ČESKÁ AKADEMIE ZEMĚDĚLSKÝCH VĚD

ROSTLINNÁ VÝROBA
Plant Production

ÚSTAV ZEMĚDĚLSKÝCH A POTRAVINÁŘSKÝCH INFORMACÍ

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Ročník 47
Leden 2001
ISSN 0370-663X

ROSTLINNÁ VÝROBA

Mezinárodní vědecký časopis vydávaný z pověření Ministerstva zemědělství České republiky a pod gescí České akademie zemědělských věd

PLANT PRODUCTION

An international journal published under the authority of the Ministry of Agriculture and under the direction of the Czech Academy of Agricultural Sciences

Cíl a odborná náplň: Časopis publikuje původní vědecké práce, výsledky výzkumu, studie a analýzy z oblasti rostlinné výroby, především pěstování rostlin, tvorby výnosů plodin, kvality jejich produktů, semenářství, fyziologie rostlin, agrochemie, pedologie, mikrobiologie, meliorací a agroekologie. Časopis je citován v bibliografickém časopise Current Contents – Agriculture, Biology and Environmental Sciences. Abstrakty z časopisu jsou zahrnuty v těchto databázích: Agricola, Agris, CAB Abstracts, Czech Agricultural Bibliography, Food Science and Technology Abstracts, Toxline Plus.

Periodicita: časopis vychází měsíčně (12krát ročně), ročník 47 vychází v roce 2001.

Přijímání rukopisů: Rukopisy ve dvou vyhotoveních je třeba zaslat na adresu redakce: RNDr. Eva Stříbrná, vedoucí redaktorka, Ústav zemědělských a potravinářských informací, Slezská 7, 120 56 Praha 2, Česká republika, tel.: + 420 2 22 52 04 11, fax: + 420 2 22 51 40 03, e-mail:editor@uzpi.cz. Den doručení rukopisu do redakce je publikován jako datum přijetí k publikaci.

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Periodicity: The journal is published monthly (12 issues per year), Volume 47 appearing in 2001.

Acceptance of manuscripts: Two copies of the manuscript should be addressed to: RNDr. Eva Stříbrná, editor-in-chief, Institute of Agricultural and Food Information, Slezská 7, 120 56 Praha 2, Czech Republic, tel.: + 420 2 22 52 04 11, fax: + 420 2 22 51 40 03, e-mail: editor@uzpi.cz. The day the manuscript reaches the editor for the first time is given upon publication as the date of receipt.

Subscription information: Subscriptions may be ordered only by calendar year (January–December) and should be sent to: Institute of Agricultural and Food Information, Slezská 7, 120 56 Praha 2. Subscription price for 2001 is 195 USD (Europe), 214 USD (overseas).

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Sulphur concentrations and distribution in three varieties of oilseed rape in relation to sulphur fertilization at vegetative stages

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ABSTRACT

A pot trial was conducted on three varieties of winter rape: line variety Lirajet (L), its genetically modified form Lirajet Roundup Ready (GML) and hybrid variety Pronto (P) to study the effect of graded sulphur application rates on concentrations and distribution of total sulphur, sulphates and glucosinolates in the parts of oilseed rape plants at the stage of spring regeneration of leaf rosette, stem extension and flowering. Large differences in the concentration and distribution of total sulphur and sulphates were determined between the varieties, particularly between the line variety Lirajet and its genetically modified form. The effect of graded sulphur application rates on the concentration and distribution of total sulphur and sulphates in the plant parts was confirmed. The highest increase in their contents at vegetative stages was observed in leaves. The content of total sulphur and sulphates in rape leaves clearly reflects the nutrient status of oilseed rape plants. Sulphates were an important component of the total sulphur content in the vegetative parts. It is questionable whether it is a result of low effectiveness of their utilization for synthesis of primary and secondary metabolites or a reflection of the mineral form of sulphur – sulphates play other roles in oilseed rape plants. The trends of glucosinolate contents and distribution were not found to be explicitly related with S-fertilizing. Their proportions in the vegetative parts of oilseed rape were minimum. In the course of vegetative stages, a shift was observed in their higher contents in these vegetative parts of oilseed rape: roots, stem, racemes, leaves. Only the variety Pronto had somewhat higher values of glucosinolate contents in all vegetative parts including leaves.

Keywords: oilseed rape; variety; S-fertilization; sulphur; sulphate; glucosinolate; concentration; distribution

Sulphates are the main form of sulphur uptake by plants while it is supposed that an active uptake is necessary to overcome the negative electrochemical gradient behind the cell plasmalemma. Metabolizing of SO_4^{2-} into organic compounds requires their reduction similarly like in NO_3^- (Mengel and Kirkby 1982). The function of glucosinolates as sinks is challenged by a low concentration of glucosinolates in the vegetative parts of oilseed rape plants (Fieldsend and Milford 1994). Glucosinolates are supposed to play an important role in the defence mechanism of oilseed rape against pests and diseases (Mithen 1992; Wallsgrove et al. 1999).

Appropriate sulphur supplies to oilseed rape plants also imply important environmental consequences in the intensive system of crop production. Fertilizer nitrogen utilization is increased while possible environmental contamination with surplus mineral nitrogen is decreased (Haneklaus et al. 1999).

The goal of this study was to determine the effect of graded sulphur application rates in soil with sulphur status detected by soil tests, as affected the concentrations and distribution of total sulphur, sulphates and glucosinolates in three different types of varieties (line, hybrid and genetically modified ones) at the oilseed rape vegetative stages. This research is aimed at gradual collection of diagnostic data for optimization of sulphur supplies to oilseed rape plants and of oilseed rape production quality by efficient fertilizing.

MATERIAL AND METHODS

Three varieties were tested in a pot trial: a) line variety Lirajet (L), b) its genetically modified form Lirajet Roundup Ready (GML) and c) hybrid variety Pronto (P). The pot was filled with 5 kg of Hapludalfs soil from Ruzyně locality. The soil properties were as follows: $pH_{(0.2\,M\,KCl)}$ = 6.7; $C_{(LECO)}$ = 1.215%; $N_{(LECO)}$ = 0.112%; $S_{(total\,LECO)}$ = 112.7 mg S/kg; soil test KVK-UF (Matula and Pirkl 1988; Matula 1996): CEC = 211 mmol(+)/kg, $S_{(ICP)}$ = 20 mg/kg, K = 194 mg/kg; Mg = 72 mg/kg; P = 3 mg/kg; Mn = 3.1 mg/kg. An amount of 0.304 g $Ca(H_2PO_4)_2.H_2O$ was admixed with the whole volume of each pot on the basis of the soil test. As the soil had a lower content of magnesium, magnesium sulphate was used for fertilizing with graded sulphur application rates; the sulphate was also admixed with soil before the pots were filled. $MgSO_4.7\,H_2O$ application rates: variant 1 = 0; variant 2 = 0.514 g; variant 3 = 1.028 g; variant 4 = 2.056 g. The values of water extracted Mg (1:5) were minimally influenced by an addition of magnesium sulphate. The soil test values increased by 2.5% in variant 3 and by 3.75% in variant 4. Increases in the values of exchange Mg determined by the soil test of KVK-UF were much higher: by 2.4% in variant 2, by 14.3% in variant 3 and by 35.7% in variant 4. An amount of 0.8 g N per pot was applied at the vegetative stages in the form of NH_4NO_3 solution at eight split doses between 11/3/99 and 26/5/99. A vegetation experiment started on 10/3/99 by transplanting the pre-cultivated plants to pots. The plants were pre-cultivated in pots containing 440 g of identical soil: sowing 3/9/98; heeling-in in a cold frame 2/11/98 – winter rest. Each variant had 14 replications. Four replications were brought to full maturity – to harvest (7/7/99). Other replications were parallelly used for plant samplings: 1. at the end of spring regeneration of leaves (7/4/99), 2. at stem extension (22/4/99), 3. at flowering (13/5/99).

Plants sampled at vegetative stages were cut into parts (see the results – graphs), instantly frozen in liquid nitrogen and lyophilized. Dry mass of homogenized plant parts was mineralized in a microwave device MILESTONE in the medium of nitric acid and hydrogen peroxide. Total sulphur was determined on an apparatus ICP-OES Trace SCAN. An analyzer SAN Plus System – SKALAR was used to determine sulphates after plant dry matter extraction into water (0.5 g + 25 ml H_2O, 1 hour rotary shaking). Statistical programme GraphPad PRISM, CA, USA, version 3.0, and Microsoft Excel 97 were used for experimental data processing.

RESULTS AND DISCUSSION

Stage of spring regeneration of leaf rosette

Figs. 1 and 2 show concentrations and distribution of total sulphur. A large difference in total sulphur concentrations in relation to S-fertilizing was determined in leaves only, namely in the variety GM-Lirajet. Graphs of sulphate concentrations (Fig. 3) illustrate the capacity of GM-Lirajet to take up substantially more sulphates at a lower intensity of sulphur fertilizing but without their noticeable metabolizing. Sulphates accounted for more than 80% of the total sulphur concentration in this variety while they accounted for 38–40% in Lirajet and Pronto (variant 2). The above-ground leaf rosette was the main sink of sulphur and sulphates (Figs. 2 and 4).

Fig. 5 shows glucosinolate concentrations in relation to S-fertilizing variants. Large differences in glucosinolate distribution were observed between the variety Pronto and the varieties Lirajet and GM-Lirajet (Fig. 6). In the Pronto variety, the leaves were more important sinks of

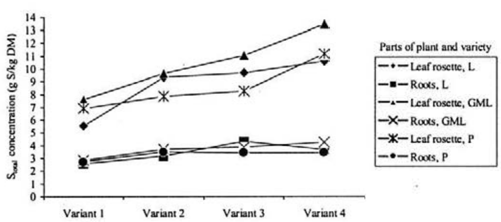

Figure 1. Concentration of total sulphur in oilseed rape at the end of spring regeneration of leaves

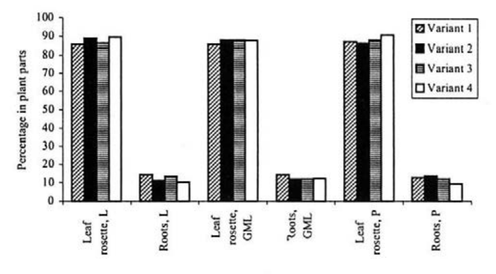

Figure 2. Distribution of total sulphur in oilseed rape at the end of spring regeneration of leaves

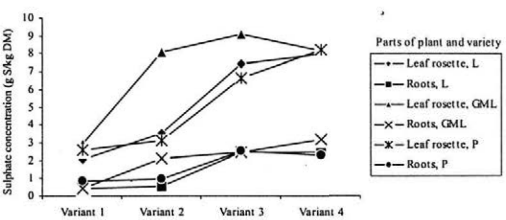

Figure 3. Concentration of sulphate in oilseed rape at the end of spring regeneration of leaves

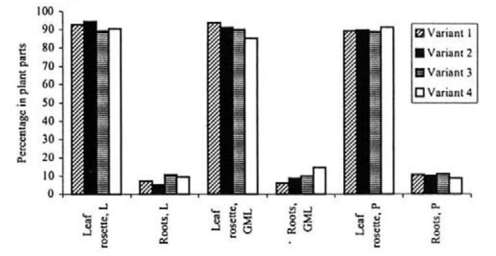

Figure 4. Distribution of sulphate in oilseed rape at the end of spring regeneration of leaves

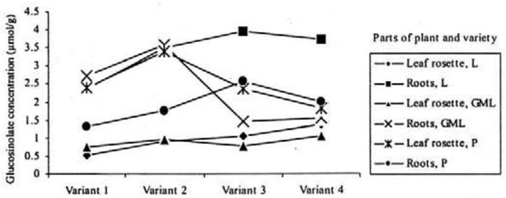

Figure 5. Concentration of glucosinolate in oilseed rape at the end of spring regeneration of leaves

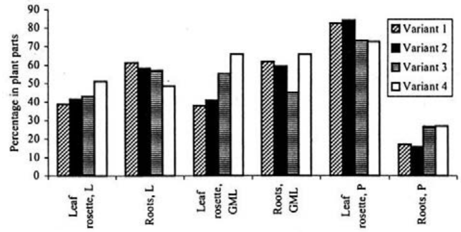

Figure 6. Distribution of glucosinolate in oilseed rape at the end of spring regeneration of leaves

glucosinolates than the roots. Glucosinolate distribution in Lirajet and GM-Lirajet was higher in roots than in leaves.

Stem extension stage

Graded S application rates were reflected only in an increase in total sulphur concentration in leaves (Fig. 7), with a stagnation between variant 2 and 3 (i.e. between the 1st and 2nd sulphur dose) that could be explained by activation of higher uptake capacity as a result of sulphur deficiency (Cram 1990; Massonneau et al. 1997). The variety GM-Lirajet had substantially higher concentrations of total sulphur in leaves than Lirajet and Pronto. Sulphates accounted for 68.22% of total sulphur concentration (*SD* 8.123) in Lirajet and Pronto; the proportion of sulphates in the variety GM-Lirajet was obviously higher (mean 78.30%; *SD* 8.093). The high sulphate concentration in leaves could be ascribed to sulphur allocation in cell vacuoles and to their limited transport through the tonoplast (Zhao et al. 1999). There were no substantial differences in total sulphur concentrations between roots and stems, but sulphate proportions were different. Stem concentrations amounted to 56.71% on average (*SD* 4.456), root concentrations were lower (mean 34.72%, *SD* 8.087). Fig. 9 shows sulphate concentrations in the vegetative parts of oilseed rape plants in relation to S-fertilizing variants. Leaves were the main sink of total sulphur and sulphates in oilseed rape plants (Figs. 8 and 10).

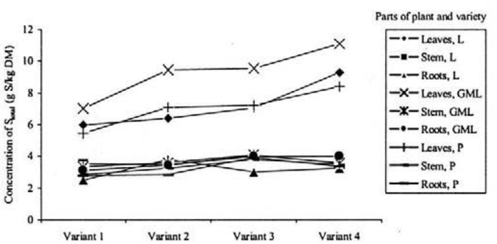

Figure 7. Concentration of total sulphur in oilseed rape at stem extension

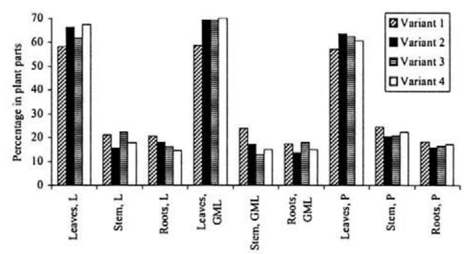

Figure 8. Distribution of total sulphur in oilseed rape at stem extension

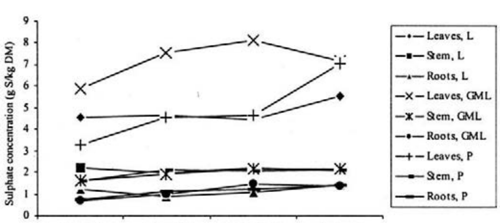

Figure 9. Concentration of sulphate in oilseed rape at stem extension

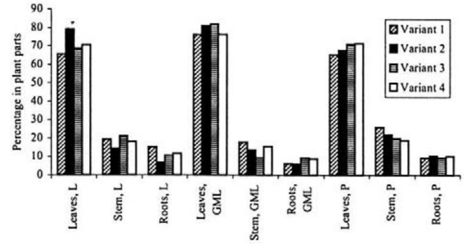

Figure 10. Distribution of sulphate in the parts of oilseed rape at stem extension

Fig. 11 shows glucosinolate concentrations. Stems were the main sinks of glucosinolates in the varieties Lirajet and GM-Lirajet (Fig. 12). Besides in stems, Pronto had higher glucosinolate concentrations also in leaves in comparison with the other varieties.

Flowering stage

Only leaves showed an evident gradient of the increase in total sulphur concentration in oilseed rape in relation to S-fertilizing (Fig. 13). Sulphates in leaves accounted for 40–70% of total sulphur and their proportion was increasing with S-fertilizing intensity. This finding documents that leaves are a suitable material to diagnose the nutrient status of oilseed rape plants on the basis of total sulphur or sulphate contents (Schnug and Haneklaus 1994; McGrath and Zhao 1996; Pinkerton 1998). The varieties obviously differed in total sulphur contents. Lirajet had the lowest concentrations, while GM-Lirajet had the highest ones.

Total sulphur contents in racemes were balanced for all varieties and all S application rates. Average concentrations ranged around 3.26 g S/kg dry matter (*SD* 0.467), sulphates accounted for 40.44% on average (*SD* 0.146). Roots had lower concentrations of total sulphur (mean 2.29; *SD* 0.476) irrelevant to the variety and S-fertilizing. The lowest concentration of total sulphur was detected in stems in the range of 1 to 2 g S/kg, tending to increase with S-fertilizing intensity.

As regards relative distribution of total sulphur in the weight parts of oilseed rape plants, racemes were the main sinks of sulphur (Fig. 14). Highest allocations were determined in Pronto (mean 54.81%, *SD* 4.066) and GM-Lirajet (mean 50.32%, *SD* 9.137), and lower ones in Lirajet (31.95%, *SD* 1.810). Leaves were another sink: Lirajet (mean 30.31%, *SD* 3.693), GM-Lirajet (mean 26.04%, *SD* 3.649) and Pronto (mean 21.13%, *SD* 4.579). The variety Lirajet also had a significant distribution of total sulphur in stems (mean 26.71%, *SD* 2.121).

Fig. 15 shows sulphate concentrations in the oilseed rape parts; differences between the varieties and relations to S-fertilizing are illustrated in leaves only. Sulphate distribution in oilseed rape is documented in Fig. 16. The main sinks of sulphates in Lirajet are leaves (mean 38.48%, *SD* 7.222) and stems (mean 27.15%, *SD* 5.676), particularly at higher S application rates. The hybrid Pronto has racemes as the main sink of sulphates (mean 50.21%, *SD* 6.087), showing a trend of decrease with increasing S application rates. Sulphate distribution in GM-Lirajet more resembled that of Pronto than distribution in the original variety Lirajet.

