoction
(tab. 1).

Table. 1. Mean content of macronutrients and micronutrients in alcohol-distilling decoctions

Kind of decoction	Dry matter	N	P	K	Ca	Mg	N:P:K	Cu	Fe	Mn	Zn
	%	$g \cdot kg^{-1}$ D.M.					-	$mg \cdot kg^{-1}$ D.M.			
Rye	6.1	52.7	10.7	14.5	4.5	3.0	1:0.2:0.3	179.9	174.8	135.2	98.2
Potato	4.8	47.6	8.7	52.0	2.2	3.8	1:0.18:1.1	250.9	2305.3	58.6	149.2
Molasses	49.7	50.9	0.7	91.6	16.4	1.3	1:0.01:1.8	14.1	1112.5	73.9	265.1

Too low phosphorus content, in relation to N and K contents is a common feature of decoctions studied and it is especially pronounced in the molasses decoction (Tab. 1). Thus, the alcohol-distilling decoctions constitute fertilizing materials with unbalanced chemical composition in respect of nutritional requirements of crops. This fact is also confirmed by the studies of a number of other authors (Kłosowski 1997, Łabętowicz et al. 1999, Mahimairaja and Bolan 2004, Mercik and Stępień 1992, Pathak et al. 1999).

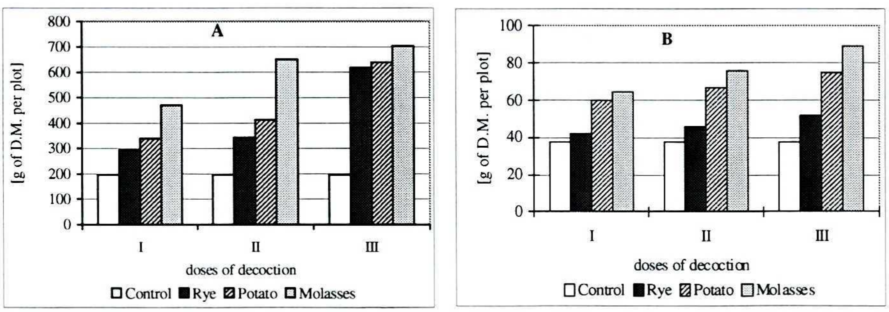
The decoctions used in our experiments affected the physical-chemical properties of the soil (tab. 2). A clear increase of pH value, in comparison with treatment (without application of decoctions), was found after use of the molasses decoction. Similar dependence was noted also in studies of Mercik and Stępień (1992) and Łabętowicz et al. (1999).

Table 2. Physical and chemical properties of soil and content of available forms of P, Cu, Fe, Mn and Zn in soil fertilized with alcohol-distilling decoctions in the second year of the experiment

Kind and dose of decoction		pH	C	N	C:N	S	T	V	P	Cu	Fe	Mn	Zn
			$g \cdot kg^{-1}$ D.M.			$mmol(+) \cdot kg^{-1}$		%	$mg \cdot kg^{-1}$ D.M.				
Control		6.05	5.3	0.53	10.0	38.2	55.0	69.5	25.2	3.47	783.1	82.4	15.5
Rye	I	5.98	5.3	0.55	9.64	39.9	56.9	70.1	23.8	3.46	826.2	80.4	38.0
	II	6.10	5.6	0.58	9.66	41.9	58.5	71.6	34.1	3.74	835.3	83.5	46.5
	III	6.15	5.8	0.63	9.21	43.7	60.2	72.6	43.3	3.84	837.9	91.4	75.0
Mean		-	**5.6**	**0.59**	**9.50**	**41.8**	**58.5**	**71.4**	**33.7**	**3.68**	**833.1**	**85.1**	**53.2**
Potato	I	6.08	5.3	0.53	10.82	39.4	56.1	70.2	24.7	3.65	825.3	85.2	31.4
	II	6.19	5.5	0.53	10.38	41.0	57.4	71.4	29.0	3.83	878.9	86.4	40.1
	III	6.23	5.7	0.55	10.36	42.4	58.6	72.3	35.7	4.13	891.6	89.3	46.6
Mean		-	**5.5**	**0.54**	**10.52**	**40.9**	**57.4**	**71.3**	**29.8**	**3.87**	**865.3**	**87.0**	**39.4**
Molasses	I	6.25	5.3	0.50	10.60	40.4	56.2	71.9	23.8	3.20	811.2	81.0	14.2
	II	6.43	5.6	0.57	9.82	43.8	58.6	74.7	20.5	3.27	822.0	86.0	15.1
	III	6.80	5.9	0.58	10.17	49.1	62.9	78.1	15.7	3.34	835.4	91.9	16.3
Mean		-	**5.6**	**0.55**	**10.20**	**44.4**	**59.2**	**74.9**	**20.0**	**3.27**	**822.9**	**86.3**	**15.2**
$LSD_{0.05}$ for kind of decoction		-	0.09	0.010	0.201	0.20	0.20	0.13	0.44	0.02	0.35	0.34	0.22

