

CONCENTRATION OF MICRONUTRIENTS IN PEA AND LUPIN PLANTS DEPENDING ON THE SOIL TILLAGE SYSTEM

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Abstract

In a two-year field study, the changes in Cu, Zn, Mn and B concentrations in aerial parts of lupine and pea were observed under traditional and no-tillage system. In each year, plant material samples were collected four times at 10-day intervals, from 30 days after sowing to the flowering stage. In plants of one species but grown under different tillage systems, differences in the content of micronutrients occurred in the early growth season, and tended to disappear in the early inflorescence phase. In general, these concentrations were higher in plants under traditional tillage system. However, under drought conditions these concentrations were higher in plants under no-tillage system. Regardless of a tillage system, some changes in micronutrient concentration during the vegetation period were observed. Concentration of copper in aerial parts of plants evidently decreased as the plants grew older. Fluctuations in the levels of Zn, Mn, and B did not follow such clearly defined tendencies and were dependent on the plant's species and individual elements.

Keywords: no-tillage, pea, lupin, microelements in plants.

ZAWARTOŚĆ MIKROELEMENTÓW W GROCHU I ŁUBINIE W ZALEŻNOŚCI OD SYSTEMU UPRAWY ROLI

Abstrakt

W 2-letnich badaniach polowych obserwowano zmiany koncentracji Cu, Mn, Zn i B w nadziemnej części łubinu i grochu uprawianych w tradycyjnym i zerowym systemie uprawy roli. W każdym roku pobierano próbki roślinne w 4 terminach, co 10 dni, w okresie od 30. dnia po siewie do fazy kwitnienia. W roślinach jednego gatunku, lecz rosnących w warunkach różnych systemów uprawy, wystąpiły różnice w poziomie zawartości mikroelementów w początkowym okresie wegetacji. Różnice te zanikały w fazie początku kwitnienia. Zawartość mikroelementów na ogół była wyższa w roślinach z uprawy tradycyjnej, natomiast w warunkach suszy – w roślinach z uprawy zerowej. W miarę upływu okresu wegetacji obserwowano pewne zmiany koncentracji mikroelementów niezależnie od systemu uprawy roli. Zawartość Cu w częściach nadziemnych roślin wyraźnie malała w miarę zbliżania się do fazy kwitnienia. Zmiany zawartości Zn, Mn i B nie były tak jednoznacznie ukierunkowane i zależały od pierwiastka i gatunku rośliny.

Słowa kluczowe: uprawa zerowa, groch, łubin, zawartość mikroelementów w roślinach.

INTRODUCTION

Reduced soil tillage techniques have certain advantages over conventional tillage in that they prevent soil erosion, limit water loss and reduce crop cultivation costs. An extreme example of minimal tillage is zero-tillage, which involves direct sowing. In general, this technique generates lower crop yields than when soil is ploughed. This may be due to the altered physicochemical properties of unploughed soil, which in turn affect the uptake of nutrients by crops.

The aim of this study has been to compare the content of some micro-nutrients in vegetative organs of pea and lupine sown directly to unploughed soil and grown under conventional tillage as well as to trace modifications in the concentration of these elements during the crops' growth.

MATERIAL AND METHODS

The material for our study consisted of a collection of pea and lupine samples gathered in 2005-2006 from fields under no-till and conventional tillage systems. The NPK fertilization, adjusted to the requirements of both crops, was identical, regardless the tillage method applied. In each year, aerial parts of the plants were collected on four dates, at ten-day intervals, beginning on day 30 after the sowing and finishing during the early inflorescence stage. The plants were sown on 11th April 2005 and 24th April 2006. Six systematically distributed points (replications) were fixed on each 4 m²

plot. On each of the sampling dates, whole aerial parts of plants were cut off from an area of 1 m². The samples were dry mineralized in a muffle furnace, diluted in hydrochloric acid and used for the following determinations: B content by the ICP method and Cu, Mn and Zn concentrations by the AAS method. For B and Mn determinations, certified material no NCSZC 76008 was used, whereas Cu and Zn determinations were referred to own material, i.e. plant samples IPE (Cu – IPE 06.2.4, Zn – IPE 06.2.4) from an interlaboratory research project in the Netherlands. The results are given as arithmetic means from 6 replications.

The soil samples, taken in early spring, underwent the following determinations: grain size distribution and concentration of available macro- and micronutrients extracted in 1 mol·dm⁻³ HCl. The properties of the soil arable horizon differed between the plots (Table 1). In general, the soil was sandy soils, containing little organic carbon, either acidic or very acidic in reaction.