Glucosinolate concentrations in the oilseed rape parts were not related to S-fertilizing (Fig. 17). There existed evident differences in glucosinolate distribution between the varieties (Fig. 18). Stems were the main sink of glu-

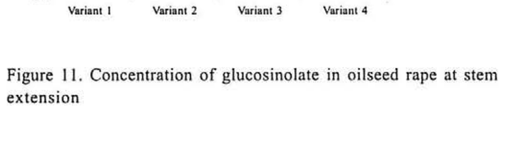

Figure 11. Concentration of glucosinolate in oilseed rape at stem extension

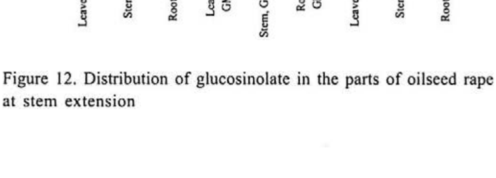

Figure 12. Distribution of glucosinolate in the parts of oilseed rape at stem extension

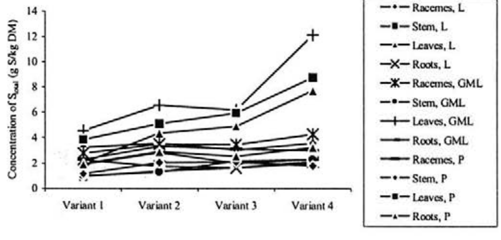

Figure 13. Concentration of total sulphur in oilseed rape at flowering

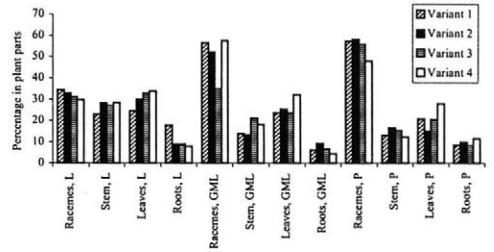

Figure 14. Distribution of total sulphur in the parts of oilseed rape at flowering

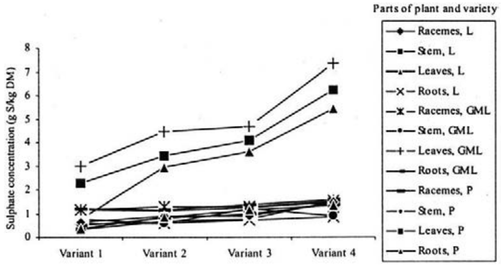

Figure 15. Concentration of sulphate in oilseed rape at flowering

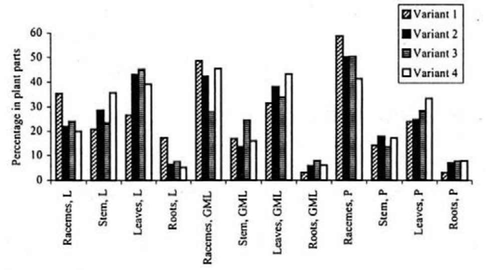

Figure 16. Distribution of sulphate in the parts of oilseed rape at flowering

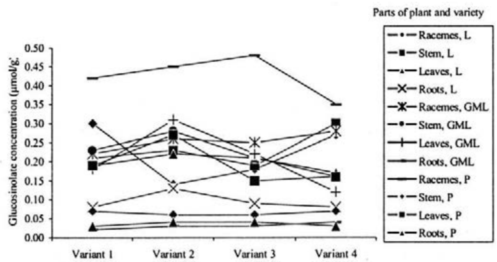

Figure 17. Concentration of glucosinolate in oilseed rape at flowering

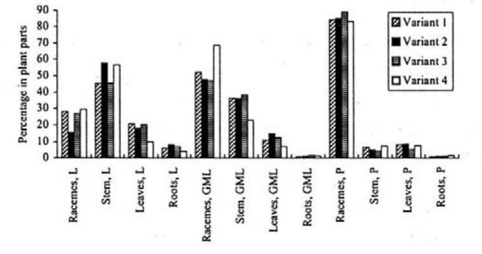

Figure 18. Distribution of glucosinolate in the parts of oilseed rape at flowering

cosinolates in Lirajet (mean 51.39%, *SD* 5.950), in Pronto it was racemes (mean 85.30%, *SD* 2.112), in GM-Lirajet racemes (mean 54.01%, *SD* 8.726) and stems (mean 33.49%, *SD* 6.122).

Glucosinolate distribution at vegetative stages was largely different from allocations of total sulphur and sulphates. The highest concentrations of glucosinolates were determined in transporting parts of the plant (roots, stems) and in seed at the end of vegetation. This finding could be in agreement with a deduction that glucosinolates are not re-synthesized in the seed but they are synthesized and transported from other parts of the plant.

Acknowledgement

This research benefited from financial support of the Grant Agency of CR (521/99/0470) and of project EP0960006472 of the National Agency for Agricultural Research.

REFERENCES

Cram W.J. (1990): Uptake and transport of sulphate. In: Sulphur nutrition and sulphur assimilation in higher plants. In: Rennenberg H. et al. (eds.): The Hague, The Netherlands, SPB Acad. Publ.: 3–11.

Fieldsend J., Milford G.F.J. (1994): Changes in glucosinolates during crop development in single and double-low genotypes of winter oilseed rape (*Brassica napus*): I. Production and distribution in vegetative tissues and developing pods during development and potential role in the recycling of sulphur within crop. Ann. Appl. Biol., *124*: 531–542.

Haneklaus S., Paulsen H.M., Gupta A.K., Bloem E., Schnug E. (1999): Influence of sulfur fertilization on yield and quality of oilseed rape and mustard. Proc. 10th Int. Rapeseed Congr. Canberra, Australia.

Massonneau A., Cathala N., Grignon C., Davidian J.C. (1997): Effect of sulphate deficiency on the plasma membrane polypeptide composition of *Brassica napus*. J. Exp. Bot., *48*: 93–100.

Matula J. (1996): Determination of potassium, magnesium, phosphorus, manganese and cation exchange capacity for fertilizer recommendations used by Czech Union of Rapeseed Growers. Commun. Soil Sci. Plant Anal., *27*: 1679–1691.

Matula J., Pirkl J. (1988): Vyluhovací roztok pro stanovení draslíku, hořčíku, vápníku, sodíku, manganu a rostlinám dostupného fosforu v půdě a hodnoty kationtové výměnné kapacity. Autorské osvědčení č. 272804. Praha.

McGrath S.P., Zhao F.J. (1996): Sulphur uptake, yield responses and the interaction between nitrogen and sulphur in winter oilseed rape (*Brassica napus*). J. Agric. Sci., *126*: 53–62.

Mengel K., Kirkby E.A. (1982): Principles of plant nutrition. 3rd ed. Switzerland, Int. Potash Inst.

Mithen R. (1992): Leaf glucosinolate profiles and their relationship to pest and disease resistance in oilseed rape. Euphytica, *63*: 71–83.

Pinkerton A. (1998): Critical sulfur concentration in oilseed rape (*Brassica napus*) in relation to nitrogen supply and to plant age. Austral. J. Exp. Agric., *38*: 511–522.

Schnug E., Haneklaus S. (1994): Sulphur deficiency in *Brassica napus* – Biochemistry – Symptomatology – Morphogenesis. Landb.-Forsch. Völkenrode, Sonder Heft 144.

Wallsgrove R., Benett R., Kiddle G., Bartlet E., Ludwig-Mueller J. (1999): Glucosinolate biosynthesis and pest/disease interactions. Proc. 10th Int. Rapeseed Congr. Canberra, Australia.

Zhao F.J., Blake-Kalff M.M.A., Riley N., Hawkesford M.J., McGrath S.P. (1999): Proc. 10th Int. Rapeseed Congr. Canberra, Australia.

Received on September 26, 1999

ABSTRAKT

Vliv hnojení sírou na její obsah a distribuci v průběhu vegetace tří odrůd ozimé řepky

U tří odrůd ozimé řepky: liniové odrůdy Lirajet (L), její geneticky modifikované formy Lirajet Roundup Ready (GML) a hybridní odrůdy Pronto (P) byl v nádobovém pokuse sledován vliv stupňovaného hnojení sírou na obsah a distribuci celkové síry, síranů a glukosinolátů v částech řepky ve fázi jarní regenerace listové růžice, dlouživého růstu a kvetení. V koncentraci a distribuci celkové síry a síranů byly zjištěny výrazné rozdíly mezi odrůdami, zvláště mezi původní liniovou odrůdou Lirajet a její geneticky modifikovanou formou. Stupňované hnojení sírou ovlivnilo koncentraci a distribuci celkové síry a síranů v částech řepky. Nejvýraznější nárůst jejich obsahu byl prokázán během vegetace v listech. Obsah celkové síry a síranů v listech řepky reflektuje nejlépe výživný stav řepky. Sírany představovaly podstatnou složku obsahu celkové síry ve vegetativních částech řepky. Je otázkou, zda je to projev pouze nízké efektivnosti jejich využití k syntéze primárních a sekundárních metabolitů, anebo minerální formy síry – sírany plní v řepce další poslání. V obsahu a distribuci glukosinolátů nebyly zjištěny jednoznačné trendy v závislosti na stupňovaném hnojení sírou. Minimální bylo jejich zastoupení ve vegetativních částech řepky. S postupem vegetace byl zaznamenán posun jejich většího obsahu v následných vegetativních částech řepky: kořeny, lodyha, květenství než v listech. Pouze odrůda Pronto vykazovala o něco větší hodnoty obsahu glukosinolátů ve všech vegetativních částech řepky včetně listů.

Klíčová slova: ozimá řepka; odrůdy; hnojení sírou; síra; sírany; glukosinoláty; obsah; distribuce

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The main features of the transfer of trace elements into plants

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ABSTRACT

The contribution represents the introduction to a set of papers, which evaluate the rules of the transfer of trace elements into testing plants in dependence on the content and mobility of hazardous elements and on specific features of every element by radish, triticale and spinach. The fact that in the set of investigated soil samples critical values of plants from the viewpoint of zoo- and phytotoxicity have been exceeded testifies the appropriate selection of samples. The summary statistics of the data concerning the content of the hazardous elements in testing plants and transfer quotients of elements (Cd > Zn > Mn > Cu, Ni > Co, V > Pb, Cr > As) are given. Transfer quotients are refered not only to total contents, but also to potentially mobilizable and mobile species. Liming decreased transfer of the most mobile elements in the indirect relation to their mobilities (Co, Mn, Ni > Cd, Zn). The liming did not affect the uptake of Cr, V, Cu, the uptake of As even increased.

Keywords: summary statistics; trace elements; transfer into crops

Presented set of contributions refers to studies of the mobility of trace elements in soils (Němeček et al. 1999; Podlešáková et al. 1999; Němeček and Podlešáková 2000; Podlešáková and Němeček, 2000). They are focused on the specific feature of uptakes of single trace elements (TEs) by testing plants and on the dependence of trace elements transfer from soil to plants upon the content and first of all upon the mobility of TEs and factors, which affect them.

Many authors have confirmed that the uptake of trace elements by crops correlates not so much with the total content but with the content of mobile or potentially mobilizable species (Soon and Bates 1982; Xian 1989). Plant uptakes of the most mobile TEs correlate with the species extractable in 0.01M $CaCl_2$ (Houba et al. 1990; Whitten and Ritchie 1991), in 0.1M $NaNO_3$ (Gupta and Häni 1981), in 1M NH_4NO_3 and 0.01M $CaCl_2$ (Hornburg and Brümmer 1989, 1990a, b, 1991) and in 1M NH_4NO_3 (Prüeß 1992) and of some other TEs with the potentially mobilizable extractable species in EDTA (e.g. Ni – Brown et al. 1989; Cu – Macnicol and Beckett 1985).

Testing crops play a very important role. For the field conditions we selected fodder plants. Some authors used the ubiquitous *Taraxacum officinale* (Kabata-Pendias et al. 1994; Marr et al. 1999). This plant can be used when we compare the summary loads from soil and atmosphere (Cd, Pb, Zn, Mn, Cu) between rural and urban areas. In pot experiments we have used the radish, triticale and spinach. Radish is considered as a model plant for a broad range of growing conditions (Zaman and Zereen 1998). This plant represents the cumulation in the root bulls. Triticale is resistant against soil acidity. It represents the transfer into the above-ground biomass. In all mentioned cases transfers can be evaluated in terms of fodder plant standards. Spinach has been used as a bioaccumulator, with the limited use, due to soil acidity.

Very important conditions to acquire the results, which are representative for the conditions of the state area, is the set of used soils (Ap horizons of agriculturally used soils). The selection has to be judged from the viewpoint of taxonomic units, range of single properties affecting TEs mobilities, contamination degree and the kind of the contamination (airborne, fluvial) and geogenic loads. Even if it has been proved that high geogenic loads are characterized by the low mobility, it is necessary to pay attention to their extremes (Moustakas et al. 1997).

In the following publications, we will focus on prediction equations of the TEs transfer into testing plants which were derived from the data of both pot experiments and field conditions with realistic soil loads of agriculturally used soils. The substitution of critical plant loads in prediction equation enables us to arrive at the assessment of limiting contents and mobilities of TEs in soils for the transfer pathway soil – plant from the viewpoint of zoo- and phytotoxicity. Considering difficulties in getting the principal aims, it means to fix limiting soil values of the protection of the food chain, based on ecotoxicological principles, we try to achieve a very modest goal. Critical limits of soil mobility and content of TEs should reflect the threat of the worsening of the quality of soil production, given by the present fodder plants and food standards and the threat of yield decline.

In this paper we present the summary statistics of the results of both pot experiments and field investigations. We explore the characteristics of transfers in the whole set and also in subsets, which represent different kinds of soil loads. We express the transfer factors (transfer coefficients) not only as the ratio of total TEs contents in plant: soil, but in accordance with Hornburg and Brümmer (1991) also as the ratio TEs plant content: mobile and mobilizable TEs species in soils.

MATERIAL AND METHODS

Transfers of TEs into plants were investigated both in pot experiments and in field conditions.

Pot experiments were conducted in four replications with 54 soil samples, contaminated in natural conditions or with samples characterized by geogenic loads. The soil samples include representative soil units (Chernozems – calcic, pelic; Luvisols – orthic, glossalbic; Stagnosols – orthic, luvic; Cambisols – eutrophic, dystric, hyperdystric; Podzols – cambic, orthic; Fluvisols – orthic) derived from typical parent materials in representative stages of anthropogenic airborne and fluvial contamination and from parent materials with geogenic loads (ultramafic substrata, metallogenic zones of acid rocks). Field observations have been made with 107 soil samples taken from analogical sites. Testing plants comprise radish, triticale and spinach in pot experiments and fodder plants in terrain investigations.

Mobile species of TEs were determined in 1M NH_4NO_3 – MN; 0.01M $CaCl_2$ – MC; potentially mobilizable species in 0.025M Na_2EDTA. Total contents of TEs in soils were determined after the destruction of soil samples in the mixture of acids HF + $HClO_4$ + HNO_3, in plants after the destruction in the mixture of HNO_3 and $HClO_4$. The analyses were made by means of the AAS method (Varian AA-300, SAAS, ETA).

The following elements were investigated: Mn, Cd, Co, Zn, Ni, Be, Pb, Cu, Cr, V, As, Hg.

The used abbreviations of subsets are:

N – subset lacking all extremes (including fluvial)

N + F – subset lacking geogenic extremes

N + F + C – the whole set

In this contribution only summary statistics was used after logarithmic (ln) transformation.

RESULTS AND DISCUSSION

The elementary statistics does not fulfill only its main role of the summary evaluation of the investigated set and subsets from the standpoint of the TEs uptake by testing plants, but it has also importance for:

- the fast evaluation whether the critical TEs contents in plants were surpassed within single subsets or the whole set, at least in maximum values of single elements,
- the fast assessment of conditions under which TEs contents and mobilities in soils affect the exceeding of critical plant loads,
- the statement whether the explored soil set is characteristic enough for the deducing of conclusions which concern the TEs transfer into testing plants from the point of view of the TEs concentration and mobilities range and factors affecting them.

The selected soil set sampled in field conditions is characterized by a wide range of soil properties (pH 3.8–7.4, clay < 1 μm content 4–30%, CEC 7–24 cmol(+).kg^{-1}, C_{ox} content 0.6–4.2%, free iron content Fe_0 0.2–1.6%), which affect the mobilities and transfers of TEs.

Tables 1 to 3 present mean contents, standard deviation and maximum values of TEs in testing plants – radish, triticale and spinach in different soil subsets. In Table 4 data concerning terrain investigations are displayed. They can be compared with reference values of zoo- and phytotoxicity. Tables involve also transfer coefficients (means, maximum values) calculated not only in relation to total contents (TO) in soils, but also to potentially mobilizable (ED) and mobile (MN) species in soils. Three sets are being compared: the whole set (N + F + G), the set lacking geogenic loads (N+ F) and the set lacking geogenic and fluvial loads (N). The comparison of TEs contents in testing crops with reference values testifies the fact, that in the explored set critical standards of both zootoxicity and phytotoxicity were exceeded not only in spinach but also in radish and triticale. For evaluation we used reference values presented by Vollmer (1995). For Be and V reference values are missing. It was stated (Podlešáková et al. 2000) that in the investigated set also total contents of elements in soils exceed the undifferentiated background, maximum permissible and in some cases even the intervention values (geogenic loads).

Tables 1 to 3 present considerable differences in uptake by radish and triticale as compared with spinach for the most mobile TEs Cd > Zn > Co, Mn. For the other elements this difference is not significant. This fact is very important for the assessment of the function of hyperaccumulators.

Transfer quotients (TQ) indicate first of all the element – specific uptakes by crops in the sequence: Cd > Zn > Mn (in oxidation conditions) > Cu > Ni > Co, V > Pb, Cr > As. Transfer factors from soils used in pot experiments and collected in field conditions are much lower than transfer quotients from soils with a simulated pollution, due to differences in TEs mobilities and slow equilibration (Brümmer et al. 1986). The comparison of mean transfer quotients with mean TEs mobilities shows that the TEs mobility cannot be automatically identified with the bioavailability (position of Mn, Co, Cu).

Now we will pay attention to the differences among subsets, which concern uptakes by plants. Not only the mentioned whole set and two subsets were analysed, but also data from geogenic and fluvial extremes.

