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Research Note

The Effects of Organic and Inorganic Fertilization on the Content of Trace Elements in Cereal Grains

ABSTRACT

To compare the effects of organic manuring and inorganic fertilization, the contents of zinc, copper, iron, manganese and selenium in wheat and oats harvested from a field experiment were analysed using atomic absorption spectrophotometry. Inorganic fertilization compared to organic manuring increased the content of copper in oats and of manganese in wheat and of zinc and iron in wheat and oats. Organic manuring was more effective for the uptake of copper by wheat, manganese by oats and selenium by both wheat and oats. Inorganic fertilization compared to organic manuring increased the yield of oats, but organic manuring was equally effective in the case of wheat to obtain higher yield. There was no correlation between yield and trace element contents either in wheat or oats.

INTRODUCTION

Among the factors which affect the trace element content of cereal grains, fertilization techniques are of importance (Pessi *et al.*, 1974). Most investigations have dealt with the effects of inorganic fertilization rather than organic manuring. A previous study indicated that different manuring and fertilization techniques had a complex influence on trace element contents in potato (Srikumar & Öckerman, 1990). The present paper deals with the effects of organic and inorganic fertilization on the contents of zinc, copper, iron, manganese and selenium in wheat and oats.

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MATERIALS AND METHODS

Experimental design

The field experiments were conducted in a clay–loam soil at Hörby in southern Sweden. The area of the field used for the experiment was 1200 m^2 divided into subplots of 100 m^2 with a net harvestable area of 60 m^2. Wheat and oats were treated with 1300 kg/ha inorganic NPK(11-5-18) or 23 t/ha organic manure (prepared from plants and pig faeces) or were grown without fertilization. Each treatment was performed on four sub-plots. The content of minerals and trace elements in NPK(11-5-18) fertilizer has been reported elsewhere (Srikumar & Öckerman, 1990). The contents of elements in organic manure were not measured.

Chemical analysis

The grain samples were harvested during the spring of 1986. One kilogram of each grain sample was washed in deionized water and dried overnight at 105°C. Ten grams of the dried samples were powdered in a high speed mill with TiO_2 inside coating and 0·5 g of samples in duplicate were digested with 7 ml conc. HNO_3:70% $HClO_4$ (5:1). The contents of zinc, copper, iron and manganese were determined using flame atomic absorption spectrophotometry (Srikumar & Öckerman, 1990). Selenium was assayed by hydride generation plus atomic absorption spectrophotometry as follows: 1 ml of the digested solution was heated at 70°C for 10 min with 5 ml of 7M HCl and then cooled to room temperature and made up to 10 ml with 7M HCl. This was aspirated into the hydride generator (Varian VGA-76) at a rate of 7 ml/min. The hydride formed was swept by a flow of nitrogen into the quartz absorption cell maintained at 950°C by an air–acetylene flame. The absorption was read several times so that uniform peaks were obtained. Working standards of 1·0–5·0 μg/litre were used to construct standard curves. The intra-assay imprecision expressed as coefficient of variation was 2·4–3%. The mean element content ($n = 7$) of bovine liver standard (1577a) from the National Bureau of Standards, USA, deviated less than 3·5% from the certified values for most elements and −13% for manganese.

Statistical analysis

Data are presented as mean(SD), n = number of analyses. Mean values were compared using Student's t-test, and correlations were calculated as linear correlation coefficients.

RESULTS AND DISCUSSION

Zinc

Inorganic fertilization compared to organic manuring was more effective for the uptake of zinc by wheat and oats (Table 1). However, inorganic fertilization did not result in a higher zinc content than in the unfertilized control, in agreement with previous findings (Pessi *et al.*, 1974). This could probably be due to the higher yield which might have decreased the zinc content due to a dilution effect. The higher content of zinc in the unfertilized wheat and oats when compared to the organically manured samples may be due to the Steenberg effect (Jansson, 1981).

Copper

Inorganic fertilization decreased the content of copper in wheat compared to organic manuring, but it marginally increased its content in oats compared to the unfertilized sample. Rebowska (1983) also reported that inorganic fertilization did not increase the content of copper in wheat. The reason for the different effects in wheat and oats is unknown. The major fraction of copper in soil is associated with organic matter (Shuman, 1979) and the availability of copper to plants could be enhanced by the addition of more organic matter to the soil (Gupta, 1971). Due to the immobility of copper in soils, its uptake by plants depends on the extent of root interception with copper-enriched zones (Gilkes, 1981). The fact that the area penetrable by the plant roots would be enlarged by the use of organic manuring (Pettersson & von Wistinghausen, 1979) would explain an enhanced uptake after organic manuring.