Table 1

Characteristic of top layer of soil from tested fields

Field				C org. (g·kg ⁻¹)	pH 1 mol KCl·dcm ⁻³	Content (mg·kg ⁻¹)						
	1.0-0.1	0.1-0.02	<0.02			P	K	Mg	Cu	Mn	Zn	B
2005 Lupin	55	28	16	5.0	4.3	46	123	31	3.2	158	7.1	0.8
2005 Pea	57	26	17	6.5	4.4	49	159	33	3.3	186	7.2	0.9
2006 Lupin	36	40	24	6.0	5.0	58	152	43	3.0	166	8.1	0.6
2006 Pea	44	36	19	6.7	5.3	74	156	32	3.0	181	9.6	0.8

The weather during the period of plant sampling also varied from year to year. The humidity conditions over the given time period were characterized using Seljoninov's hydrothermal index (after STRNAD 1979), quoting its values in every ten-day period preceding each plant material collection (Figure 1). This index includes an average air temperature and total rainfall in a specific time period. When it falls below 1, it indicates drought (<0.3 – catastrophic drought), and when it goes above 2, it suggests excess water in soil. The supply of plants with water in 2006 was much worse than in 2005. In 2006, drought was observed in all the time intervals preceding the consecutive plant material samplings except the third date. The drought was particularly severe in the last ten days.

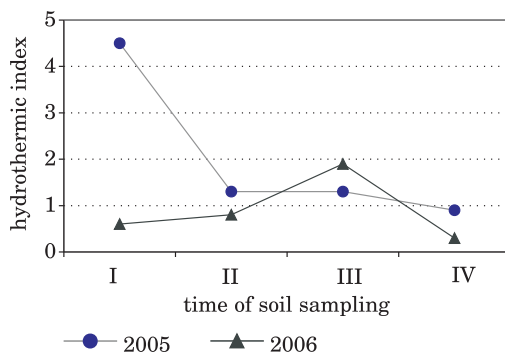


Fig. 1. Hydrothermics index values for 10-days periods

RESULTS AND DISCUSSION

The concentration of micronutrients in plants, during their vegetative growth to the inflorescence phase, was different between the two years of the study. The largest differences occurred in the amounts of copper. The content of Cu in lupine (Figure 2) and pea (Figure 3) was much higher in 2006 than in 2005, although the concentration of this element in soil was nearly identical in both years (Table 1). In 2005, the concentration of copper in plants ranged from 6.8 to 7.5 mg·kg⁻¹ for lupine and from 6.4 to 8.0 mg·kg⁻¹ for pea, whereas in the next year, 2006, it was 8.4-12.0 mg·kg⁻¹ and 7.8-13.7 mg·kg⁻¹, respectively. The content of Cu_{HCl} determined on a single occasion of soil sampling did not provide us with any information on the availability of this metal to crops over a longer period of time. It is most likely that the total pool of plant available forms of copper in 2006 was higher as the soil then contained more <0.1 mm fraction and organic carbon, which meant that its sorptive complex was greater than in 2005 (Table 1). The differences in the quantities of the other micronutrients between the years were smaller and less regular than those observed for copper. A higher level of Zn and Mn in pea was found in 2005, which may have been caused by a lower soil pH than in 2006; the content of B was higher in 2006.

Comparison of the concentrations of the micronutrients in both crops has demonstrated certain differences, too. They were the largest for manganese and smallest for boron. On the last sampling date, that is immediately before the inflorescence phase, the differences were much smaller or disappeared. The variation in the content of Mn was as high as 60% whereas that of boron ranged from less than 10 to 13%. Manganese is a particularly important microelement in nutrition of leguminous crops, especially pea,