There are practically no differences between two subsets (N, N + F) of **cadmium** neither in mean contents nor in transfer quotients. Cadmium shows the greatest transfer values in general and especially for accumulators, due to mobile species. The differences in **zinc** contents and transfers reflect more expressive differences among subset only due to acid geogenic loads (increased) and flu-

Table 1. Elementary statistics of trace elements contents in crops and their relations to TEs contents and mobilities in soils; pot experiment (unlimed variants); the whole set (mg.kg^{-1} dry weight); n = 97

Plant		Mn	Cd	Co	Zn	Ni	Be	Pb	Cu	As	Cr	V
	GM	30.2	0.861	0.273	41.1	0.88	0.023	0.397	3.01	0.150	0.612	1.418
Radish	std	83.8	1.076	1.394	40.0	4.72	0.051	3.688	4.60	2.07	1.60	2.01
	max	400	6.36	12.37	299	42.3	0.330	36.7	41.7	13.54	12.90	18.10
	GM	169	0.778	0.150	36.2	0.67	0.006	0.570	8.35	0.322	0.735	1.065
Triticale	std	339	0.831	3.284	16.1	1.25	0.005	0.436	2.73	1.48	0.297	0.564
	max	1 913	3.15	21.0	115	6.05	0.050	2.130	17.40	8.76	1.83	2.72
	GM	206	6.77	0.615	183	1.03	0.010	0.312	7.79	0.092	0.948	1.84
Spinach	std	1 264	11.63	8.00	182	4.23	0.025	0.589	5.56	9.97	1.96	1.40
	max	7 356	48.5	66.3	880	16.1	0.140	21.40	34.20	79.0	10.42	8.05
Radish/TO	GM	0.037	1.300	0.017	0.271	0.030	0.009	0.008	0.088	0.004	0.007	0.017
	max	0.578	10.96	0.256	4.537	1.78	–	1.306	2.76	0.223	0.143	0.306
Radish/ED	GM	0.139	3.171	0.082	1.646	0.200	1.00	0.016	0.401	0.093	1.47	0.154
	max	6.25	61.3	3.57	29.4	5.25	–	2.11	8.83	4.00	19.30	2.54
Radish/MN	GM	3.291	26.6	5.93	68.3	14.18	4.0	3.47	33.2	2.87	55.3	11.26
	max	125	311	156	2 290	505	–	367	497	192	717	181.0
Triticale/TO	GM	0.205	1.174	0.009	0.236	0.021	0.002	0.011	0.241	0.010	0.008	0.012
	max	1.48	12.90	0.182	0.596	0.430	–	0.146	1.12	0.038	0.071	0.042
Triticale/ED	GM	0.770	2.856	0.044	1.46	0.148	0.316	0.022	1.11	0.199	1.72	0.118
	max	27.3	70.5	2.00	36.4	4.09	–	0.282	24.2	1.50	6.20	4.83
Triticale/MN	GM	18.4	22.3	3.14	60.0	10.19	6.0	4.97	92.5	6.15	65.3	8.52
	max	397	450	79.0	1 165	270	–	20.8	765	28.33	135	67.3
Spinach/TO	GM	0.256	10.88	0.035	1.245	0.029	0.004	0.007	0.239	0.004	0.009	0.021
	max	6.59	120	0.615	6.66	0.397	–	0.472	1.029	1.07	0.071	0.090
Spinach/ED	GM	0.829	25.0	0.149	6.99	0.198	0.50	0.013	0.907	0.060	2.09	0.206
	max	23.1	318	5.49	94.4	5.88	–	1.44	6.25	30.86	26.2	2.33
Spinach/MN	GM	29.9	281	18.94	431	21.10	2.0	3.09	75.5	1.89	85.4	15.31
	max	2 650	6 200	300	13 100	147	–	214	578	1 000	763	145
Reference	zoo	250	1.1	6	500	–	?	10	30	4	10	–
value	phyto	–	–	10	250	10	?	–	–	–	–	–

vial loads (decreased values). Zinc transfers into plants, particularly radish and spinach increased, especially in relation to potentially mobilizable species (ED) and decreased in relation to mobile species (MN) in soils with acid geogenic loads, whereas they decreased both in relation to ED and MN. It is due to the lower ED and higher MN values in acid soils with high geogenic loads and higher ED and lower MN values in fluvisols with increased anthropogenic loads. The uptake of **manganese** as an element with high mobility, but lower uptake than Zn decreases both in soils derived from ultramafic rocks and in fluvisols. The small differences are shown also in transfer quotients related to ED and MN. There are no differences between transfers to triticale and spinach, but more distinct differences between radish and the others. **Nickel** has lower contents in testing plants than Mn, but very similar transfer quotients, which do not differ even in case of spinach. The higher contents are found especially in soils from ultramafic parent materials and in fluvisols due to the increased extreme contents in soils derived from ultramafic parent materials or increased mobilities in fluvisols. This is not reflected in transfer quotients, especially in quotients related to ED and MN. On the contrary, the quotients plant/ED decline in fluvisols and in a lesser degree in soils from mafic parent materials, where they even increase in case of spinach. The opposite relations, even the increase in fluvisols are found for relations plant/MN. This is due to the decreased content of mobile species in these soils, accompanied by the increased capability to take up TEs in a potentially mobilizable form, especially by spinach. The uptake of **cobalt** follows Mn with similar features.

From the other elements under study the more pronounced uptake has only **copper**. Slowly increased values of TQ are characteristic for the ratios plant/ED of spinach for acid geogenic loads and distinctly decreased for only slightly acid fluvisols. These relations are more expressive for the ratio plant/MN.

Table 2. Elementary statistics of trace elements contents in crops and their ratio to TEs contents and mobilities in soils (transfer factors); pot experiment (unlimed variants); the set lacking geogenic and fluvial loads (mg.kg^{-1} dry weight); $n = 60$

Plant		Mn	Cd	Co	Zn	Ni	Be	Pb	Cu	As	Cr	V
	GM	40.0	0.868	0.292	37.2	0.73	0.026	0.358	2.70	0.107	0.558	1.379
Radish	std	94.6	1.54	1.66	38.7	2.32	0.043	0.519	2.73	0.372	0.878	2.31
	max	400	6.36	12.37	299	14.6	0.222	3.210	18.90	2.45	7.02	18.10
	GM	243	0.736	0.150	33.0	0.59	0.006	0.586	7.92	0.222	0.710	0.962
Triticale	std	384	0.767	3.28	11.8	0.98	0.004	0.487	2.59	0.216	0.258	0.611
	max	911	2.98	21.0	65.5	4.78	0.027	2.130	17.40	1.18	1.26	2.72
	GM	276	6.04	0.814	163	0.69	0.010	0.288	7.05	0.076	0.656	1.908
Spinach	std	1 536	10.65	10.24	162	1.91	0.027	2.989	3.58	3.51	0.538	1.400
	max	7 356	48.4	66.3	793	12.10	0.140	21.40	19.74	25.00	2.13	8.05
Radish/TO	GM	0.055	1.453	0.017	0.280	0.035	0.009	0.008	0.094	0.004	0.009	0.017
	max	0.578	10.96	0.256	4.537	1.78	–	0.046	1.658	0.062	0.143	0.316
Radish/ED	GM	0.240	3.753	0.082	2.03	0.273	1.28	0.018	0.550	0.096	2.25	0.158
	max	6.25	61.3	3.57	29.4	5.25	–	0.124	8.83	2.91	13.50	2.54
Radish/MN	GM	2.95	26.3	5.93	89.1	12.65	11.5	3.13	40.35	2.50	54.8	11.00
	max	125	311	156	2 290	128	–	19.9	497	125	702	181.0
Triticale/TO	GM	0.329	1.243	0.009	0.247	0.029	0.002	0.014	0.274	0.009	0.012	0.011
	max	1.049	12.91	0.182	0.595	0.43	–	0.146	1.12	0.038	0.071	0.042
Triticale/ED	GM	1.463	3.221	0.044	1.86	0.23	0.353	0.028	1.52	0.197	2.95	0.112
	max	27.3	70.5	2.00	36.4	4.09	–	0.282	54.2	1.50	6.20	4.83
Triticale/MN	GM	17.2	22.4	3.14	79.2	10.21	3.0	5.09	123	5.24	69.8	7.67
	max	398	450	79.0	1 165	239	–	20.8	765	27.0	126	67.3
Spinach/TO	GM	0.392	10.99	0.059	1.29	0.031	–	0.008	0.260	0.004	0.011	0.023
	max	6.59	120	0.614	6.66	0.397	–	0.472	1.03	1.07	0.056	0.090
Spinach/ED	GM	1.40	26.8	0.272	8.20	0.225	–	0.015	1.11	0.067	2.42	0.211
	max	23.2	318	5.49	94.4	5.88	–	1.436	5.10	30.86	10.45	1.94
Spinach/MN	GM	37.9	290	23.6	539	20.84	–	2.83	92.3	1.74	65.6	15.01
	max	1 318	6 200	300	13 100	147	–	214	578	1 000	213	75.0
Reference	zoo	250	1.1	6	500	–	–	10	30	4	10	–
value	phyto	–	–	10	250	10	–	–	–	–	–	–

The other elements are characterized by very low transfer quotients for all investigated plants. This counts for beryllium, lead, chromium and arsenic. **Beryllium** has extraordinary low transfer quotients. Increased transfer quotients plant/MN for **lead** are found for soils derived from acid geogenic anomalies, or spinach from fluvisols with increased content of potentially mobilizable species. Increased transfers of **chromium** occur also only in plants grown on soils with a very high contents of Cr. **Arsenic** is hold in metalliferous zones of some acid rocks. Increased transfer quotients are characteristic for relations plant/ED and plant/MN.

The comparison of the mean values and transfer quotients of fodder plants taken in field conditions (Table 4) with crops growing in pot experiments proves that the plant contents of trace elements are quite similar except mainly of Mn, Pb and Cd and Zn. Higher content of Pb can be caused by immission and of Mn by redox potentials. For the most mobile elements the uptake conditions in pot experiments are more favorable. This is testified by transfer quotients, which are higher in particular in the case of Mn, Cd, Zn, Ni.

We also investigated the influence of liming (Fig. 1) on TEs mobilities. It was found that liming diminished mainly the effective mobility of TEs, which are highly (negatively) pH-dependent like Zn, Mn, Be, Cd, Co, Ni and Pb in the range 83 to 13%. The lowest liming effect on the transfer into radish and triticale shows (Fig. 2) Zn and Cd (18 to 20%) – elements with highest mobilities in soils and transfers into plants. Liming affects the transfer quotients of these elements in a minimum way. Plants are adapted to take up the mentioned elements even from slightly acid soils. Liming reduces the transfer of Co and Mn by 48 to 52%. Then follows Ni (35%) and Pb (10%). The lowest effects of liming on plant uptake have Cu, Cr. What concerns As, the liming caus-

Table 3. Elementary statistics of trace elements contents in crops and their ratio to TEs contents and mobilities in soils (transfer factors); pot experiment (unlimed variants); the set lacking geogenic loads (mg.kg^{-1} dry weight); $n = 81$

Plant		Mn	Cd	Co	Zn	Ni	Be	Pb	Cu	As	Cr	V
	GM	32.9	0.861	0.248	37.6	0.81	0.023	0.370	2.88	0.110	0.568	1.38
Radish	std	89.7	1.076	1.52	35.7	2.48	0.051	3.936	4.87	0.520	0.905	2.18
	max	400	6.36	12.37	299	14.60	0.330	36.7	41.7	3.84	7.02	18.1
	GM	189	0.778	0.158	35.1	0.63	0.006	0.556	8.09	0.243	0.697	1.01
Triticale	std	362	0.831	3.62	16.2	1.13	0.006	0.456	2.69	0.209	0.245	0.595
	max	1 913	3.15	21.0	115	4.78	0.050	2.130	14.40	1.18	1.26	2.72
	GM	222	6.77	0.788	176	0.84	0.011	0.308	7.36	0.075	0.836	2.08
Spinach	std	1 396	11.63	9.03	174	3.87	0.025	2.711	5.14	3.16	1.84	1.40
	max	7 356	48.5	66.3	880	16.1	0.140	21.40	34.20	25.00	10.42	8.05
Radish/TO	GM	0.045	1.300	0.018	0.250	0.034	–	0.008	0.088	0.005	0.008	0.017
	max	0.578	10.96	0.256	4.537	1.78	–	1.306	2.76	0.223	0.143	0.306
Radish/ED	GM	0.168	3.171	0.086	1.494	0.216	–	0.016	0.395	0.087	1.61	0.146
	max	6.25	61.3	3.57	29.4	5.25	–	2.11	8.83	4.00	19.30	2.54
Radish/MN	GM	3.29	26.6	5.30	83.0	14.57	–	3.31	31.9	2.56	52.2	10.61
	max	125	311	156	2 290	505	–	367	497	192	702	181
Triticale/TO	GM	0.260	1.174	0.011	0.230	0.026	0.002	0.012	0.244	0.010	0.010	0.012
	max	1.48	12.90	0.182	0.595	0.43	–	0.146	1.12	0.038	0.071	0.042
Triticale/ED	GM	0.967	2.856	0.055	1.40	0.167	0.352	0.023	1.16	0.190	1.95	0.108
	max	27.3	70.5	2.00	36.4	4.09	–	0.282	24.23	1.50	6.20	4.83
Triticale/MN	GM	17.8	22.3	3.21	77.2	10.87	3.0	4.95	90.3	5.63	63.5	7.75
	max	397	450	79	1 165	239	–	20.8	765	27.50	126	67.3
Spinach/TO	GM	0.322	10.88	0.056	1.21	0.033	–	0.007	0.239	0.004	0.011	0.025
	max	6.59	120	0.615	6.66	0.397	–	0.472	1.03	1.07	0.071	0.090
Spinach/ED	GM	0.980	25.0	0.231	6.35	0.192	–	0.013	0.872	0.058	2.10	0.210
	max	23.2	318	5.49	94.4	5.88	–	1.436	5.10	30.86	17.10	1.94
Spinach/MN	GM	36.0	281	28.04	495	24.19	–	3.04	73.0	1.71	78.01	16.07
	max	1 318	6 200	300	13 100	147	–	214	578	1 000	634	145
Reference	zoo	250	1.1	6	500	–	?	10	30	4	10	–
value	phyto	–	–	10	250	10	?	–	–	–	–	–

es even the increase of plant uptake. The plant uptake of the most mobile trace elements with the highest transfer factors (Cd, Zn) was affected in a lesser degree than the uptake of mobile elements with lower transfer factors (Mn, Co, Ni). This fact is deduced from the comparison of the sequence of transfer factors of the most mobile elements (Cd >> Zn >> Mn, Ni, Co) with the sequence in which crop uptake is affected (Co, Mn, Ni > Cd, Zn) by liming. Liming does not influence the plant uptake of elements with very low transfer factors, like Be, Pb, Cr, As. Liming also does not affect the uptakes of copper, which is an element characterized by higher uptake rates, but a low mobility, which can be even increased by liming.

Table 4. Elementary statistics of trace element contents in fodder plants and their ratio to TEs contents and mobilities in soils (transfer factors); the whole set (mg.kg^{-1} dry weight); $n = 107$

Plant		Mn	Cd	Co	Zn	Ni	Be	Pb	Cu	As	Cr	V
Fodder	GM	74.6	0.097	0.113	34.1	1.756	0.011	1.138	8.13	0.134	1.043	0.748
plants	std	68.6	0.107	0.144	18.3	1.86	0.010	1.606	4.23	0.154	1.089	0.693
	TO	0.099	0.170	0.008	0.294	0.075	0.005	0.019	0.260	0.0048	0.016	0.008
Fodder plant to	ED	0.312	0.413	0.040	1.45	0.59	0.423	0.045	1.12	0.071	3.70	0.331
	MN	7.93	4.62	3.90	25.2	24.7	0.85	8.62	145.1	6.09	130	5.19

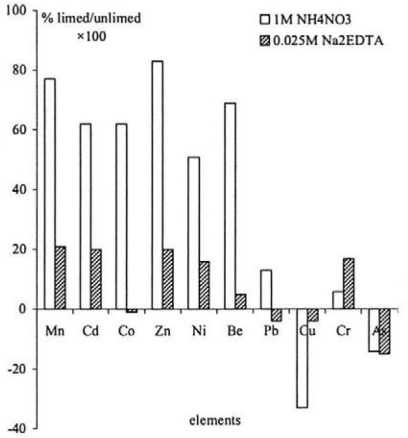

Figure 1. Decreasing of trace elements mobility by liming (%)

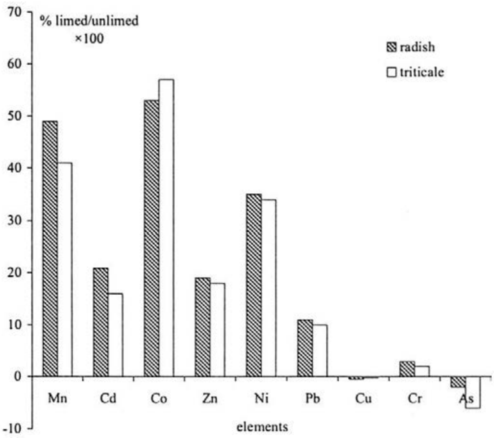

Figure 2. Decreasing of trace element contents in plants after liming (%)

REFERENCES

Brown P.H., Dunemann L., Schulz R., Marschner H. (1989): Influence of redox potential and plant species on the uptake of nickel and cadmium from soils. Z. Pfl.-Ernähr. Bodenkde, *152:* 85–91.

Brümmer G.W., Gerth J., Herms V. (1986): Heavy metal species, mobility and availability in soils. Z. Pfl.-Ernähr. Bodenkde, *149*: 382–398.

Gupta S., Häni H. (1981): Einfluß von leicht extrahierbaren Boden – Cd auf die Reaktion verschiedener Testpflanzen (unter spezieller Berücksichtigung der Wurzelaustauschkapazität) und einige mikrobiologische Parameter. Korresp. Abwass., *4*: 211–213.

Hornburg V., Brümmer G. (1989): Untersuchungen zur Mobilität und Verfügbarkeit von Schwermetallen in Böden. Mitt. Dtsch. Bodenk. Gesell., *59*: 727–731.

Hornburg V., Brümmer G.W. (1990a): Einflußgrößen der Schwermetallmobilität und Verfügbarkeit in Böden. Arb. Univ. Jena, Leipzig, *2*: 415–423.

Hornburg V., Brümmer G.W. (1990b): Schwermetall-Verfügbarkeit in Böden und Gehalte im Weizenkorn und in anderen Pflanzen. Kongr.-bd. VDLUFA, Schr.-R., *32*: 821–826.

Hornburg V., Brümmer G.W. (1991): Schwermetall-Verfügbarkeit und -Transfer in Abhängigkeit von pH und Stoffbestand des Bodens. Mitt. Dtsch. Bodenk. Gesell., *66*: 661–664.

