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Mineral element content of oats (*Avena sativa* L.) in an acid sulphate soil area of Tupos village, northern Finland

MARKKU YLI-HALLA* and JUKKA PALKO**

* *Kemira Oy, Espoo Research Centre, Luoteisrinne 2, SF-02270 ESPOO, Finland*
** *National Board of Waters, SF-90100 OULU, Finland*

Abstract. The mineral element content of oat grains grown in acid sulphate soils (n = 35) and other soils (n = 19) in Tupos was studied. In terms of P, K, Ca, Mg, S, Cu and Zn concentrations, Tupos oats did not differ from the averages and ranges presented for Finnish oats in other studies. Instead, Tupos oats were in general rich in Fe and Co and low in Se. High concentrations of Mn and Ni occurred in samples originating from acid sulphate soils. The lower the soil pH, the higher were the concentrations of Ni and Co in oats. Na and Ni were the only elements displaying a clear relationship between the concentration of the element in oats and the amounts of the element easily soluble in the soil. Tupos oats deviated less than Tupos timothy from the mineral contents of both these plant species usually reported in Finland.

Index words: plant analysis, soil acidity, macronutrients, trace elements

Introduction

The fields of Tupos village, situated on a coastal plane 20 km south of Oulu, consist of an even mixture of acid sulphate soils and other soils. Recently, a soil survey was made in Tupos in which samples were taken from timothy and oat fields (Erviö and Palko 1984). The analyses revealed that due to abundant sulphide material in the subsoil, the plough layer pH was low in most samples and, consequently, soils were rich in easily soluble Al, Fe, Mn, Cr, Co, Mg, Zn and S. This was reflected in the chemical composition of timothy grown in the area: the plant material contained more Co, Cr and also Ni than is usual in Finland (Palko 1986). The contents of macronutrients Ca, Mg, K and P as well as micronutrient Zn were, in turn, lower than the Finnish averages, being as much an indicator of soil properties as of insufficient fertilization.

The purpose of the present study was to investigate the chemical composition of oat grains grown in the Tupos area. It was hoped that the study would indicate possible excesses and deficiences of mineral elements in Tupos oats and would thus be of use in assessing the fertilization requirements of the acid sulphate soils and the mineral intake of

Table 1. Chemical characteristics of oat field soils in Tupos village.

Property		Acid sulphate soils n = 35			Other soils n = 19		
		mean	s	range	mean	s	range
pH(H_2O)		4.8	0.6	4.0—6.7	5.9	0.6	4.4—6.9
P	mg/l	7.8	7.7	1.8—42	9.9	13.8	2.4—64
K	»	139	94	23—511	63	31	21—128
Ca	»	1197	1082	106—5139	1646	1182	385—4773
Mg	»	358	318	60—1327	273	195	47—924
Na	»	112	102	11—465	146	184	7—678
S	»	550	634	21—3433	62	72	9—320
Fe	»	2033	1495	373—6333	1617	1338	533—5693
Mn	»	74	68	4.6—343	49	43	6.1—148
Cu	»	7.1	4.3	2.1—19.6	4.7	2.8	0.5—10.6
Zn	»	7.4	7.1	1.0—32.9	1.9	1.4	0.6—5.8
Ni	»	6.4	5.2	1.1—26.3	2.2	1.9	0.2—8.5
Co	»	2.3	1.9	0.4—9.3	0.9	0.6	0.1—2.2

cattle fed with the local oats. In addition, the relationship between some soil properties and mineral element content of oats was studied.

Materials and methods

The oat grains were harvested from 51 fields in 1983 in Tupos village (lat. 64 50', long. 25 30') when the grains were fully ripe. The grain samples were air-dried, ground and analysed for K, Ca, Mg, P, S, Cu, Zn, Fe, Mn, Na, Co, Ni and Se at Kemira Oy, Oulu Research Laboratory, according to the methods described by SAARI and PAASO (1980).

Tupos soils have previously been characterized in detail by ERVIÖ and PALKO (1984). Soil samples corresponding to the present oat fields were included in that material. K, Ca, Mg, P and S were extracted with 0.5 M acetic acid-0.5 M ammonium acetate (AAAc) (pH 4.65) (VUORINEN and MÄKITIE 1955) and other elements with AAAc-0.02 M Na_2EDTA (LAKANEN and ERVIÖ 1971). The soils were identified according to PALKO and RÄSÄNEN (1987) as acid sulphate soils. For identification purposes the soils were classified according to the properties of the subsoil, not the plough layer, thus avoiding the effect of farming practices. The chemical properties of the present soil material are listed in Table 1.