Iron

The inorganic fertilization resulted in a higher content of iron in wheat and oats compared to organic manuring. The inorganic fertilization was also favourable compared to the unfertilized control samples for the uptake of iron by wheat but not by oats. More than 90% of Fe(III) in the soil is complexed with organic ligands and the uptake depends on the concentration of such ligands (Benians *et al.*, 1977). Iron also exhibits a synergistic effect with nitrate (Pendias & Pendias, 1984) which could explain the higher content of iron in wheat after NPK administration. Also the lower soil pH after inorganic fertilization might have stimulated the uptake of iron.

Manganese

While inorganic fertilization was more effective for the uptake of manganese by wheat, organic manuring was more favourable for oats. The former effect

TABLE 1
The Soil pH, Yield Obtained (kg/ha) and Content of Trace Elements Determined in Wheat and Oats

Sample	*Soil pH*	*Yield*	*Zinc (mg/kg)*	*Copper (mg/kg)*	*Iron (mg/kg)*	*Manganese (mg/kg)*	*Selenium (μg/kg)*
Wheat							
Inorganic	5·2	2019	40·3 (2·6)^{a,f}	5·9 (1·3)^{a}	40·5 (2·7)^{f}	37·8 (2·5)^{f,e}	7·2 (1·3)^{f}
Organic	5·4	2126	36·1 (3·1)^{a,c}	8·3 (1·9)^{a,c}	28·4 (2·3)^{f,g}	32·5 (2·2)^{e}	13·1 (2·1)^{j}
Unfertilized	5·3	960	41·2 (2·5)^{c}	6·8 (1·0)	28·8 (1·6)^{g}	30·6 (1·3)^{f}	12·7 (1·8)^{f}
Oats							
Inorganic	5·2	2873	57·3 (3·1)^{f,g}	6·3 (1·0)^{b}	39·9 (1·9)^{h}	44·6 (1·7)^{g}	16·5 (2·6)^{b,g}
Organic	5·4	1432	40·2 (2·6)^{g,h}	5·6 (0·9)^{c}	32·5 (1·7)^{h,i}	55·3 (1·5)^{g,h}	26·3 (1·3)^{g,h,i}
Unfertilized	5·3	637	52·3 (2·9)^{h}	4·4 (1·3)^{b}	40·4 (2·0)^{i}	43·3 (2·9)^{h}	19·6 (1·5)^{b,h}

Data with the same superscripts were significantly different. a, $b = p < 0{\cdot}05$, $c = p < 0{\cdot}01$, and f–$i = p < 0{\cdot}001$.

might be due to decreased soil pH, and the latter effect could be due to the formation of organo-metallic compounds in the rhizosphere soil as described by Olumu *et al.* (1973). Nilsson (1984) reported that organic manuring increased the manganese content of barley. The two different fertilizer treatments affected the contents of manganese in wheat and oats differently, and the reason for this is unknown.

Selenium

The organically manured wheat and oats contained higher concentrations of selenium than in those treated with inorganic fertilizer. Gissel-Nielsen (1974) reported that also the uptake of selenium by barley decreased due to inorganic fertilization containing sulphur. The inhibited uptake after inorganic fertilization could be due to the lowering of soil pH which reduces the selenium uptake. A clayey soil with a higher water content and bad soil structure has a low redox-potential, but a higher humus content increases the redox-potential and thereby the conversion of selenate to selenite. Selenite was reported to be a good source for improving the selenium content of wheat (Korkman, 1980). The fixation of selenite in clayey soil is stronger at a lower soil pH. Iron also forms complexes with selenium in the soil, but the effect of complex formation is reduced at a higher soil pH and the selenium content in the soil is thus correlated to the content of iron (Hamdy & Gissel-Nielsen, 1977). Selenium might also have an antagonistic effect with nitrogen of the inorganic NPK(11-5-18) fertilizer.

CONCLUSIONS

Inorganic fertilization compared to organic manuring increased the content of copper in oats and of manganese in wheat and of zinc and iron in wheat and oats. But organic manuring increased the contents of copper in wheat, manganese in oats and selenium in both wheat and oats. Inorganic fertilization compared to organic manuring increased the yield of oats, but not of wheat. There was no correlation between yield and trace element contents either in wheat or in oats.

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T. S. Srikumar[a,b] **& P. A. Öckerman**[a]
[a] *Department of Clinical Chemistry,*
[b] *Department of Medical and Physiological Chemistry,*
University of Lund, PO Box 94,
S-221 00 Lund,
Sweden

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