Houba V.J.G., Novozamsky I., Lexmond T.M., Lee van der (1990): Applicability of 0.01M $CaCl_2$ as a single extraction solution for the assessment of the nutrient status of soils and other diagnostic purposes. Commun. Soil Sci. Pl. Anal., *21*: 2281–2290.

Kabata-Pendias A., Zmudzki J., Szteke B., Krakowiak A. (1994): Cadmium and lead in selected food-chain samples in Poland. 3rd Int. Symp. Envir. Geochem., Krakow: 12–15.

Macnicol R.D., Beckett P.H.T. (1985): Critical tissue concentration of potentially toxic elements. Pl. and Soil, *85*: 107–129.

Marr K., Fyles H., Hendershot W. (1999): Trace metals in Montreal urban soils and the leaves of *Taraxacum officinale*. Can. J. Soil Sci., *79*: 385–387.

Moustakas M., Ouzounidou G., Symeonidis L., Karataglis S. (1997): Field study of the effects of excess copper on wheat photosynthesis and productivity. Soil Sci. Pl. Nutr., *43*: 531–539.

Němeček J., Podlešáková E. (2000): Stopové prvky s nízkou mobilitou v půdě. Věd. Práce VÚMOP (11): 65–74.

Němeček J., Podlešáková E., Roth Z. (1999): Possibilities of the prediction of trace elements mobility in soils. Rostl. Výr., *45*: 345–350.

Podlešáková E., Němeček J. (2000): Faktory diferenciace mobility stopových prvků v půdě. Věd. Práce VÚMOP (11): 105–125.

Podlešáková E., Němeček J., Roth Z. (1999): Mobility of trace elements in soils. Rostl. Výr., *45*: 337–344.

Podlešáková E., Němeček J., Vácha R. (2000): Mobility and bioavailability of trace elements in the soils. Trace elements in soil. Ann. Arbor Press Inc. (in print)

Prüeß A. (1992): Vorsorgewerte und Prüfwerte für mobile und mobilisierbare potentiell ökotoxische Spurenelemente in Böden. Verlag Ulrich E., Graner Wendlingen.

Soon Y.K., Bates T.E. (1982): Chemical pools of cadmium, nickel and zinc in polluted soils and some preliminary indications of their availability to plants. J. Soil Sci., *33*: 477–488.

Vollmer M.K. (1995): Herleitung und Anwendung von Prüf- und Sanierungswerten für schwermetallbelastete Böden in der Schweiz. Eidg. Forsch.-Anst. Agrik.-Chem. Umw.-Hyg. (FAC), Schweiz.

Whitten M.C., Ritchie G.S.P. (1991): Calcium chloride extractable cadmium as an estimate of cadmium uptake by subterranean clover. Austral. J. Soil. Res., *29*: 215–221.
Xian X. (1989): Effect of chemical forms of cadmium, zinc and lead in polluted soils on their uptake by cabbage plants. Kluwer Acad. Publ., *113*: 257–264.
Zaman M.S., Zereen F. (1998): Growth responses of radish plants to soil cadmium and lead contamination. Springer-Verlag, *61*: 44–50.

Received on May 25, 2000

ABSTRAKT

Hlavní rysy transferu stopových prvků do rostlin

Publikace je úvodní prací k sérii příspěvků hodnotících zákonitosti transferu stopových prvků do testovacích rostlin v závislosti na obsahu, mobilitě prvků a specifice příjmu každého prvku ředkvičkou, tritikale a špenátem. Skutečnost, že v souboru studovaných vzorků půd bylo dosaženo překročení kritických hodnot zátěže rostlin z hledisek zoo- a fytotoxicity, svědčí o vhodném výběru vzorků. Je podána základní statistika údajů o obsahu rizikových prvků v testovacích rostlinách a transferových kvocientech prvků (Cd > Zn > Mn > Cu, Ni > Co, V > Pb, Cr > As), vztažených nejen k celkovému obsahu prvků, ale i k potenciálně mobilizovatelným a mobilním speciím. Vápnění snižuje transfer nejmobilnějších prvků v obráceném poměru jejich mobilit: Co, Mn, Ni > Cd, Zn. Vápnění nesnižuje příjem Cr, V, Cu, u As dokonce zvyšuje příjem.

Klíčová slova: základní statistika; stopové prvky; transfer do rostlin

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Sulphur concentrations and distribution in three varieties of oilseed rape in relation to sulphur fertilization at a maturity stage

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ABSTRACT

A pot trial was conducted on three varieties of winter rape: line variety Lirajet (L), its genetically modified form Lirajet Roundup Ready (GML) and hybrid variety Pronto (P) to study the effect of graded sulphur application rates on concentrations and distribution of total sulphur, sulphates and glucosinolates in the parts of oilseed rape plants at a maturity stage. Large differences in the concentration and distribution of total sulphur and sulphates were determined between the varieties, particularly between the line variety Lirajet and its genetically modified form. The effect of graded sulphur application rates on the concentration and distribution of total sulphur and sulphates in the plant parts was confirmed. The highest increase in their contents at vegetative stages was observed in pod walls. The concentration of total sulphur and sulphates in pod walls clearly reflects the intensity of S-fertilizing. Sulphates were an important component of the total sulphur content in the vegetative parts of oilseed rape (i.e. in stems and pod walls). The seeds did not appear to contain any sulphates. The trends of glucosinolate contents and distribution were not found to be explicitly related to S-fertilizing. Seeds were the main sink of glucosinolates. Their concentrations in the vegetative parts were minimum. A little higher values of glucosinolate contents were determined in the vegetative parts of the variety Pronto.

Keywords: oilseed rape; variety; S-fertilization; sulphur; sulphate; glucosinolate; concentration; distribution

Oilseed rape has high requirements for sulphur supplies, e.g. McGrath et al. (1996) report the need of 16 kg S for production of 1 ton of rapeseed. Sulphur is a structural element of essential amino acids (methionine, cysteine) that are integral components of full-value proteins. Products of amino acid synthesis can be considered as primary metabolites. Secondary metabolites in oilseed rape are glucosinolates (Zhao et al. 1993a), which are sinks of sulphur mainly in seeds. The anti-quality nature of glucosinolates in the nutrition of humans and farm animals was a reason for breeders' efforts to minimize their contents in products. They brought about important interventions in sulphur metabolizing in oilseed rape.

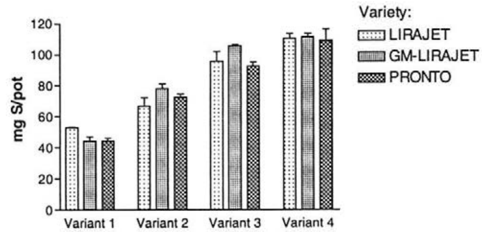
Appropriate sulphur supplies to oilseed rape plants also imply important environmental consequences in the intensive system of crop production. Fertilizer nitrogen utilization is increased while possible environmental contamination with surplus mineral nitrogen is decreased (Haneklaus et al. 1999). Our survey of the nutrient status of soils provided by rape producers shows that the frequency of occurrence of S-deficiency sites ranks after that of magnesium, which is a common deficiency nutrient in the Czech Republic.

The goal of this study was to determine the effect of graded sulphur application rates on the concentrations and distribution of total sulphur, sulphates and glucosinolates in three different types of varieties (line, hybrid and genetically modified ones) at oilseed rape maturity stage. This research is aimed at gradual collection of diagnostic data for optimization of sulphur supplies to oilseed rape plants and of oilseed rape production quality by efficient fertilizing.

MATERIAL AND METHODS

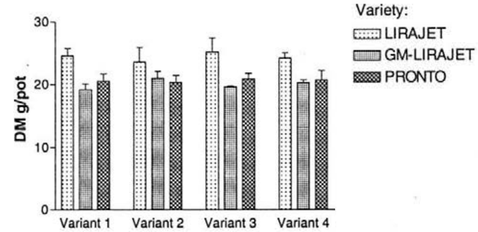
Three varieties were tested in a pot trial: a) line variety Lirajet (L), b) its genetically modified form Lirajet Roundoup Ready (GML) and c) hybrid variety Pronto (P). The pot was filled with 5 kg of Hapludalfs soil from Ruzyně locality. The soil properties were as follows: $pH_{(0.2\,M\,KCl)}$ = 6.7; $C_{(LECO)}$ = 1.215%; $N_{(LECO)}$ = 0.112%; $S_{(total\ LECO)}$ = 112.7 mg S/kg; soil test KVK-UF (Matula and Pirkl 1988; Matula 1996): CEC = 211 mmol(+)/kg, $S_{(ICP)}$ = 20 mg/kg, K = 194 mg/kg; Mg = 72 mg/kg; P = 3 mg/kg; Mn = 3.1 mg/kg. An amount of 0.304 g $Ca(H_2PO_4)_2.H_2O$ was admixed with the whole volume of each pot on the basis of soil test. As the soil had a lower reserve of magnesium, magnesium sulphate was used for fertilizing along with graded sulphur application rates; the sulphate was also admixed with soil before the pots were filled. $MgSO_4.7\,H_2O$ application rates: variant 1 = 0; variant 2 = 0.514 g; variant 3 = 1.028 g; variant 4 = 2.056 g. An amount of 0.8 g N per pot was applied at the vegetative stages in the form of NH_4NO_3 solution at eight split doses between 11/3/99 and 26/5/99. A vegetation experiment started on 10/3/99 by transplanting the pre-cultivated plants to pots. The plants were pre-cultivated in pots containing 440 g of identical soil: sowing 3/9/98; heeling-in in cold frame 2/11/98 – winter rest. Each variant had 14 replications. Four replications were brought to full maturity – to harvest (7/7/99).

Dry mass of homogenized plant parts was mineralized in a microwave device MILESTONE in the medium of nitric acid and hydrogen peroxide. Total sulphur was determined on an apparatus ICP-OES Trace SCAN. An analyzer SAN Plus System – SKALAR was used to determine sulphates after plant dry matter extraction into water (0.5 g + 25 ml H_2O, 1 hour rotary shaking). Statistical programme GraphPad PRISM, CA, USA, version 3.0, and Microsoft Excel 97 were used for experimental data processing.



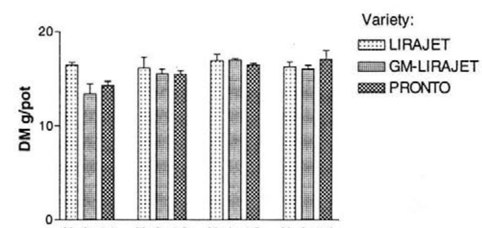
Parameter	Data Set-A	Data Set-B
Two-way ANOVA		
Source of Variation	% of total variation	P value
Interaction	1.98	0.1208
Variety	0.80	0.1242
Variant	90.71	P<0.0001

Figure 1. S-uptake by biomass at harvest



Parameter	Data Set-A	Data Set-B
Two-way ANOVA		
Source of Variation	% of total variation	P value
Interaction	2.86	0.9277
Variety	41.55	P<0.0001
Variant	0.29	0.9789

Figure 2. Vegetative biomass yield



Parameter	Data Set-A	Data Set-B
Two-way ANOVA		
Source of Variation	% of total variation	P value
Interaction	14.33	0.1614
Variety	6.80	0.1094
Variant	26.84	0.0017

Figure 3. Seed yield

RESULTS AND DISCUSSION

Sulphur uptake by oilseed rape aboveground biomass increased with the intensity of S-fertilizing without any significant differences between the varieties (Fig. 1). Significant differences between the varieties were determined in vegetative biomass yields but the S-fertilizing variants were not demonstrated to have any significant effects (Fig. 2). On the contrary, there were no significant varietal differences in seed yield but seed yield increased with the intensity S-fertilizing, particularly in the variety Lirajet and Pronto until the rate 1.02 g $MgSO_4.7\ H_2O$ per pot was applied, which would correspond to 80 kg S/ha after conversion (1 ha of farm land = 3 000 t), (Fig. 3).

Fig. 4 shows the concentrations of total sulphur in biomass of the aboveground plant parts (seeds, pod walls, stems of racemes and stems) as related to S-fertilizing. Sulphur concentrations in seeds were slightly increased by S-fertilizing but the level of S-fertilizing did not play any role. All sulphur was organically bound in seeds. On the other hand, the steepest increase in total sulphur concentration in relation to S-fertilizing was determined in pod walls, and it differed in the particular rape varieties. The highest and the steepest increase in total sulphur concentration in pod walls was observed in the variety GM-Lirajet, followed by Pronto and finally by the original variety Lirajet, in which the increase was relatively lower. Total sulphur concentrations in stems of racemes evidently increased showing similar trends of the varieties like in pod walls, but the increase was not so high. Sulphates accounted for dominant proportions in the total sulphur concentration in these vegetative parts ranging from 50 to 90%, their increase was related to the sulphur application rates.

Fig. 5 shows relative distribution of total sulphur in the weight parts of oilseed rape plants. The highest allocation of total sulphur was in seeds, it logically decreased with increasing S-fertilizing, so the total sulphur proportion in vegetative tissues of oilseed rape reciprocally increased.

Trends of sulphate concentration and distribution in the plant parts in relation to S-fertilizing are illustrated in Figs. 6 and 7. Pod walls were the main sink of sulphates, followed by stems of racemes with substantially lower amounts, and by stems.

Our results document in agreement with the paper by Tyson and Wallsgrove (1999) that seeds are the main sink of sulphur taken up by oilseed rape. As a result of sulphur supplies, unlike nitrogen supplies, unusually high proportions of the mineral form – sulphates are detected in vegetative tissues, especially in pod walls (Zhao et al. 1993b; Fismes et al. 1999). Sulphate proportions in the total sulphur content increased with the intensity of S-fertilizing. Although different contents of total sulphur and sulphates in pod walls of the particular varieties were documented by our results, they can indicate the level of sulphur supply efficiency. Oilseed rape utilization of sulphur appears to be rather inefficient (Tyson and Wallsgrove 1999).

Fig. 8 shows glucosinolate concentrations. The glucosinolate concentration, especially in vegetative biomass, was not found to be explicitly related to S-fertilizing. This finding is in contradiction with the results reported by Wielebski et al. (1999). Seeds were a dominant sink of glucosinolates (Fig. 9). The proportion of glucosinolate sulphur in the total sulphur content in seeds ranged from 20 to 60%; it underlies the importance of this secondary form of sulphur in seeds. Zhao et al. (1999) reported the maximum proportion of sulphur in seed glucosinolates below 50%.

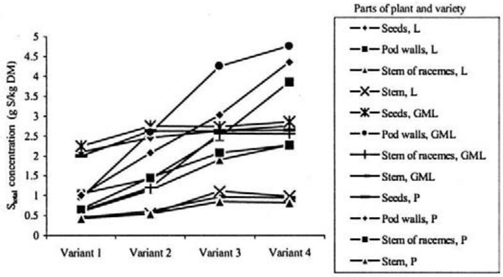


Figure 4. Concentration of total sulphur at maturity

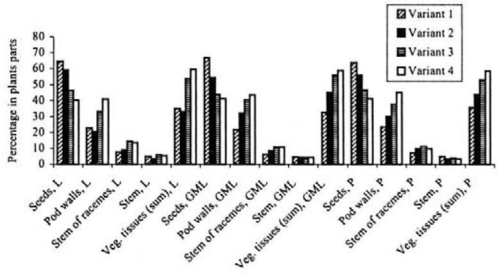


Figure 5. Distribution of total sulphur in the parts of oilseed rape at maturity

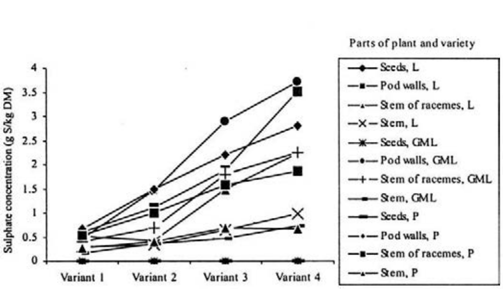


Figure 6. Concentration of sulphate at maturity

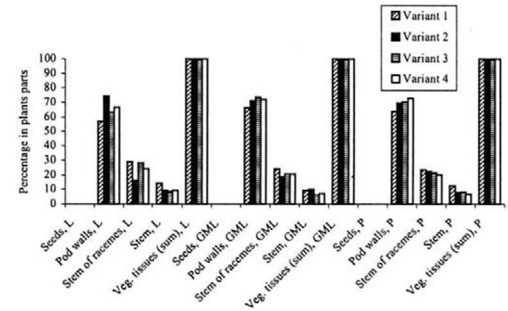


Figure 7. Distribution of sulphate in the parts of oilseed rape at maturity

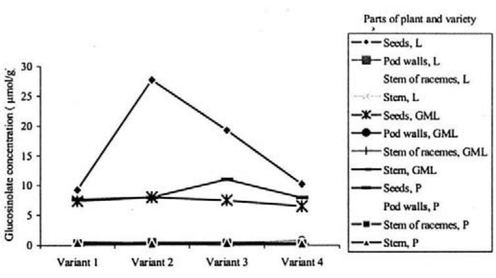


Figure 8. Concentration of glucosinolate at maturity

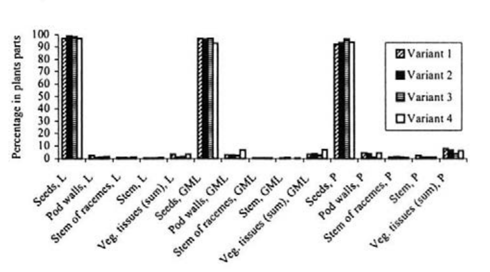


Figure 9. Distribution of glucosinolate in the parts of oilseed rape at maturity

Acknowledgement

This research benefited from financial support of the Grant Agency of CR (521/99/0470) and of project EP0960006472 of the National Agency for Agricultural Research.

REFERENCES

Fismes J., Vong P.C., Guckert A. (1999): Use of labeled sulphur-35 for tracing sulphur transfers in developing pods of field-grown oilseed rape. Commun. Soil Sci. Plant Anal., *30*: 221–234.

Haneklaus S., Paulsen H.M., Gupta A.K., Bloem E., Schnug E. (1999): Influence of sulfur fertilization on yield and quality of oilseed rape and mustard. Proc. 10th Int. Rapeseed Congr. Canberra, Australia.

Matula J. (1996): Determination of potassium, magnesium, phosphorus, manganese and cation exchange capacity for fertilizer recommendations used by Czech Union of Rapeseed Growers. Commun. Soil Sci. Plant Anal., *27*: 1679–1691.