The alcohol-distilling decoctions caused slight increase of organic carbon and total nitrogen contents in soil compared with the control treatment. The rye decoction increased the nitrogen content more than the carbon content. For this reason application of this waste caused limitation of the C:N ratio in comparison with the control treatment (tab. 2). The decoctions used in the experiment increased also the cation exchange capacity and base saturation of the sorption complex. The sorption properties of soil increased most as a result of application of molasses decoction, whereas this increase was the least when using potato decoction (tab. 2). Increase of cation exchange capacity as a result of applications the alcohol-distilling decoctions and other wastes from agricultural and food industry was also observed by other authors (Gobeille et al. 2006, Hati et al. 2007, Łabętowicz et al. 1999, Mercik and Stępień 1992, Pathak et al. 1999, Resende at. al. 2006, Singh et al. 2007). The greatest increase of available phosphorus in soil was noted in the case of rye decoction. However, a decrease of this form of phosphorus in soil was noted after use of molasses decoction, in comparison with the control treatment. The studies of other authors (Mercik and Stępień 1992) also noted a significant decrease in the available forms of this element after applications of only molasses decoction over a longer time period. For this reason it is necessary to correction molasses decoction with phosphorus or to apply additional mineral phosphoric fertilizers. The content of HCl (1 mol · dm^{-3}) soluble forms of Fe and Mn increased as a result of use of all alcohol-distilling decoctions. It was noted that the applications of rye and potato decoctions caused an increase of Zn and Cu contents in soil, and the molasses decoction decreased the content of both nutrients in soil (tab. 2). The quantities of HCl (1 mol · dm^{-3}) soluble forms of micronutrients in soil, obtained in the experiment, were, in the majority of cases, within the natural range of these elements according to Kabata-Pendias et al. (1993).

The alcohol-distilling decoctions, applied in our experiments, significantly affected yields and chemical composition of plants (fig. 1, tab. 3).



$LSD_{0.05}$ for:
kind of decoction = 6.74
doses of decoction = 3.10

$LSD_{0.05}$ for:
kind of decoction = 0.22
doses of decoction = 0.14

Fig. 1. Influence of alcohol-distilling decoctions on A – maize yields (direct effect) and B – turnip (after-effect)

When comparing the effect of alcohol-distilling decoctions it was noted that the least yields of both maize green forage and turnip roots were obtained in treatments with the rye decoction, and the greatest yields – after application of molasses decoction. On the objects fertilized with alcohol-distilling decoctions, the maize yields increased on an average by 112.5 % for the rye decoction, by 136 % for the potato one and by 209 % for the molasses one, in comparison with yields of test plant grown on control treatment, without fertilization. The yields of turnip increased by 25.5 % after rye decoction application, by 81.5 % after potato decoction and by 105 % after molasses decoction. Increasing the doses of decoctions significantly increased yields of test plants. However, it should be underlined, that the increase of yields in the after-effect of decoctions (turnip) was considerably lower than in the direct effect (fig. 1). The favorable effect of the alcohol-distilling decoctions on crop yields is a result of direct action by nutrient supply, but it is also an result of indirect action, as a consequence of improved physical and chemical properties of the soil (Hati et al. 2007, Łabętowicz et al. 1999, Mercik and Stępień 1992, Pathak et. al. 1999, Ramana et al. 2002, Resende et al. 2006).