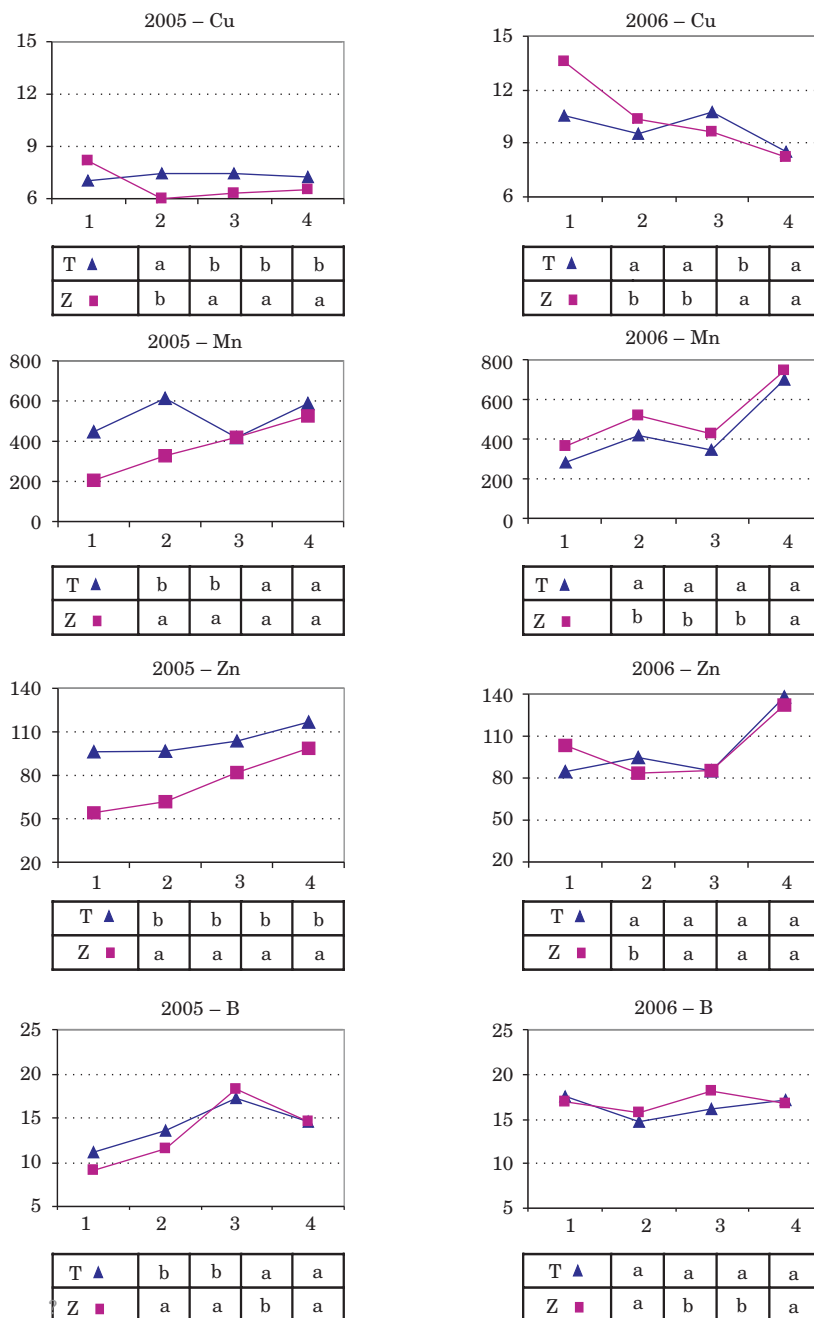


Fig. 2. Dynamics of the content of micronutrients ($\text{mg} \cdot \text{kg}^{-1}$) in dry matter of aerial parts of lupine under conventional (T) and zero-tillage (Z) in ten-day intervals from day 30 after sowing to the onset of the inflorescence stage. There is no significant difference between the same letters in columns (method of tillage) according to Tukey's test ($p < 0.05$)