Matula J., Pirkl J. (1988): Vyluhovací roztok pro stanovení draslíku, hořčíku, vápníku, sodíku, manganu a rostlinám dostupného fosforu v půdě a hodnoty kationtové výměnné kapacity. Autorské osvědčení č. 272804. Praha.

McGrath S.P., Zhao F.J., Withers P.J.A. (1966): Development of sulphur deficiency in crops and its treatment. Proc. Fertil. Soc. No. 379. Peterborough, UK.

Tyson R.H., Wallsgrove R.M. (1999): Sulphur allocation in seeds and pods of oilseed rape. Proc. 10th Int. Rapeseed Congr. Canberra, Australia.

Wielebski F., Wojtowicz M., Krzymanski J. (1999): Influence of sulphur fertilization on glucosinolate quality and quantity in seeds of two double low oilseed rape varieties (*Brassica napus* L.). Proc. 10th Int. Rapeseed Congr. Canberra, Australia.

Zhao F.J., Blake-Kalff M.M.A., Riley N., Hawkesford M.J., McGrath S.P. (1999): Proc. 10th Int. Rapeseed Congr. Canberra, Australia.

Zhao F.J., Evans E.J., Bilsborrow P.E., Syers J.K. (1993a): Influence of sulphur and nitrogen on seed yield and quality of low glucosinolate oilseed rape (*Brassica napus* L.). J. Sci. Food Agric., *63*: 29–37.

Zhao F.J., Evans E.J., Bilsborrow P.E., Syers J.K. (1993b): Sulphur uptake and distribution in double and single low varieties of oilseed (*Brassica napus* L.). Plant and Soil, *150*: 69–76.

Received on September 26, 1999

ABSTRAKT

Obsah a distribuce síry v době zralosti tří odrůd ozimé řepky v závislosti na hnojení sírou

U tří odrůd ozimé řepky: liniové odrůdy Lirajet (L), její geneticky modifikované formy Lirajet Roundup Ready (GML) a hybridní odrůdy Pronto (P) byl v nádobovém pokuse sledován vliv stupňovaného hnojení sírou na obsah a distribuci celkové síry, síranů a glukosinolátů v částech řepky v době zralosti. V koncentraci a distribuci celkové síry a síranů byly zjištěny výrazné rozdíly mezi odrůdami, zvláště mezi původní liniovou odrůdou Lirajet a její geneticky modifikovanou formou. Stupňované hnojení sírou ovlivnilo koncentraci a distribuci celkové síry a síranů v částech řepky. Nejvýraznější nárůst jejich obsahu byl prokázán v obalech šešulí. Obsah celkové síry a síranů v obalech šešulí dobře odráží intenzitu hnojení sírou. Sírany představovaly podstatnou složku obsahu celkové síry ve vegetativních částech řepky (tj. v lodyze a obalech šešulí). V semenu sírany nebyly zjištěny. V obsahu a distribuci glukosinolátů nebyly zaznamenány jednoznačné trendy v závislosti na stupňovaném hnojení sírou. Hlavním distribučním místem glukosinolátů bylo semeno. Minimální bylo jejich zastoupení ve vegetativních částech řepky. Odrůda Pronto vykazovala o něco větší hodnoty obsahu glukosinolátů i ve vegetativních částech řepky.

Klíčová slova: ozimá řepka; odrůdy; hnojení sírou; síra; sírany; glukosinoláty; obsah; distribuce

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The effect of the content of water-soluble sulphur in the soil on the utilisation of nitrogen and on the yields and quality of winter rape

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ABSTRACT

In pot experiments conducted in 1997–1999 we studied the effect of increasing doses of N (0.3, 0.6, 0.9 and 1.2 g per pot) under the increasing content of water-soluble S in the soil (13, 20, 30, 40, 50, 60 and 90 $mg.kg^{-1}$ of soil) and constant nutrition with other nutrients on the concentration of N and S in winter rape (variety Lirajet) in the DC 31–39 stage. A content of water-soluble S lower than 20 $mg.kg^{-1}$ decreased the S concentration in plants below 0.6%. An increased content of water-soluble S in the soil increased its concentration to more than 0.7% as early as in the DC 31–39 stage and created favourable conditions for increased N utilisation for yield formation. Lower doses of N fertilisation had a positive effect on seed yields even when the content of water-soluble S in the soil was only 30–40 $mg.kg^{-1}$. The S dose must be adapted to the dose of N which ensures its optimal content in the plant. N nutrition of winter rape accompanied with a suitable S content significantly increased yields, stabilised the oil content, increased the production effect and the index of N efficiency.

Keywords: winter rape; sulphur; nitrogen; utilisation; yields; quality

Sulphur and its deficiency in agricultural crops is becoming a serious problem in European agriculture. This is based on the fact that while the consumption of N-fertilisers is growing considerably, the application of fertilisers containing S is stagnating or even decreasing (Cecotti and Messick 1994). In literature, more than 40 agricultural crops have been indicated that may respond to S deficiency and which show a direct relationship between S-containing fertilisers and yields (Tandon 1991). Byers and Bolton (1979), Dijkshoorn and Wijk (1967), Schnug (1993), Schnug and Haneklaus (1994) and others proved the importance of adequate S nutrition.

Sulphur, together with nitrogen, are elements necessary for protein biosynthesis and for processes determining yields and their quality. A lack of S reduces the utilisation of other biogenic elements (Sepúlveda et al. 1993), but also reduces the utilisation of N, in this way increasing the possibility of it being washed out from the soil.

In Europe, the acute lack of sulphur began to appear in the 1980s, in the Czech Republic after 1990. Due to the reduction of S immission and limited use of S-containing fertilisers the level of S available for plants decreased considerably. The result was a very sensitive response of crops requiring a higher supply of S. Plants also take up S from the atmosphere in the form of SO_2, but the most important source of S are sulphates taken up by the roots (Marschner 1995). Sulphate reduction is more intensive in leaves, where their transformation is stimulated by light (Fankhauser and Brunold 1978). The primary constant products in which S is present in a reduced, at the same time organically bound form are cysteine, methionine and proteins. Specifically both amino acids are precursors of the other S-containing compounds. Substances containing S are important in plant defense systems against biotic and abiotic influences (Marschner 1995).

Crops which require high levels of this nutrient are particularly oil crops, and among them namely winter rape. Winter rape responds to the lack of biogenic elements in lower yields and lower content of oil in the seeds. From the economic, but also ecological, point of view it is necessary to ensure an optimal level of water-soluble S in the soil, and in this way to contribute to the efficient utilisation of nutrients for yield formation (Schnug 1993; Schnug and Haneklaus 1994, etc.).

The objective of the present study was to find the optimal levels of S incorporated into soil containing lower levels of water-soluble S which would result in increased yields of winter rape plants and how these levels would affect N utilisation.

MATERIAL AND METHODS

In 1997–1999 a vegetation pot experiment with medium heavy soil, characterised as alluvial soil with agrochemical parameters given in Table 1, was established. Table 2 gives a survey of the experimental variants.

Increasing doses of nitrogen per pot were applied, N_0 – natural content, N_1 – 0.3 g, N_2 – 0.6 g, N_3 – 0.9 g, N_4 – 1.2 g. During the three-year investigations, various levels of water-soluble S in the soil were tested. Into the experiments we gradually incorporated variants with 20 (S_1), 30 (S_2), 40 (S_3), 50 (S_4), 60 (S_5) and 90 (S_6) mg $S.kg^{-1}$ of soil,

Table 1. Agrochemical soil properties (Mehlich II)

pH/KCl	Available nutrients for mg/kg of soil					
	P	K	Ca	Mg	$S_{water-soluble}$	S_{SO_4}
6.0	58	235	3 705	311	13.9	11.0

using soil with a natural content of water-soluble S (13.9 $mg.kg^{-1}$ of soil) which also served as a control (S_0).

The vegetation pots were filled with 5.5 kg of soil and sand in a 1:1 ratio. Nitrogen was applied in DAM 390, sulphur in ammonium sulphate or SK-sol (21.5% K, 30% S), potassium in CK-sol, K_2SO_4 and KH_2PO_4. In all the variants we added 0.4 g P and 1.4 g K per pot. Each variant was repeated five times.

Winter rape plants, variety Lirajet, were transplanted from the field into the vegetation pots: 1997 – 24 March, 1998 – 20 March, 1999 – 15 March. The transplanting was conducted very carefully to avoid any damage of the root system. Healthy plants in the same stage of growth and development were selected. We managed to eliminate the stress of transplanting and after three weeks the number of plants was singled to four. The experiment was conducted in a vegetation hall and treatment consisted of regular watering with distilled water to 60% of the maximal water capacity and protection against blossom beetles, ceutorrhynchid beetles and aphids (Nurelle D, Karate 2.5 EC). Prior to harvest the stand was treated with Spodnam DC.

The number of variants in the experiment was gradually extended to the value of the optimal content of water-soluble S in the soil (giving maximal seed yields under the selected N dose).

During vegetation, chemical analyses of the plants in the stage of elongation growth were performed (DC 31–39). Kjeldahl's method was used to determine the N content and S was determined after burning the plant mass in HNO_3 and H_2O_2 on ICP. The oil content was determined at the Research Institute for Oil Plants in Opava using the method of magnetic resonance. Yields were estimated using statistical methods and the significance of differences was expressed by determination of the minimal significant difference.

RESULTS AND DISCUSSION

Winter rape is a crop which has high demands for all nutrients (Fábry et al. 1992). Due to its intensive growth in early spring, rape requires immediately available nutrients. The optimal level of N influences the proportion of N with regard to the other nutrients and effects the yield-forming elements. According to Schnug (1993), particularly S has a favourable effect on yields, and a positive effect on the oil content.

If the level of water-soluble S in the soil is low, hidden deficiency occurs, in the period of intensive growth frequently showing marked symptoms on the youngest leaves of the winter rape. It gradually affects the flowers and inhibits the growth of branches. Schnug and Haneklaus (1994) reported that if the S content in leaves in the upper third of the plant decreased below 0.6%, the yields were by 11–12% lower.

Figs. 1–3 show the concentrations of N and S in the growth stage DC 31–39. The results give evidence that in 1997 the average content of S (S_0) in whole plants of the variant with low levels of S was 0.56%, while it was only 0.7% in the variants with S (S_4). In 1998 the S content in the control variant was 0.50% and with increasing doses of S in the soil it increased from 0.63% to as much as 0.71%. In 1999 the situation was similar, where the differences in the S concentration in plants were even greater in dependence on the S content in the soil (Fig. 3).

Tables 3–5 show the seed yields of winter rape in the respective years giving the minimal significance of differences. In 1997 the effect of N doses on seed yields was statistically significant. The yields of variant N_2S_0 (0.6 N per pot) increased from 38.3 g to 47.3 g, i.e. a 23.5% growth. The following increase in N doses (N_3S_0 and N_4S_0) had no significant effect on yields.

Table 2. Survey of the variants in 1997–1999

S level (mg/kg)	N_0PK			N_1PK (0.3 g)			N_2PK (0.6 g)			N_3PK (0.9 g)			N_4PK (1.2 g)		
	1997	1998	1999	1997	1998	1999	1997	1998	1999	1997	1998	1999	1997	1998	1999
S_0 (13.9)	×	×			×	×	×	×	×	×	×	×	×		×
S_1 (20)						×			×			×			×
S_2 (30)		×			×	×		×	×		×	×			×
S_3 (40)						×			×			×			×
S_4 (50)	×					×	×		×	×		×	×		×
S_5 (60)		×			×	×		×	×		×	×			×
S_6 (90)		×			×			×			×				

× – variant included in the experiment in the respective year

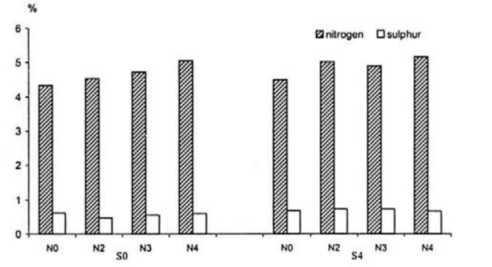

Figure 1. Average results of chemical analyses of plants (DC 31–39) in 1997

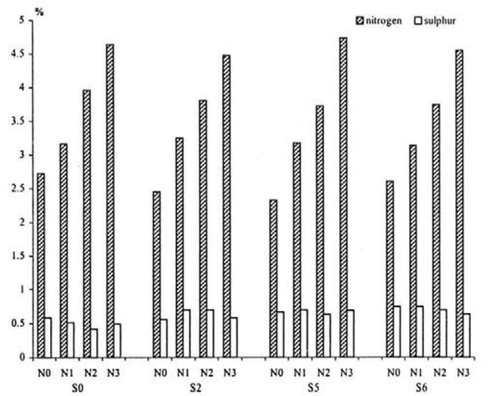

Figure 2. Average results of chemical analyses of plants (DC 31–39) in 1998

Adjusting the level of S in the soil to 40 mg.kg^{-1} significantly increased seed yields in variant 5 (N_0S_4) to 44.4 g per pot, i.e. a yield increment of 15.9%. In the other variants, where various levels of N nutrition were applied, the yields did increase but this increase was below the level of significance. The application of S to the soil increased the oil content in seeds. While the average oil content in variants 1–4, i.e. with a natural S content in the soil, was 39.97%, in variants with increased S content it was 41.45%.

With regard to the fact that 40 mg.kg^{-1} of S in the soil under higher doses of N had no effect on the nutrition of winter rape, in 1998 the experiment was extended by three more variants where the level of water-soluble S was adjusted to 30, 60 and 90 mg.kg^{-1} of soil.

The results again proved that the effect of N on seed yields was statistically significant. Increasing the S content in the soil to 30 mg.kg^{-1} (S_2) resulted in an average yield increase of 6.1%. The yields increased significantly in variant 11 (N_2S_5) compared with variant 3 (N_2S_0). In this case the seed increment was 27.9%. As a whole, in variants with 60 mg.kg^{-1} of S in the soil (S_5) under various intensities of N nutrition it was 9.9%. Also in variants 13–16, where the level of S in the soil was the highest (90 mg.kg^{-1}), it was stabilised on this level. The seed yields were found to increase in all variants where the level of S was higher than natural. With increasing levels of N the technological quality of the seed became worse. This tendency was very clear in variants with a natural level of S, where the oil content decreased from 46.1% to 43.8%. The effect of S fertilisation was positive in variants with the highest content of N (variants 8, 12, 16) under higher levels of S in the soil. Here the oil content decreased with S doses and stabilised on values above 44%.

Extending the number of variants in 1999 helped to determine the optimal content of water-soluble S in the soil. The content of S in the soil grew from the natural content to 90 mg.kg^{-1}. The results presented in Table 5 and Fig. 3 confirmed the significant effect of N doses on seed yields which increased in proportion with the increase in N doses from 100 to 223%. Also S had a statistically significant effect on seed yields, and favourably increased the weight of seeds per pot to the level of S_2 and S_3. Therefore, the results proved that the optimal content of S in the soil ranged between 30 and 40 mg.kg^{-1} of soil. Increasing the level of S in the soil from a natural level to 20 mg water-soluble S increased yields by 29%; 30 mg.kg^{-1} of S increased yields by 48.7% and 40 mg.kg^{-1} of S in the soil increased yields by as much as 52.7%. Higher levels of water-soluble S had no effect on seed yields (S_4) or even caused a significant reduction. These results prove the positive effect of S, in dependence on N doses, on seed yields.

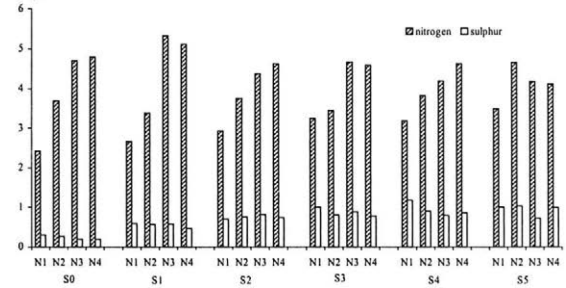

Figure 3. Average results of chemical analyses of plants (DC 31–39) in 1999

Table 3. Average yield results in 1997

No.	Variant	Seed yields		Oil content		Oil production	
		g/pot	rel. %	%	rel. %	g/pot	rel. %
1	N_0PK+S_0	38.3	100.0	39.3	100.0	15.05	100.0
2	N_2PK+S_0	47.3	100.0	39.7	100.0	18.78	100.0
3	N_3PK+S_0	49.3	100.0	41.1	100.0	20.26	100.0
4	N_4PK+S_0	51.9	100.0	39.8	100.0	20.65	100.0
5	N_0PK+S_4	44.4	115.9	42.8	108.9	19.00	126.2
6	N_2PK+S_4	49.0	103.6	42.6	107.3	20.87	111.1
7	N_3PK+S_4	49.6	100.6	40.7	99.0	20.18	99.6
8	N_4PK+S_4	52.1	100.4	39.7	99.7	20.68	100.1
	$DT_{0.05}$	4.6					
	$DT_{0.01}$	6.3					

The relationships between the respective nutrients which exist in the nutrient environment of the plants, their uptake by plants and the yields can be evaluated by means of the productive effect of the nutrient (VRE) (Baier 1970). The proportion of the yield of the main economic products determines this value, i.e. seeds per unit of total nutrients depleted by the harvest. In the framework of the experiments, under unbalanced nutrition, the VRE value for N decreased (Fig. 4). This effect was the most marked in variant 4 (1999), i.e. only 15.4; with increasing doses of N it decreased. In our case it was proved that this low value was strongly affected by S deficiency both in the soil and plant. With increasing S levels the VRE value became balanced and remained on a value around 30.