Results and discussion

Macronutrients (P, K, Ca, Mg, S)

The average content of various macronutrients in Tupos oats (Table 2) was similar to the contents reported for oat grains in other Finnish studies (PESSI et al. 1974, JAAKKOLA and VOGT 1978, SYVÄLAHTI and KORKMAN 1978, VARO et al. 1980, JANSSON et al. 1985). The present results also fell within the range reported in them. The oats from acid sulphate soils were poorer in Ca than oats grown in other soils ($t = 2.96^{**}$). Although the soils were very rich in soluble S, oat grains did not contain S more than usual in Finland. P and K are usually added yearly into the field soil in fertilizers, and Ca and Mg are given in liming materials. The influence of the native macronutrient reserves on oat grains is likely to be masked by these farming practices.

Copper and Zinc

In the present study, the micronutrients Cu and Zn were also within the concentration range presented earlier. Only JAAKKOLA and VOGT (1978) have reported considerably lower Cu contents. In the present material, two samples had a very high Cu content, making the ranges wide. However, the bulk of Cu concentrations were within the normal range.

Table 2. Mineral element content of oats (g or mg/kg dry matter) grown in acid sulphate soils and other soils in Tupos village.

Element		Acid sulphate soils (n = 35)			Other soils (n = 19)		
		mean	s	range	mean	s	range
P	g/kg	3.64	0.36	2.90—4.50	3.87	0.26	3.30—4.40
S	»	1.92	0.29	1.50—2.70	1.84	0.19	1.50—2.20
K	»	4.81	0.44	3.80—6.20	4.92	0.24	4.50—5.20
Ca	»	0.58	0.11	0.41—0.82	0.75	0.24	0.50—1.60
Mg	»	1.45	0.12	1.20—1.70	1.46	0.11	1.30—1.60
Na	mg/kg	81	170	14—770	48	51	15—240
Fe	»	142	46	57—300	164	62	74—310
Mn	»	136	32	48—200	94	44	39—190
Cu	»	5.3	1.8	3.7 —15.0	5.2	2.5	3.6 —15.0
Zn	»	39.9	5.7	28.0—54.0	40.5	7.1	29.0—50.0
Ni	»	6.35	4.00	0.99—15.0	2.70	1.93	0.36—8.4
Co	»	0.50	0.20	0.20—0.90	0.39	0.30	0.20—1.50

Iron and manganese

The samples of Tupos oats proved to be rich in Fe. Even the lowest concentrations were higher than the averages in other Finnish studies in which the usual Fe content falls within the range of 40—100 mg/kg. High concentrations of Mn also occurred in Tupos oats, most of the results, however, falling within the normal range reported elsewhere, 40—80 mg/kg. The oats grown in acid sulphate soils exhibited a higher mean Mn content than the rest of the samples ($t = 3.65^{**}$), even if the ranges were equal in both sample groups.

Sodium

The recent marine history of the Tupos soils was reflected in the rather high Na content found in some oat samples, although most results were in accordance with the values reported by JAAKKOLA and VOGT (1978), 20—30 mg/kg. In 80 % of the oat samples the Na content was below 50 mg/kg. The Na content of cereal grains may, however, be of minor importance in animal nutrition due to the high Na requirement of animals.

Nickel and cobalt

The heavy metals Co and Ni are not, according to the present knowledge, needed by oats. However, especially the Ni content in the plants was rather high, being usually of the same magnitude as the content of Cu. The Ni content of Tupos oats grown in soils not classified as acid sulphate soils was of the same order as the Ni contents of oats reported elsewhere (PESSI et al. 1974, SYVÄLAHTI and KORKMAN 1978, VARO et al. 1980). Oats grown in acid sulphate soils, on the other hand, had an average Ni content two to three times higher. In the present material there were five samples of oats, all from acid sulphate soils, having Ni content even greater than 10 mg/kg.

The Co content of cereals generally range only in micrograms per kilogram of plant material. The present means for Co were even 10 times higher than those mentioned in other studies. SYVÄLAHTI and KORKMAN (1978) and VARO et al. (1980) have published results where the Co content of oats has been within the range of 0.05—0.10 mg/kg. The highest concentration in the study be VARO et al. was 0.20 mg/kg, which was in fact the lowest value found in the present material. ERVIÖ and PALKO (1984) have indeed reported unusually high contents of easily soluble Co for Tupos soils, and according to PALKO (1986), the Co concentrations for timothy in the Tupos area average five times higher than those reported elsewhere.