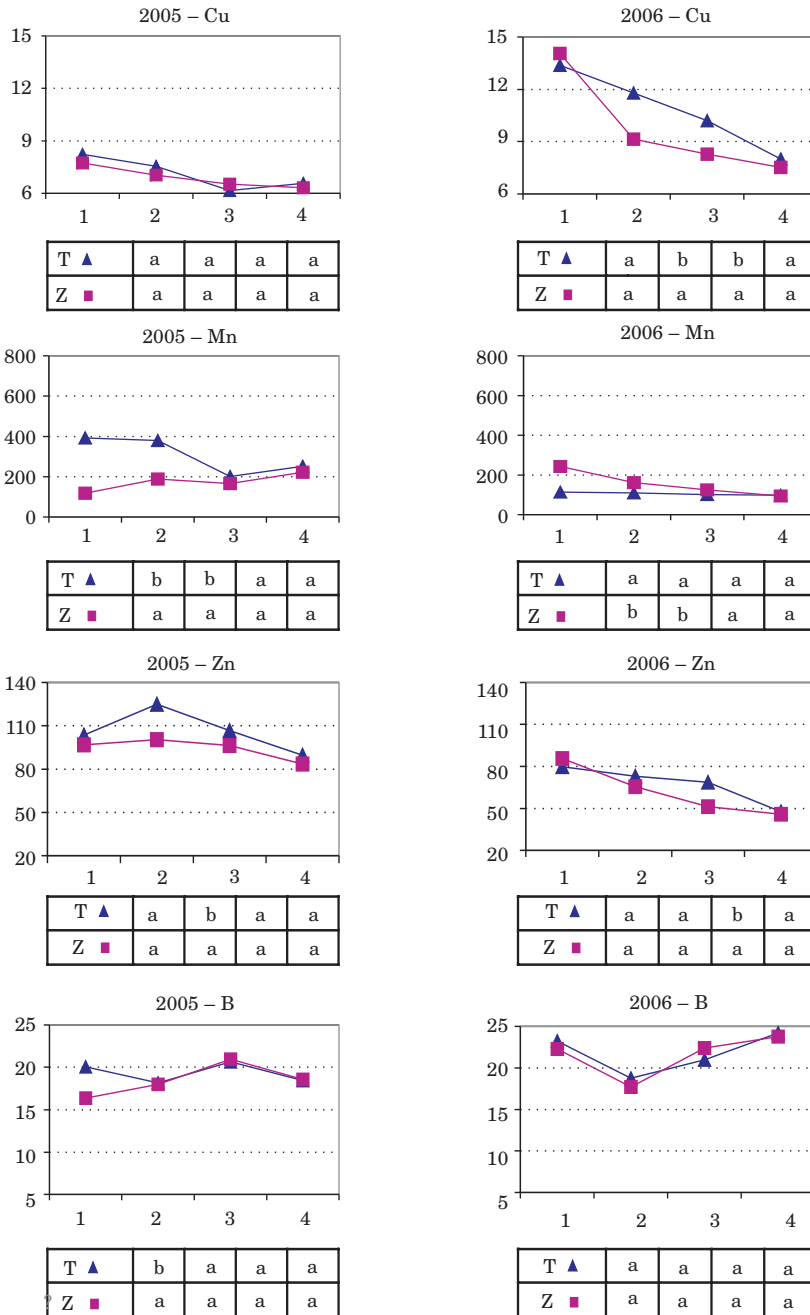


Fig. 3. Dynamics of the content of micronutrients (mg · kg⁻¹) in dry matter of aerial parts of pea under conventional (T) and zero-tillage (Z) in ten-day intervals from day 30 after sowing to the onset of the inflorescence stage. There is no significant difference between the same letters in columns (method of tillage) according to Tukey's test (*p*<0.05)

because these plants are highly intolerant to its deficit (KATYAL, RANDHAWA 1983). Consequently, the level of Mn can affect the volume of yields produced by legumes. In their study, YU, RENGEL (1999) found out that manganese deficit caused depressed green matter yield of lupine as early as in the initial growth phases of this crop.

KORZENIOWSKA and STANISŁAWSKA-GLUBIAK (2006) reported that different tillage methods caused differences in the nutrition of oats. Many authors report that the content of organic matter in soil as well as the concentration of N, P, K, Fe, Mn, Cu and Zn in the surface soil horizon are larger under no-till farming than when soil is ploughed (FRANZLUEBBERS, HOSS 1996, LAVADO et al. 1999, MARTIN-RUEDA et al. 2007), thus it can be expected that the concentration of nutrients in crops grown under reduced tillage should also be higher. Contrary to this, in our study sometimes the opposite was true. In 2005, lupine contained more micronutrients, especially Mn and Zn, when grown under conventional tillage than no-till systems. However, in the following year, lupine sown directly to unploughed soil contained more Cu, Mn and B. It seems that one possible reason is the differences in the humidity conditions observed between both years. ARSHAD et al. (1999) and PABIN et al. (2002) emphasize the positive influence that zero-tillage has on water accumulation in soil, especially in dry years. The drought observed during the first sampling dates in 2006 was less harsh on crops growing under minimal tillage than the ones sown to ploughed soil, which facilitated the uptake of micronutrients from unploughed soil. ZECH et al. (2000) demonstrated that the content of nutrients in tilled and non-tilled soil varied between the dry and wet seasons.

SANTIAGO et al. (2008) did not discover significant differences in the content of Fe, Cu and Zn in sorghum grown under traditional and zero-tillage systems, even though the soil content of available forms of nutrients was higher in non-tilled soil. However, unlike our tests, their study was carried out on alkaline soil, in which the availability of nutrients to plants is limited.

The course of the curves which illustrate the direction of the modifications in the concentrations of micronutrients in pea and lupine depended on a plant species, but was similar for both tillage methods. The vegetative parts of lupine were found out to contain decreasing levels of copper; in pea, both Cu and Zn tended to decline. In another study, performed under controlled conditions, PODLEŚNA and WOJCIESKA (1996) also observed declining levels of Cu and Zn in vegetative parts of pea. Changes in the concentration of other micronutrients were not so regular.

CONCLUSIONS

1. Changes in the concentration of micronutrients in vegetative parts of lupine and pea observed over the growth season were similar for both tillage methods. The concentration of Cu tended to decline, whereas the changes in the content of Mn, Zn and B were less regular and depended on the micronutrient and crop species.

2. The differences in the content of micronutrients in plant tissues, observed during this study, were the largest in the early vegetative growth and tended to disappear as the inflorescence stage was approaching.

3. Under drought conditions, levels of micronutrients were generally higher in crops grown under zero-tillage; when water supply was good, more micronutrients accumulated in crops cultivated traditionally, with soil ploughing.

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