Table 4. Average yield results in 1998

No.	Variant	Seed yields		Oil content		Oil production	
		g/pot	rel. %	%	rel. %	g/pot	rel. %
1	N_0PK+S_0	5.32	100.0	46.1	100.0	2.45	100.0
2	N_1PK+S_0	11.10	100.0	45.3	100.0	5.03	100.0
3	N_2PK+S_0	14.65	100.0	44.7	100.0	6.55	100.0
4	N_3PK+S_0	20.70	100.0	43.8	100.0	9.07	100.0
5	N_0PK+S_2	6.87	129.1	46.5	100.9	3.19	130.2
6	N_1PK+S_2	10.90	98.2	45.3	100.0	4.94	98.2
7	N_2PK+S_2	16.10	109.9	45.9	102.7	7.39	112.8
8	N_3PK+S_2	21.07	101.8	44.9	102.5	9.46	104.3
9	N_0PK+S_5	7.65	143.8	45.7	99.1	3.50	142.9
10	N_1PK+S_5	9.17	82.6	43.8	96.7	4.02	79.9
11	N_2PK+S_5	18.75	127.9	44.9	100.4	8.42	128.5
12	N_3PK+S_5	21.33	103.0	44.4	101.4	9.47	104.4
13	N_0PK+S_6	6.33	118.9	42.6	92.4	2.70	110.2
14	N_1PK+S_6	13.21	119.0	45.9	101.3	6.06	120.5
15	N_2PK+S_6	18.26	124.6	46.3	103.6	8.45	129.0
16	N_3PK+S_6	19.17	92.6	44.2	100.9	8.47	93.4
	$DT_{0.05}$	4.0					
	$DT_{0.01}$	5.4					

Another criterion of the effect of the depleted nutrients for efficient yields is the index of nutrient utilisation (IU). According to Matula (1977) the IU indicates the situation when a deficit, effective, luxury or toxical concentration of the nutrient may occur. Lower doses of S did not considerably affect the IU value which decreased with increasing doses of N. The interaction between N and S was favourable when the S level in the soil was natural with a N_2 dose, we consider a higher intensity of N fertilisation as deficit in terms of S requirements, and luxury to toxical in N uptake. In dependence on the N dose the IU increased with increased levels of S to S_2–S_5, but the effect was the highest in variant S_3 under the highest dose of N_4 (variant 16). High values were obtained also in variants S_2N_4 (variant 12), S_4N_4 (variant 20) and S_3N_3 (variant 15) (Fig. 5). It was therefore proved that increasing doses of S favourably affected the uptake and utilisation of N.

The present study was supported by the NAZV, under number 7EP 7024, and research project of the Faculty of Agronomy of Mendel University of Agriculture and Forestry of the Czech Ministry of Education, Youth and Physical Training – CEZ 2.308/98:432100001.

Table 5. Average yield results in 1999

No.	Variant	Seed yields		Oil content		Oil production	
		g/pot	rel. %	%	rel. %	g/pot	rel. %
1	N_1PK+S_0	11.56	100.0	45.8	100.0	5.29	100.0
2	N_2PK+S_0	17.72	100.0	46.5	100.0	8.24	100.0
3	N_3PK+S_0	16.56	100.0	40.8	100.0	6.76	100.0
4	N_4PK+S_0	11.16	100.0	37.0	100.0	4.13	100.0
5	N_1PK+S_1	10.96	94.8	45.6	99.6	5.00	94.5
6	N_2PK+S_1	17.52	98.9	46.4	99.8	8.13	98.7
7	N_3PK+S_1	22.80	137.7	44.3	108.6	10.10	149.4
8	N_4PK+S_1	22.72	203.6	40.3	108.9	9.16	221.8
9	N_1PK+S_2	11.40	98.6	45.8	100.0	5.22	98.7
10	N_2PK+S_2	18.92	106.8	46.8	100.6	8.85	107.4
11	N_3PK+S_2	23.84	144.0	46.5	114.0	11.09	164.1
12	N_4PK+S_2	30.68	274.9	44.9	121.3	13.78	333.7
13	N_1PK+S_3	10.56	91.4	46.2	100.9	4.88	92.3
14	N_2PK+S_3	19.24	108.6	47.2	101.5	9.08	110.2
15	N_3PK+S_3	27.40	165.5	46.6	114.2	12.77	188.9
16	N_4PK+S_3	29.88	267.7	45.7	123.5	13.66	330.8
17	N_1PK+S_4	12.80	110.7	46.6	101.7	5.96	112.7
18	N_2PK+S_4	20.44	115.4	47.4	101.9	9.69	117.6
19	N_3PK+S_4	24.64	148.8	46.9	115.0	11.56	171.0
20	N_4PK+S_4	30.04	269.2	46.3	125.1	13.91	336.8
21	N_1PK+S_5	11.08	95.9	46.2	100.9	5.12	96.8
22	N_2PK+S_5	18.00	101.6	47.1	101.3	8.48	102.9
23	N_3PK+S_5	20.12	121.5	46.9	115.0	9.44	139.6
24	N_4PK+S_5	28.20	252.7	46.8	126.5	13.20	319.6
	$DT_{0.05}$	3.8					
	$DT_{0.01}$	5.1					

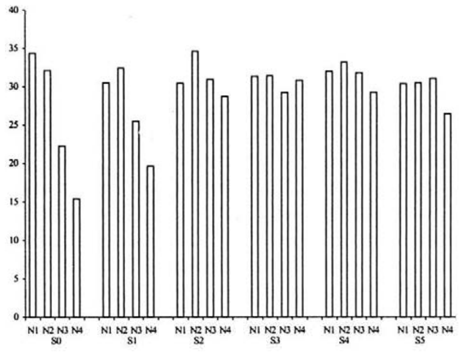

Figure 4. Evaluation of the production effect in 1999 (VRE)

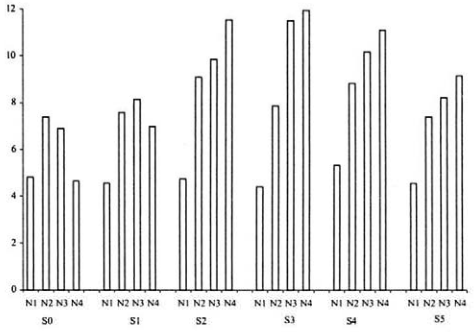

Figure 5. Evaluation of the utilisation index in 1999 (IU)

REFERENCES

Baier J. (1979): Soustava hnojení polních plodin. Praha, SZN.

Byers M., Bolton J. (1979): Effects of nitrogen and sulphur fertilizers on the yield, N and S content and amino acid composition of the grain of spring wheat. J. Sci. Food Agric., *30*: 251–263.

Cecotti S., Messick L. (1994): Overview of the global sulphur problems. Norw. J. Agric. Sci., 7–25.

Dijkshorn N., Wijk A.L. (1967): The sulphur requirements of plants as evidenced by the sulphur-nitrogen ration in the organic matter. Plant and Soil, *26*: 129–157.

Fankhauser H., Brunold C. (1979): Localization of O-acetyl-L-serine sulfhydrolase in *Spinacia oleracea* L. Plant Sci. Lett., *14*: 185–192.

Fábry A. a kol. (1992): Olejniny. Praha, MZVž ČR.

Marschner H. (1995): Mineral nutrition of higher plants. London, Acad. Press.

Matula J. (1977) Výživa rostlin. Praha, MZVž.

Sepúlveda I., Réfega A., Sequeira E. (1993): Sulphur deficiency in verisols: N/S and P/S interaction effects on the yield and sulphur content of annual ryegrass. Sulphur Agric., *17*: 18–23.

Schnug E. (1993): Ökosystemare Auswirkungen des Einsatzes von Nährstoffen in der Landwirtschaft. Angew. Wiss., *426*: 25–48.

Schnug E., Haneklaus S. (1994): Sulphur deficiency in *Brassica napus*. Landb.-Forsch. Völkenrode FAL, *144*: 31.

Tandon H.L.S. (1991): Sulphur research and agricultural production in India. 3rd ed. TSI. Washington DC.

Received on May 25, 2000

ABSTRAKT

Vliv obsahu vodorozpustné síry v půdě na využití dusíku a na výnos a kvalitu ozimé řepky

Ve vegetačních nádobových pokusech, realizovaných v letech 1997 až 1999, byl při rostoucím obsahu vodorozpustné síry v půdě (13, 20, 30, 40, 50, 60 a 90 mg.kg^{-1} zeminy) a konstantní hladině ostatních živin sledován vliv stupňovaných dávek dusíku (0,3; 0,6; 0,9 a 1,2 g na nádobu) na koncentraci N a S v rostlinách ozimé řepky (odrůda Lirajet) ve fázi DC 31–39. Obsah vodorozpustné S v půdě pod 20 mg.kg^{-1} snižoval koncentraci S v rostlinách pod hodnotu 0,6 %. Zvýšený obsah vodorozpustné S v půdě vedl k nárůstu její koncentrace nad hodnotu 0,7 % již v DC 31–39 a vytvářel příznivé podmínky pro lepší využití N na tvorbu výnosu. Při nižší úrovni N hnojení působil na výnos semene pozitivně již obsah vodorozpustné S v rozmezí 30 až 40 mg.kg^{-1} zeminy. Dávce N je třeba přizpůsobit také dávku S, která zajistí její optimální obsah v rostlině. Výživa ozimé řepky dusíkem při vhodném obsahu síry zvyšovala průkazně výnos, stabilizovala obsah tuku, zvyšovala hodnotu výrobního efektu a indexu účinnosti dusíku.

Klíčová slova: ozimá řepka; síra; dusík; utilizace; výnos; kvalita

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The effect of physical soil properties on metabolism and technological quality of sugar beet

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ABSTRACT

In the four trial years 1996–1999 the basic physical parameters of beet growing soils in the region of the Dobrovice sugar plant were measured, in particular the degree and depth of soil compaction by penetrometer and physical soil properties by undisturbed soil sampling. Chlorophyll content measured by chlorophyllmeter, pH value of beet juice in leaves and roots, numbers of leaves, weight of roots and leaves, sugar content, concentration of alpha-amino N, potassium and sodium were determined in parallel trial. It was repeatedly found in all the years that penetrometric soil resistance in headlands was higher by 60–90% than in the inner parts of lands. It gradually increased from the beginning of vegetation until harvest. Until the formation of the 6th pair of true leaves penetrometric soil resistance in rut-rows was significantly higher than in the rows and inter-rows of sugar beet stand. The dynamics of soil porosity in the course of vegetation was in logical correspondence with changes in bulk density of soil. Chlorophyll content and root weight showed the relatively closest negative correlation with penetrometric soil resistance in the whole set of measured data (–0.61 and –0.58, respectively). Sodium and potassium contents were less affected by soil compaction. The data proved higher penetrometric resistance in the ruts of harvesters after harvest and removal of sugar beet from the field. The minimum relative increase in comparison with the value of penetrometric resistance before harvest was 20%.

Keywords: soil; physical properties; soil compaction; penetrometric resistance; bulk density; porosity; sugar beet; metabolism and technological quality of sugar beet; chlorophyll content

A significant and still current problem of the Czech agriculture is the unsatisfactory condition of soil. In particular, high compaction, increased bulk density, deteriorated soil structure, low porosity, air deficit limiting the conditions of yield potential and production quality (Dexter 1986; Šařec et al. 1998; Zahradníček et al. 1998, etc.). Most of these physical properties condition quality and fertility, biological and chemical properties of soil (Krejčí et al. 1984; Lhotský et al. 1984; Zahradníček et al. 1996).

The main cause of deterioration of quality of soils in the Czech Republic is compaction (Šařec et al. 1998; Zahradníček et al. 1998) which is in most cases due to heavy mechanisation, high specific pressures on soil, high number of field passages, excessive number of working operations as well as bad plant nutrition. Soil compaction and limited production and environmental functions are caused by pressures exceeding present bearing capacity of soil. The limit value of contact pressure is 50–150 kPa with higher values causing deformation or even destruction of soil profile with negative impact on the above-mentioned physical soil parameters (Blaszkiewicz 1995). According to the above-mentioned authors the maximum pressure stress occurs in sub-soil with top-soil predominantly suffering from wheel slipping.

Sugar beet is a plant with very sensitive reaction to soil and climatic growing conditions (Čatský et al. 1996; Zahradníček et al. 1996; Švachula et al. 1997; Bajči et al. 1998; Pačuta et al. 1999). The issue of soil compaction by sugar beet harvesters was surveyed by Šařec et al. (1997, 1998). According to them repeated passages of tractors and harvesters across the field have a strong impact on soil density to the depth of 52 cm and not strong one to the depth 60–70 cm.

The objective of this paper is to examine this significant issue, potential moderation of the harmful effect of soil compaction on sugar beet with the intention to contribute to the examination of causes, consequences as well as measures to increase soil fertility and to improve technological quality of sugar beet.

MATERIAL AND METHODS

In the years 1996–1999 the pedological relations in select plots in seven sugar beet growing plants in the region of the Dobrovice sugar plant were assessed (Table 1) and the dynamics of development of physical soil properties and sugar beet yield formation were evaluated. The

Table 1. Pedological characteristics of surveyed locations

Location/plot	ASEU	Soil class top-soil	Soil class sub-soil	Soil type (FAO)
Ml. Boleslav/Čejetice Přední	3.10.00	sl	l	Orthic Luvisol
Ml. Boleslav/Spikaly U Agra	3.09.00	sl	l	Luvic Chernozem
Ml. Boleslav/Spikaly Ke Kováni	3.09.00	sl	l	Luvic Chernozem
Ml. Boleslav/Skalsko Klouček	3.10.00	sl	l	Orthic Luvisol
Ml. Boleslav/Skalsko U remízku vpravo	3.09.00	sl	l	Luvic Chernozem
Ml. Boleslav/Skalsko U remízku vlevo	3.09.00	sl	l	Luvic Chernozem
Ml. Boleslav/Katusice beet deposit	3.10.00	sl	l	Orthic Luvisol
Ml. Boleslav/Trnová beet deposit	3.09.00	sl	l	Luvic Chernozem
Ml. Boleslav/Spikaly beet deposit	3.09.00	sl	l	Luvic Chernozem
Prague-East/H. Počernice Za dvorem	2.02.00	l	l	Luvi Haplic Chernozem
Prague-East/H. Počernice Vodojem vlevo	2.02.00	l	l	Luvi Haplic Chernozem
Prague-East/H. Počernice U vojáků	2.26.01	sl	l	Cambisol
Prague-East/Rostoklaty Zahrady	2.10.00	l	l	Orthic Luvisol
Prague-East/Rostoklaty Pod vsí	2.01.00	l	l	Chernozem
Prague-East/Šestajovice Pětičtvrtí	2.01.00	l	l	Chernozem

experimental survey was concentrated in the Mladá Boleslav area – the Čejetice, Spikaly, Katusice and Skalsko locations and in the Prague-East area – the H. Počernice, Rostoklaty, Šestajovice and Jirny locations. Each year two plots sown with sugar beet and two plots sown with cereal crops were set aside and surveyed in each of the above mentioned locations.

Besides penetrometric soil resistance as the main indicator of compaction soil properties were also measured by sampling by means of Kopecký wheels and determination of Or – dry bulk density, $V_{obj.}$ – volume moisture, ζ – specific weight, $V_{hm.}$ – specific moisture, P – porosity (total), NS – water absorption capacity, Vz_{min} – minimum air content, MKK – maximum capillary capacity, Vz_{mom} – actual air content and RVK – water storage capacity. The measurement of penetrometric resistance and other physical properties included row, inter-row and headland and was also made after harvest and in the place of deposit of roots after their removal to sugar plant.

Together with the survey of these physical soil properties on trial sites chlorophyll content measured by chlorophyllmeter, pH value of beet juice in leaves and roots, numbers of leaves, weight of roots and leaves, sugar content, concentration of alpha-amino N, potassium and natrium were determined in parallel trial.

After sugar beet harvest correlations between the values of penetrometric soil resistance and measured yield and quality parameters were assessed.

The climatic and growing conditions in the trial years were different. The weather conditions in the years 1996 and 1997 were closed to the long-time normal conditions while those in the following years 1998 and 1999 were strongly contrasting. The weather conditions in the year 1998 were unfavourable for sugar beet growing and sugar production in the CR. Characteristic of the year was cool and wet spring with late beginning of spring works and sugar beet sowing. In the course of sugar beet vegetation there was a strong water deficit in the months of June and July with a sensible deficit particularly occurring in the period of maximum growth of sugar beet. On the contrary, the year 1999 was very favourable for growth, development and formation of technological quality of sugar beet. The quantity and distribution of precipitation in the course of vegetation, low weed infestation rate and very low occurrence of diseases and pests were favourable. The measured key parameters of technological quality of sugar beet (sugar content, refined sugar yield, content of technologically harmless non-sugars) were among the best ones in the whole 54 years of the post-war era.

RESULTS AND DISCUSSION

As penetrometric soil resistance is an objective parameter of the degree and depth of compaction its values were measured in the whole course of vegetation of sugar beet and cereal crops. In case of sugar beet also after harvest, removal of roots from the field and after storage of roots in deposits. The four-year results document that soil compaction gradually increases with the depth of top-soil and reaches the maximum value in the sub-soil of soil horizon. Accordingly, the degree of soil compaction increases in the course of sugar beet vegetation. These conclusions about compaction of beet growing soils deepen the earlier data (Zahradníček et al. 1998) as well as the data of Šařec et al. (1998). Soil humidity and water content decreases in parallel to the increase in penetrometric soil resistance in the course of sugar beet vegetation.