Table 3. Influence of alcohol-distilling decoctions on chemical composition of maize and turnip roots (average for 3 doses and 2 years)

Kind of decoction	N	P	K	Ca	Mg	Cu	Fe	Mn	Zn
	$g \cdot kg^{-1}$ D.M.					$mg \cdot kg^{-1}$ D.M.			
	Maize								
Control	6.8	2.0	11.2	1.5	1.2	3.16	230.7	33.8	24.0
Rye	7.5	1.4	11.5	1.6	1.1	3.25	378.3	26.4	42.9
Potato	8.6	1.4	12.2	1.8	1.1	3.89	387.9	29.0	31.6
Molasses	11.0	1.1	12.9	2.0	1.1	4.12	335.6	28.7	26.9
$LSD_{0.05}$	0.16	0.11	0.93	0.10	0.008	0.025	2.759	0.758	0.770
	Turnip roots								
Control	16.1	2.6	3.1	3.3	1.3	2.24	132.2	24.6	14.7
Rye	16.3	2.6	4.1	4.0	1.5	2.72	229.2	15.1	28.8
Potato	17.9	2.6	5.1	4.4	1.4	3.40	236.1	15.9	34.6
Molasses	18.5	2.3	5.7	5.1	1.4	2.65	234.3	12.8	28.3
$LSD_{0.05}$	0.10	0.09	0.11	0.11	0.009	0.027	0.470	0.232	0.285

The decoctions, used in the experiment, also affected the macro- and micronutrient content in analysed plants (tab. 3). Both in the direct and the after- effect, the decoctions applied in our experiments caused an increase of nitrogen, potassium and calcium contents and a decrease of phosphorus content in both plants, and a decrease of magnesium content in maize. The Mg content in the dry matter of turnip increased by 15 % as a result of the application of potato and molasses decoctions, compared with content of this element in control plants. The greatest increase of macronutrients content in plant dry matter was found in treatments fertilized with the molasses decoction, and the lowest increase – on treatments using rye decoction. As a result of application of the molasses decoction, the nitrogen content in dry matter increased by 62 % in maize and by 15 % in turnip, the potassium content increased by 15 % (maize) and 84 % (turnip), the calcium content increased by 33.3 % (maize) and 54 % (turnip) in comparison with respective contents of nutrients in plants on control treatments. The results concerning nutrient content in plants obtained in the present study correspond well with those in the study by Ramana et al. (2002).
The contents of copper, iron and zinc in dry matter of maize and turnip increased, and the content of manganese decreased on treatments with application of the alcohol-distilling decoctions compared with plants grown on control treatment (tab. 3).

CONCLUSIONS

1. The alcohol-distilling decoction as fertilizing material is unbalanced with respect to N, P and K content. The potato decoction is characterized by the most favourable N:K ratio from the point of view of nutritional requirements of plants. The rye decoction contains too little potassium and the molasses one - too much of this element in relation to N content.
2. The utilization of alcohol-distilling decoctions with fertilizing purposes requires correction with phosphorus in the case of molasses and improvement with potassium in case of the rye decoction.

3. The use of alcohol-distilling decoctions increases the organic carbon and total nitrogen contents and it improves the sorption properties of soil. Fertilizing with molasses decoction decreases the content of available phosphorus in soil.
4. Alcohol-distilling decoctions increase crop yields both in the direct and after- effect. The molasses decoction is characterized by the greatest yield-forming action. The rye and potato decoctions have a similar influence on yields.
5. Fertilizing with alcohol-distilling decoctions causes an increase of nitrogen content and a decrease in the phosphorus content in plants. This indicates the necessity to correct these wastes with phosphorus or to apply additional mineral phosphoric fertilizers.

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