Selenium

The Se content of oat grains in Tupos was very low. Only three samples, none of which were growing in acid sulphate soil, exceeded the reliable level of detection, 0.01 mg/kg. In addition, five samples had an approximate Se concentration of 0.005—0.01 mg/kg. The rest, including all 35 samples collected from acid sulphate soils, had a Se content lower than 0.005 mg/kg. The average Se content of Finnish oats has also been reported as being near the detection limit: mean 0.010 mg/kg, range 0.005—0.021 mg/kg (VARO et al. 1980). In the study by PALKO (1986), none of the 45 timothy samples had a Se content higher than 0.01 mg/kg. Significantly, both plant materials were taken before the addition of Se in compound fertilizers in Finland.

Soil properties and plant analyses

As the distribution of soil and plant analysis data was not normal, the Spearman rank correlation coefficients were calculated between soil properties (soil pH and AAAc- or AAAc-EDTA-extractable amounts of elements) and the mineral element content in oats. The statistically significant ($P \leq 0.05$) correlation coefficients were as follows:

Element	soil pH	content of the element
Na	n.s.	0.52***
P	0.45***	n.s.
Mn	—0.30*	0.37**
Co	—0.60***	n.s.
Ni	—0.59***	0.47***
S	—0.33*	n.s.

Soil pH correlated very significantly only with the concentration of Ni, P and Co in the oats. The correlation between soil pH and Mn concentration in oats was low compared with the previous study on the mineral element content of timothy grown in the same village (PALKO 1986). In that study the content of Co, Ni and Mn in timothy increased very significantly as the soil pH decreased. As for Zn, its solubility in Tupos soils proved to be dependent on soil pH (PALKO and YLI-HALLA 1987), but the variation in the Zn content of the oats seemed not to be affected by this relationship. The varying concentrations of Ni and Na and, to a lesser extent, that of Mn were reflected in the composition of plants. The Ni content of Tupos timothy was also higher when the AAAc-EDTA-extractable Ni in the soil was higher (PALKO 1986).

Conclusions

In terms of macronutrient concentration Tupos oats did not differ considerably from oats grown in other parts of Finland. The higher Fe, Mn, Ni and Co content of oats grown in acid sulphate soils is obviously connected with soil acidity, but the apparently high concentrations of Co warrant further investigation. The present results suggest that oats grown in Tupos fields are able to maintain their normal level of plant nutrients despite the somewhat exceptionally high concentrations of certain elements in the soil. It was, however, noticed that the elements which are not plant nutrients (i.e. Na, Co and Ni) exhibited greater variation of concentration in the grain than especially macronutrients.

The composition of the Tupos oats deviated less than that of the Tupos timothy from the mineral contents usually reported for these plant species in Finland. However, it should be recognized that the timothy samples have consisted mainly of the vegetative parts of the plant, while in the present study only grains were analysed. JAAKKOLA et al. (1982) noticed that the composition of grains varies less than that of the vegetative parts of cereals, i.e. straw. The results by YLÄRANTA and SILLANPÄÄ (1984) also show that the concentration ranges of most elements in cereal grain are narrower than the ones in cereal straw and timothy. From the scientific point of view, it is possible that leaf and straw analysis would more probably reflect the concentrations of easily soluble mineral elements in the soil. Yet,

as far as cereals are concenred, only the composition of grains is important since straw is seldom used as fodder.

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SELOSTUS

Happamalla sulfaattimaalla kasvaneen kauran kivennäisainepitoisuudet

Markku Yli-Halla

Kemira Oy, Espoon tutkimuskeskus, Luoteisrinne 2, SF-02270 ESPOO

Jukka Palko

Vesihallitus, SF-90100 OULU

Limingan kunnan Tupoksen kylästä kerättiin 51 kpl kauran jyvänäytteitä, joista 35 kpl oli kasvanut happamaksi sulfaattimaaksi luokitelluilla pelloilla. Kun jyvien kivennäisainepitoisuudet määritettiin, todettiin, että ne sisälsivät fosforia, kaliumia, kalsiumia, magnesiumia, rikkiä, kuparia ja sinkkiä tavanomaiset määrät. Sen sijaan näytteiden rauta- ja kobolttipitoisuus oli suurehko ja seleenipitoisuus hyvin pieni. Muutamissa happamilta sul-

faattimailta kerätyissä jyvänäytteissä oli tavallista enemmän mangaania ja nikkeliä. Mitä enemmän maassa oli helppoliukoista natriumia ja nikkeliä, sitä enemmän näitä alkuaineita oli kauran jyvissä. Jyvien kobolttı- ja nikkelipitoisuudet olivat suurimmat happamimmilla kasvupaikoilla. Tupoksen alueen kauran jyvien kivennäisainepitoisuudet poikkesivat tavanomaisista arvoista vähemmän kuin samalla alueella kasvaneen timotein kivennäisainepitoisuudet.