Penetrometric soil resistance measured in all locations and sites (headland, row, inter-row, rut-row) in the course of sugar beet vegetation in all the trial years 1996–1999 increased with the maximum reached at harvest. Its values were relatively by 40 to 70% and in some cases even by > 90% higher at harvest than at the beginning of vegetation (the stage of the 1st to 2nd pair of true leaves). The most evident differences in the values of penetrometric soil resistance were found in the inter-row and headland space of sugar beet plot (Figs. 1 and 2). The effect of passages and turns of machines in the course of vegetation and the negative effect of harvest are stronger in headland. Penetrometric soil resistance increased in the order: inter-row, row, rut-row, headland. The measurement of weight of roots, sugar content, chlorophyll content in leaves and number of leaves showed another order. The worst quality parameters of sugar beet were found in the headland of plots, the best in rows. Sugar content in absolute figures decreased in relation to the year and plot by 0.5– 4%, weight of roots decreased in more compact headland by 10–30%. The differences in the measured values of the other sugar beet quality parameters were less evident although they bring the same evidence that the worst values of physiological and technological parameters of sugar beet quality are in headland and the best ones in places of low penetrometric resistance. The measured values of chlorophyll content were also lower in more compact soils. Table 2 with the values and order of correlation coefficients shows the relation between penetrometric soil resistance and physiological and technological parameters of sugar beet removed from field. The relatively closest negative dependence on penetro-

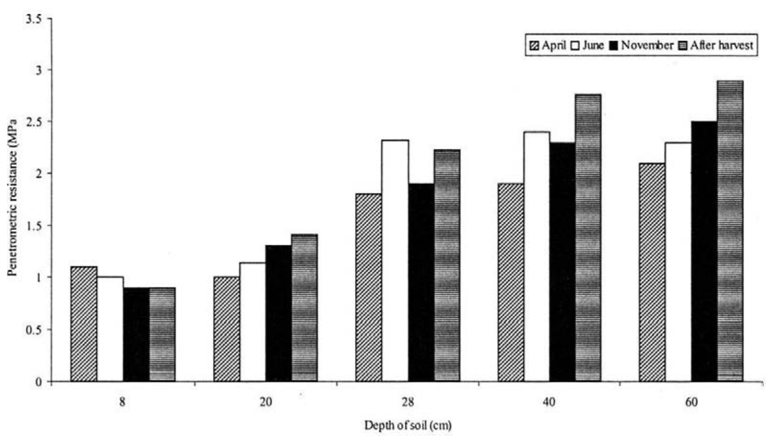

Figure 1. Changes in soil compaction in the course of vegetation and after harvest of sugar beet (average values of the years 1996–1999 and locations)

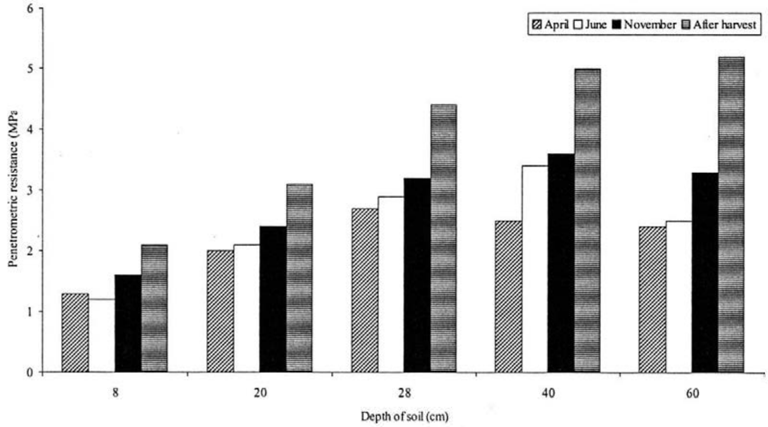

Figure 2. Changes in soil compaction in headland in the course of vegetation and after harvest of sugar beet (average values of the years 1996–1999 and locations)

Table 2. Dependence of physiological and technological parameters of sugar beet on penetrometric soil resistance

Parameter	Correlation coefficient
Units of chlorophyllmeter	−0.610
Weight of roots (g)	−0.581
Temperature of leaves (°C)	−0.460
pH of leaves	−0.360
Number of leaves	−0.271
Temperature of roots (°C)	−0.226
pH of roots	−0.096
Content of alpha-amino N (mmol/100 g)	−0.095
Sugar content (%)	−0.070
Content of K (mmol/100 g)	0.030
Content of Na (mmol/100 g)	0.041

Table 3. Dependence of physical soil properties on penetrometric soil resistance

Parameter	Correlation coefficient
Volume moisture (% weight)	0.524
Specific weight (g/cm³)	0.485
Dry bulk density (g/cm³)	0.391
Water storage capacity (% vol.)	0.368
Specific moisture (% weight)	0.206
Maximum capillary capacity (% vol.)	0.118
Water absorption capacity (% weight)	−0.295
Total porosity (% vol.)	−0.300
Minimum air content (% vol.)	−0.346
Actual air content (% vol.)	−0.418

metric soil resistance in the whole set of measured data is found in chlorophyll content (–0.61) and weight of roots (–0.58), which is documented in graphic form in Figs. 3 and 4. The effect of soil compaction on the contents of sodium and potassium was very small.

The data presented by Šařec et al. (1998) is closest to the assessed data; however, the former is without link to quantity and quality parameters of harvested sugar beet. Šařec et al. (1997, 1998) states that repeated passages of tractors and harvesters across field with soil compaction in the interval of 250–500 kPa/cm² has a strong impact on soil compaction in the depth of 52 cm and not a strong impact in the depth of 60–70 cm. The measured data shows that soil compaction due to a little number of passages in the same rut affects soil to the depth of 30 cm while a higher number of passages affects soil in the depth of 20–70 cm. It is evident from the measured data that in case of sugar beet harvested with multi-row harvesters (Holmer HK, Matrot M31 and Moreau MG-4) the maximum soil resistance occurs in headland, namely 5.8 MPa for the Moreau MG-4 harvester and the least value for Matrot M31. The minimum soil compaction occurs in rows of harvested sugar beet.

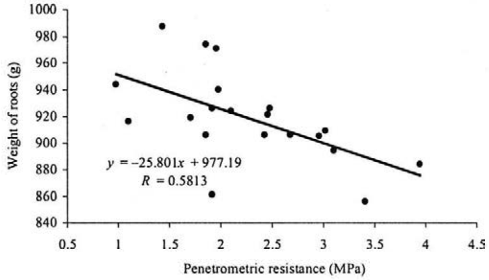

Figure 3. Correlation between penetrometric soil resistance and weight of sugar beet roots

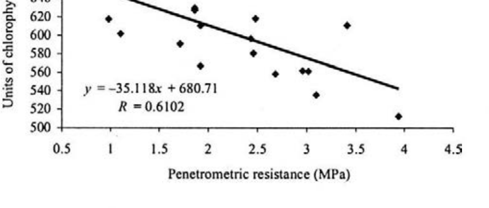

Figure 4. Correlation between penetrometric soil resistance and chlorophyll content

Table 3 shows the relation between the assessed physical soil properties and penetrometric soil resistance. Volume moisture ($R = 0.52$) and specific weight ($R = 0.48$) showed the closest positive correlation with penetrometric resistance in the whole set of measured data. The correlation with porosity is negative ($R = -0.30$).

The results of all four trial years prove that there is a close relation between increase in penetrometric soil resistance and deterioration of the other measured physical soil properties. The consequence of such negative changes is damaged metabolism of sugar beet vegetation and degradation of the key parameters of technological quality of sugar beet (average decrease in sugar content by one-third, decrease in weight, but mainly increased shape irregularity of roots by more than one-third) which strongly reduce refined sugar yield. Furthermore, soil compaction has a negative influence on the effect of exogenous application of cytokinins and other biologically active substances (Kotyk et al. 1996; Švachula et al. 1996).

Solved with support of NAZV grant project 6348 *Farming of Plant Closely Specialized in Sugar Beet*.

REFERENCES

Bajči P., Pačuta V., Černý I. (1998): Cukrová repa. Nitra, ÚVTIP.

Blaszkiewicz Z. (1995): Polowe badanie wplywu opon rolniczych na opór penetracji gleby lekkiej. Probl. Inz. Roln., *4*: 5–15.

Čatský J., Pospíšilová J., Kamínek M., Gaudinová A., Pulkrábek J., Zahradníček J. (1996): Seasonal changes in sugar beet photosynthesis as affected by exogenous cytokinin N^6-(m-hydroxybenzyl)adenosine. Biol. Plant., *38*: 511–518.

Dexter A. R. (1986): Model experiments in the behaviour of roots at the interface between a tilled seed-bed and a compacted sub-soil. Plant and Soil, *95*: 123–133.

Kotyk A., Kamínek M., Pulkrábek J., Zahradníček J. (1996): Effect of *in vivo* and *in vitro* application of the cytokinin N^6-(m-hydroxybenzyl)adenosine on respiration and membrane transport processes in sugar beet. Biol. Plant., *38*: 363–368.

Krejčí V. et al. (1984): Zhutnělé půdy a jejich zúrodňování. Praha, MZVž ČSR.

Lhotský J., Váchal J., Ehrlich P. (1984): Soustava opatření k zúrodňování zhutnělých půd. Metodika. Praha, ÚVTIZ (14).

Pačuta V., Karabínová M., Černý I. (1999): Kvantita a kvalita úrody cukrovej repy vo vzťahu k vybraným pestovateľským faktorom. Rostl. Výr., *45*: 61–67.

Šařec O., Hudík J., Prošek V. (1998): Vliv mechanizace na zhutňování půd a měření zhutnění půdy. In: Sbor. Konf. Řepařství, Praha: 157–162.

Šařec O., Prošek V., Dobek T. (1997): Odzialywanie maszyn do zbioru buraków cukrowych na zwiezlość gleby. IV. Miedzyn. Konf. Nauk. Warszawa: 155–195.

Švachula V., Pulkrábek J., Šroller J., Zahradníček J. (1997): Vliv stresových faktorů na kvalitu cukrovky. Listy cukrov. řepař., *113*: 101–105.

Švachula V., Pulkrábek J., Zahradníček J. (1996): Changes in betaine content in selected cultivars of sugar beet treated with biologically active compounds. Scientia Agric. Bohemoslov., *27*: 183–197.

Zahradníček J., Čatský J., Kamínek M., Kotyk A., Pospíšilová J., Pulkrábek J. (1996): Effect of cytokinins and growth regulators on the yield, technological quality and metabolism of the sugar beet *Beta vulgaris* L. Chem. Listy, *90*: 688–689.

Zahradníček J., Froněk D., Beran P., Pulkrábek J., Švachula V. (1998): Vliv zhutnění řepařských půd na jejich produkční potenciál. Listy cukrov. řepař., *114*: 115–118.

Received on August 1, 2000

ABSTRAKT

Vliv fyzikálních vlastností půdy na metabolismus a technologickou jakost cukrovky

Ve čtyřech pokusných ročnících 1996 až 1999 byly sledovány základní fyzikální parametry řepařských půd v rajonu cukrovaru Dobrovice, a to zejména měření stupně a hloubky utužení půdy penetrometrem a fyzikální vlastnosti půdy odběrem neporušených půdních vzorků. Paralelně byla sledována hodnota chlorofylu stanovená chlorofylmetrem, pH řepné šťávy listů a bulev, počty listů, hmotnost bulev a listů, cukernatost, koncentrace α-aminodusíku, draslíku a sodíku. Opakovaně ve všech ročnících byl na souvratích zjištěn penetrační odpor půdy o 60 až 90 % vyšší než na vnitřních částech pozemků. Od počátku vegetace cukrovky do sklizně postupně narůstal. Do tvorby 6. páru pravých listů byl výrazně vyšší penetrační odpor půdy na kolejových řádcích oproti řádkům a meziřádkům porostu cukrovky. Dynamika pórovitosti půdy během vegetace logicky korespondovala se změnami objemové hmotnosti půdy. Relativně nejtěsnější negativní závislost na penetračním odporu půdy v celém souboru zjištěných údajů vykazuje obsah chlorofylu (–0,61) a hmotnost bulev (–0,58). Koncentrace sodíku a draslíku byla utužením půdy ovlivněna méně. Po sklizni cukrovky a odvozu řepy z pole byl prokázán vyšší penetrační odpor půdy v kolejích sklízecích strojů. Oproti stavu těsně před sklizní byl penetrační odpor relativně vyšší minimálně o 20 %.

Klíčová slova: půda; fyzikální vlastnosti; utužení půdy; penetrační odpor; objemová hmotnost; pórovitost; cukrovka; metabolismus a technologická jakost cukrovky; obsah chlorofylu

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The energy efficiency of sugar beet cultivation

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ABSTRACT

The influence of application of growth regulators on the energy balance of sugar beet cultivation was observed in the yield stationary experiments accomplished in 1996 to 1998 on the Fluvi-Eutric Gleysols. The problems were followed at the variety Ibis on the followed variants of growth regulators application: 1. seed incrusted by Elorisan, 2. seed incrusted by Elorisan and foliar application of Elorisan, 3. foliar application of Elorisan, 4. the control without application of Elorisan. According to the results obtained the annual variability of additional energy inputs was observed whose values varied between 35.571 and 40.859 $GJ.ha^{-1}$. The reasons for the annual variability were different dosages of applied industrial fertilizers and of the human work used. The most significant part of additional energy inputs were represented by fertilizers (43.85–47.60%) of which the rate of industrial fertilizers varied from 25.26 to 29.35% and the rate of dung was from 18.13 to 20.83%. The second largest part of the total input of additional energy was formed by the fossil energy (22.27–24.28%). The negligible portion was represented by energy under form of growth regulators. Average outputs of energy in the dry matter of roots varied from 204.87 to 261.30 $GJ.ha^{-1}$ and in the dry matter of total biomass of sugar beet was the scale of 288.79 to 342.96 $GJ.ha^{-1}$. On the variants with the growth regulators application the statistically significant higher yield roots were gained over from 2.26 to 5.77 $t.ha^{-1}$ and of beet tops over from 0.42 to 1.42 $t.ha^{-1}$ in comparison to untreated control and that is why also higher increase of energy in production was observed. Having comparable inputs of additional energy the higher energy profit was observed in the variants treated by Elorisan while the highest profit values of roots energy (204.78 $GJ.ha^{-1}$) and of the total biomass energy (291.33 $GJ.ha^{-1}$) were found in the variant with the combined application of Elorisan. The annual variability was marked also in the determined values of energy coefficients. The highest values of energy coefficients for roots and the total biomass were reached in 1997 where the lowest inputs of additional energy were used. Growth regulators application caused the average increase of the values of energy coefficients of roots over from 0.26 to 0.45 and of the total biomass of sugar beet over from 0.26 to 0.47 in comparison to the control untreated by Elorisan.

Keywords: sugar beet; growth regulator; Elorisan; energy balance; additional energy; energy output; yield; energy coefficient

The assessment of energy arduousness of the productive process enables us to receive the general picture of the efficiency of vegetable production. The high productivity of the productive process of sugar beet is kept at the cost of high supplies of additional energy under the forms of soil treating, fertilization, protection of diseases and pests, weed control, irrigation and others. All those measures of cultivation are to assure the generation of the optimum structure of the plant cover, the quick formation of the photosynthetically active leaf cover as well as its functional maintenance over the longest period of vegetation possible by which the more effective exploitation of solar radiation is assured.

Sugar beet belongs to the most energy demanding crop, but having a high energy rate of the yield it enters significantly into the total energy balance. This is the reason for paying the considerable attention to the observation of the yield-influencing factors of sugar beet, regarding the climatic and soil conditions (Černý 1996; Frančáková et al. 1996; Kováčová 1996). Conditions suitable for optimization of crop yield are also assured by utilisation of growth regulators. Šanta (1995) and Tománková (1995) pointed out a positive influence of growth regulators on regulation of nutrient intake, the yield and the quality of sugar beet.

The growth regulators influence positively the energy balance of sugar beet cultivation, as their portion of the total additional energy of the whole cultivated system is not high, but having raised the yield they influence the increase of energy output expressed by production.

The aim of the contribution presented was to evaluate the influence of the growth regulator Elorisan applied on the energy balance of sugar beet cultivated on the heavy soils of East Slovakian Lowland.

MATERIAL AND METHODS

Research problems were followed in the years 1996 to 1998 by stationary experiments of the Research Institute of Agroecology Michalovce. The experiments with sugar beet were found in the experimental workplace Milhostov. The work station is located in the central part of the East Slovakian Lowland with the altitude of 101 m above see level. On the land mentioned the Fluvi-Eutric Gleysols (FEG) are situated. The detailed characteristic of the place is described in the thesis of Šoltysová (1999).

The climatic region is the lowland, warm and very dry. The average annual rainfalls through the years 1951 to 1980 counts 559 mm, during the months of April to September it counts 348 mm. The average temperature is 8.9 °C, during the months of April to September it is 16.0 °C. The climatic factor's data were taken from the meteorological station of the Slovak Hydrometeorological Institute in Milhostov and the years 1996 to 1998 are shown in Fig. 1.

The problems of influencing the energy balance of sugar beet cultivation by the factors of biological nature were followed in the variety IBIS. Sugar beet was rationally fertilized. Lime substances in dosage 6 t.ha^{-1} of $CaCO_3$ were worked in the soil and dung was incorporated by middle ploughing in dosage 40 t.ha^{-1}. The level of fertilization was realised for level 45 t.ha^{-1}. The dosage of the pure nutrients applied in the years 1996 to 1998 is shown in Table 1.

In the sugar beet cover the following variants of growth regulator Elorisan were applied:

1. seed incrusted by Elorisan
2. seed incrusted by Elorisan + foliar application of Elorisan
3. foliar application of Elorisan
4. the control without application of Elorisan

In terms of energy balance the direct and indirect inputs of additional energy (GJ.ha^{-1}) and the energy output of agricultural yield (GJ.ha^{-1}) were established. The equivalents of energy inputs for the calculation of inputs of additional energy were determined by the thesis of Preininger (1987) and Čislák (1990). For the energy content of production calculation the energy equivalent 17.64 GJ was used for the gross energy of 1 ton of dry matter of production.

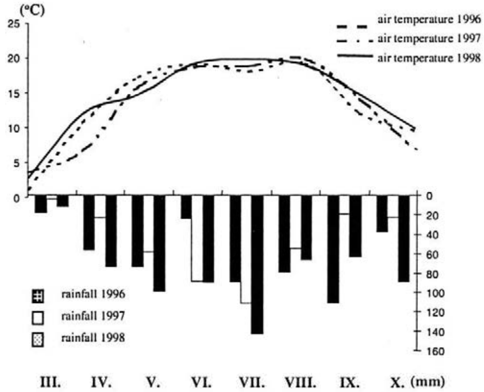

Figure 1. The climatic condition 1996–1998

Table 1. Rates of applied nutrients (kg.ha^{-1} of pure nutrients)

	1996	1997	1998	Average 1996–1998
N	116.0	83.0	93.0	97.0
P	31.5	31.5	31.5	31.5
K	138.0	138.0	138.0	138.0

Energy efficiency of the cultivation process, the comparison of additional energy inputs and energy output, was represented by energy coefficient (EC):

EC = energy output (GJ.ha^{-1}) / additional energy input (GJ.ha^{-1})

The yields were evaluated statistically by the analysis of variance and each variant had energy evaluation.

RESULTS AND DISCUSSION

The structure of additional energy inputs in particular experimental years and in the variants observed is shown in Table 2. Additional energy inputs represented the sum of inputs in the forms of human work, fossil energy, energy of machines, seed energy, energy of organic and industrial fertilizers, energy of pesticides and of growth regulators. From the data given it is obvious that the cultivation process of sugar beet is very demanding on the energy. Total additional energy inputs to the cultivation process moved in the interval of 35.571 to 40.859 GJ.ha^{-1}, which is in fact identical with additional energy inputs given by Repka and Danko (1994) or Cigl'ar and Pospíšil (1997).

According to the results obtained the annual variability of additional energy inputs was established of which the reasons were the different dosages of industrial fertilizers applied and of the human work used. Higher total additional energy inputs were found in 1996 and 1998 where in comparison to 1997 higher dosages of nitrogen fertilizers were used and hoeing of sugar beet was realized.

No significant differences of the total energy inputs were observed among the variants, as the values of energy given in the form of growth regulators and their application represented a minimum part of the total additional energy inputs.

Still fertilizers covered the most significant part of additional energy inputs, even of the experiments were rationally fertilized. Energy inputs of industrial fertilizers reached 9.266–11.912 GJ.ha^{-1}, what was 25.26–29.35% of total additional energy inputs. From the energy given in the form of industrial fertilizers in particular years was generated by nitrogen of 71.84–78.10%, while the portion of the phosphoric (8.46–10.88%) and potassic (13.44–17.28%) fertilizers was lower on energy (Table 3).

The portion of dung on the energy inputs to the cultivation system of sugar beet represented 18.13–20.83%.

Table 2. The structure of inputs of total energy into the sugar beet cultivation

Variant	Years	Human work		Fuels		Machine		Manure		Fertilizers		Pesticides		Elorisan		Seeds		Additional energy
		GJ.ha^{-1}	% AE	GJ.ha^{-1}	% AE	GJ.ha^{-1}	% AE	GJ.ha^{-1}	% AE	GJ.ha^{-1}	% AE	GJ.ha^{-1}	% AE	GJ.ha^{-1}	% AE	GJ.ha^{-1}	% AE	(GJ.ha^{-1})
1.	1996	7.273	17.92	9.040	22.27	3.451	8.50	7.408	18.25	11.912	29.35	0.208	0.51	0.001	0	1.296	3.20	40.589
	1997	5.620	15.80	8.621	24.24	3.298	9.27	7.408	20.83	9.266	26.05	0.062	0.17	0.001	0	1.296	3.64	35.572
	1998	8.010	20.23	9.174	23.18	3.341	8.44	7.408	18.72	10.068	25.44	0.284	0.72	0.001	0	1.296	3.27	39.582
	average	6.968	17.98	8.945	23.23	3.363	8.74	7.408	19.26	10.415	26.95	0.185	0.47	0.001	0	1.296	3.37	38.581
2.	1996	7.355	18.00	9.123	22.33	3.556	8.70	7.408	18.13	11.912	29.16	0.208	0.51	0.001	0	1.296	3.17	40.859
	1997	5.702	15.91	8.704	24.28	3.403	9.50	7.408	20.67	9.266	25.85	0.062	0.17	0.001	0	1.296	3.62	35.842
	1998	8.092	20.31	9.257	23.23	3.446	8.65	7.408	18.59	10.068	25.26	0.284	0.71	0.001	0	1.296	3.25	39.852
	average	7.050	18.07	9.028	23.28	3.468	8.95	7.408	19.13	10.415	26.76	0.185	0.46	0.001	0	1.296	3.35	38.851
3.	1996	7.355	18.00	9.123	22.33	3.556	8.70	7.408	18.13	11.912	29.16	0.208	0.51	0.001	0	1.296	3.17	40.859
	1997	5.702	15.91	8.704	24.28	3.403	9.50	7.408	20.67	9.266	25.85	0.062	0.17	0.001	0	1.296	3.62	35.842
	1998	8.092	20.31	9.257	23.23	3.446	8.65	7.408	18.59	10.068	25.26	0.284	0.71	0.001	0	1.296	3.25	39.852
	average	7.050	18.07	9.028	23.28	3.468	8.95	7.408	19.13	10.415	26.76	0.185	0.46	0.001	0	1.296	3.35	38.851
4.	1996	7.273	17.92	9.040	22.27	3.451	8.50	7.408	18.25	11.912	29.35	0.208	0.51	–	0	1.296	3.20	40.588
	1997	5.620	15.80	8.621	24.24	3.298	9.27	7.408	20.83	9.266	26.05	0.062	0.17	–	0	1.296	3.64	35.571
	1998	8.010	20.23	9.174	23.18	3.341	8.44	7.408	18.72	10.068	25.44	0.284	0.72	–	0	1.296	3.27	39.581
	average	6.968	17.98	8.945	23.23	3.363	8.74	7.408	19.26	10.415	26.95	0.185	0.47	–	0	1.296	3.37	38.580

AE = additional energy

Table 3. Energy in the fertilizers

Years	N		P		K		Fertilizers energy
	$GJ.ha^{-1}$	% FE	$GJ.ha^{-1}$	% FE	$GJ.ha^{-1}$	% FE	
1996	9.303	78.10	1.008	8.46	1.601	13.44	19.266
1998	7.459	74.09	1.008	10.01	1.601	15.90	10.068
Average	7.806	74.68	1.008	9.78	1.601	15.54	10.415

FE = fertilizers energy

Table 4. Sugar beet yield

Variant	Roots ($t.ha^{-1}$)				Beet tops ($t.ha^{-1}$)			
	1996	1997	1998	average	1996	1997	1998	average
1.	76.53	67.33	65.55	69.80	43.90	37.82	40.21	40.64
2.	76.09	65.44	72.33	71.29	44.00	37.92	42.10	41.34
3.	73.00	61.11	69.22	67.78	41.67	38.66	40.70	40.34
4.	73.53	62.00	61.03	65.52	42.47	38.41	38.90	39.92

From that point, the application of industrial and organic fertilizers created 43.85–47.60% of inputs of additional energy. High portion of fertilizers in energy inputs established Gorzelany and Piszczalka (1995) or Kostrej and Danko (1996).

The fossil energy represented in the second largest item of all inputs of additional energy, when in the years observed and in the variants its part was 22.27–24.28%. High portion of fossil energy is connected with the need of fuels for the pre-planting treatment of heavy soil and for the gathering of sugar beet.

A great portion in the structure of using additional energy in the process of cultivation of sugar beet in such soil conditions represents also the energy under the form of human work (15.80–20.31%) and the machine energy (8.44–9.50%).

Other groups of inputs do not load of the cultivation system in a significant extent. Energy in a seed form represented 3.17–3.64% of total inputs of additional energy. The lowest portion takes the energy given as pesticides (0.17–0.72%) and the negligible part of energy in the form of growth regulators.

Energy balance consists of the comparison of additional energy inputs to the cultivation system and of the outputs in form of energy value of production. In dependence on the variant the average output of energy in the dry matter of roots ranged from 204.87 to 261.30 $GJ.ha^{-1}$ and in the total biomass of the sugar beet it was from 288.79 to 342.96 $GJ.ha^{-1}$ (Table 6). Higher output of energy was found in the variants where the growth regulator was used as those variants had significantly higher yield of roots ranging from 2.26 to 5.77 $t.ha^{-1}$ and the yield of beet tops ranged from 0.42 to 1.42 $t.ha^{-1}$ in comparison to untreated control (Table 4). The positive influence of biologically active substances on the yield of sugar beet was also pointed by Tománková (1995).

Sugar beet yields were statistically significantly influenced by the year of cultivation (Table 5) and thus the output energy was different in particular years. The yield roots in the Fluvi-Eutric Gleysols conditions correspond to the values of hydrothermic coefficient, whose numbers reached its climax in 1996 (1.84) and its lowest point in 1997 (1.14) during the second half of vegetation (July to September). The similar conclusion was also reached by Pačuta et al. (1999).

The gap between the energy output of production and the input of additional energy gives the profit of energy. At the comparable inputs of additional energy given to variants treated by Elorisan the higher profit of energy in roots production and in total sugar beet biomass production was established. Similar results about energy profit were also found by Pospíšil (1998).

Table 5. Multiplied 95% *LSD* test comparing the yield of sugar beet

Parameter		Roots				Beet tops		
		homogeneous group						
Variant	4.	+				+		
	3.		+				+	
	1.			+			+	
	2.				+			+
Years	1997	+				+		
	1998		+				+	
	1996			+				+

Table 6. Parameters of energy efficiency in the sugar beet cultivation

Variant	Year	Energy outputs in the dry matter (GJ.ha^{-1})		Profit of energy in the dry matter (GJ.ha^{-1})		Difference of profit of energy in comparison with 4th variants (GJ.ha^{-1})		Energy coefficient	
		root	total biomass	root	total biomass	root	total biomass	root	total biomass
1.	1996	241.65	337.12	201.06	296.53	10.78	18.90	5.95	8.31
	1997	261.30	342.96	225.73	307.39	26.16	20.76	7.35	9.64
	1998	216.81	303.34	177.23	263.76	11.94	14.55	5.48	7.66
	average	239.92	327.81	201.34	289.23	16.29	18.07	6.26	8.54
2.	1996	240.65	328.43	199.79	287.57	9.51	9.94	5.89	8.04
	1997	251.66	332.46	215.82	296.62	16.25	9.99	7.02	9.28
	1998	238.59	329.64	198.74	289.79	33.45	40.58	5.99	8.27
	average	243.63	330.18	204.78	291.33	19.74	20.17	6.30	8.53
3.	1996	231.78	320.87	190.92	280.01	0.64	2.38	5.67	7.85
	1997	233.38	316.85	197.54	281.01	–2.03	–5.62	6.51	8.84
	1998	241.52	329.68	201.67	289.83	36.38	40.62	6.06	8.27
	average	235.56	322.47	196.71	283.62	11.66	12.46	6.08	8.32
4.	1996	230.87	318.22	190.28	277.63		–	5.69	7.84
	1997	235.14	322.20	199.57	286.63	–	–	6.61	9.06
	1998	204.87	288.79	165.29	249.21	–	–	5.18	7.30
	average	223.63	309.73	185.05	271.15	–	–	5.82	8.06

The highest average profit of energy was observed in the variants with the combined application of Elorisan (204.78 GJ.ha^{-1}) and the seed incrusted with Elorisan (201.34 GJ.ha^{-1}). Also the variant of foliar application of Elorisan established the higher average energy profit than in the control variant but here the increase was represented only by roots production of sugar beet obtained in 1998. The similar trend applies also to the total biomass with the maximum average profit of energy of 291.33 GJ.ha^{-1} from the second variant.

The rationality of using the energy inputs to the cultivation process of sugar beet declares the energy coefficient. The values of energy coefficient of the roots on the level 5.18–7.35 and of the total biomass of sugar beet on the level 7.30–9.64 confirm that sugar beet is the crop with high energy effectiveness. Also values of this index of energy effectiveness are dependent on the year of cultivation and thus on the climate conditions and energy inputs of additional energy in a particular year. The highest energy coefficient for the roots and the total biomass were reached in 1997 when additional energy inputs were the lowest.

The utilisation of growth regulators was positively displayed on the energy effectiveness of sugar beet cultivation as during the period observed the average values of energy coefficient were increased over from 0.26 to 0.45 for the roots and over from 0.26 to 0.47 for the total biomass compared to the control. Energy effectiveness of sugar beet cultivation was comparable in our observations with the data given by Cigľar and Pospíšil (1997) for the fertilized variants.

REFERENCES

Cigľar J., Pospíšil R. (1997): Energetické zhodnotenie pestovania cukrovej repy v integrovanej sústave hospodárenia. 2. ved. celoslov. rep. Konf. Nitra, SPU: 129–130.

Černý I. (1996): Analýza vplyvu poveternostných podmienok a rôznych pestovateľských faktorov na úrodu cukrovej repy. Listy cukrov. řepař., *112*: 330–332.

Čislák V. (1990): Energetická efektívnosť poľnohospodárskej sústavy. 1. vyd. Bratislava, Veda.

Frančáková H., Lacko-Bartošová M., Muchová Z., Bajči P. (1996): Úrody vybraných plodín a kvalita cukrovej repy v ekologickom a integrovanom systéme hospodárenia. Rostl. Výr., *42*: 471–477.

Gorzelany J., Piszczalka J. (1995): Prácnosť a energetická náročnosť niektorých technológií pestovania cukrovej repy. Poľnohospodárstvo, *41*: 268–277.

Kostrej A., Danko J. (1996): Analýza a modelovanie energetických ukazovateľov produkčného procesu poľných plodín. 1. vyd. Nitra, VŠP.

Kováčová M. (1996): Reakcia cukrovej repy na priebeh klimatických podmienok. Listy cukrov. řepař., *112*: 264–266.

Pačuta V., Karabínová M., Černý I. (1999): Kvantita a kvalita úrody cukrovej repy vo vzťahu k vybraným pestovateľským faktorom. Rostl. Výr., *45*: 61–67.

Pospíšil R. (1998): Cukrová repa – významný článok v energetickej bilancii rastlinnej výroby. Listy cukrov. řepař., *114*: 141–143.

Preininger M. (1987): Energetické hodnocení výrobních procesů v rostlinné výrobě. Metodika. Praha, ÚVTIZ: (7).

Repka J., Danko J. (1994): Energetická efektívnosť pestovania cukrovej repy pri veľkovýrobných technológiách. Poľnohospodárstvo, *40*: 582–591.

Šanta I. (1995): Využitie regulátora rastu Rastim 30 DKV v podmienkach Východoslovenskej nížiny. Agrochémia, *35*: 93–94.

Šoltysová B. (1999): Tvorba úrody a kvality cukrovej repy v závislosti od jej výživy v interakcii s rastovými regulátormi v podmienkach ťažkých pôd VSN: [Doktorandská dizertácia.] Michalovce, OVÚA.

Tománková E. (1995): Vplyv Supresivitu a Biostímu na úrodu a kvalitu cukrovej repy. Listy cukrov. řepař., *111*: 254–255.

Received on September 26, 2000

ABSTRAKT

Energetická efektivnost pěstování cukrovky

V polních stacionárních pokusech realizovaných v letech 1996 až 1998 na fluvizemi glejové byl sledován vliv aplikace stimulátoru růstu Elorisanu na energetickou bilanci pěstování cukrovky. V pokusech byla použita odrůda Ibis. Pokusy proběhly v těchto variantách: 1. osivo obalené Elorisanem, 2. osivo obalené Elorisanem a foliární aplikace Elorisanu, 3. foliární aplikace Elorisanu, 4. kontrola bez aplikace Elorisanu. Byla zjištěna ročníková variabilita vkladů dodatkové energie, jejichž hodnoty se pohybovaly v rozmezí 35,571 až 40,859 GJ.ha^{-1}. Příčinou ročníkové variability byly rozdílné dávky průmyslových hnojiv a použité lidské práce. Nejvýraznější položku z energetických vkladů tvořila hnojiva (43,85 až 47,60 %), přičemž podíl průmyslových hnojiv představoval 25,26 až 29,35 % a podíl chlévského hnoje 18,13 až 20,83 %. Druhou nejvýznamnější energickou položkou z celkových vstupů byla fosilní energie (22,27 až 24,28 %). Ve struktuře vstupů tvoří nepatrný podíl energie regulátoru růstu. Průměrný výstup energie v sušině bulev se pohyboval v rozmezí 204,87 až 261,30 GJ.ha^{-1} a v celkové biomase cukrové řepy v rozmezí 288,79 až 342,96 GJ.ha^{-1}. U variant s aplikací regulátorů růstu byl zjištěn vyšší výstup energie v produkci. U těchto variant byl zároveň zaznamenán vyšší zisk energie, přičemž nejvyšší hodnoty zisku energie bulev (204,78 GJ) a energie celkové biomasy (291,33 GJ) byly prokázány u varianty s kombinovanou aplikací Elorisanu. Projevila se i ročníková variabilita – nejvyšší hodnoty energetických koeficientů byly nalezeny v roce 1997, kdy byly použity nejnižší vstupy dodatkové energie. Aplikace regulátorů růstu zvýšila hodnoty energetických koeficientů bulev o 0,26 až 0,45 a celkové biomasy o 0,26 až 0,47 v porovnání s kontrolou.

Klíčová slova: cukrovka; regulátor růstu; Elorisan; energetická bilance; vstupy dodatkové energie; výstupy energie; výnos; energetický koeficient

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The changes in germinability of *Ambrosia artemisiifolia*, *Panicum dichotomiflorum* and *Sorghum halepense* seeds stored in maize silage and cattle slurry

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ABSTRACT

Three-step experiments were carried out from October 1997 to October 1999 in which the time dependent changes in per cent germination of ragweed (*Ambrosia artemisiifolia* L.), tall panicum (*Panicum dichotomiflorum* Michx.) and Johnson grass [*Sorghum halepense* (L.) Pers.] seeds stored in maize silage and in cattle slurry were studied. First, seeds were stored in maize silage, then they were fed to cows and afterwards the mixture of digested seeds and dung was placed in the cattle slurry. Seeds of ragweed stopped to germinate after being stored in maize silage for 13 months, seeds of tall panicum after 10 months, and seeds of Johnson grass after 9 months. The decrease of per cent germination of seeds stored in cattle slurry was significantly influenced by the time of seed storage in maize silage. Depending on the time of seed storage in maize silage, seeds of ragweed stopped to germinate after 3 to 5 month storage in slurry, seeds of tall panicum after 1 to 4, and seeds of Johnson grass after 2 to 8 months.

Keywords: maize silage; cattle slurry; seed germination; *Ambrosia artemisiifolia*; *Panicum dichotomiflorum*; *Sorghum halepense*

Ragweed (*Ambrosia artemisiifolia* L., AMART), smooth witch-grass or tall panicum (*Panicum dichotomiflorum* Michx., PADIH) and Johnson grass [*Sorghum halepense* (L.) Pers., SOHAL] have become troublesome weeds in many maize fields of Slovenia. All three neophyte weed species have a high competitive ability against field crops and produce a lot of seeds. In last two decades they have spread from the Mediterranean region of Europe and the Balkans far to Eastern and Central Europe, despite the fact that they originate from much warmer climates (Ries 1991; Győrffy et al. 1995; Ammon 1997). In Slovenia, they are spreading fast especially in regions with the most intensive livestock farming where the fields are fertilised with large quantities of mineral fertilisers and also with organic manures. When silage is prepared from the maize grown in the fields heavily infested with those weeds, the silage contains also many of their seeds. Despite herbicide control, they can still produce a lot of seeds in maize stands. According to our previous research, even at intensive herbicide use and dense maize stands, ragweed can produce between 1 and 2 thousand, Johnson grass 2–4 thousand and tall panicum between 2 and 5 thousand seeds m^{-2}. Freshly harvested maize silage samples originating from fields infested with 5 to 10 plants of investigated weeds m^{-1}, contained 10 to 500 their seeds kg^{-1}. After the passage of silage through a cattle digestive tract, the seeds get into slurry which is returned to the fields. In 1 L of randomly taken slurry samples, 3 to 200 seeds of investigated weeds were found. In the region of Dravsko and Ptujsko polje in north-eastern Slovenia a weed survey carried out in 1993 showed that out of 250 randomly selected fields (of approx. 3000 ha) 8% of them were infested with ragweed, 7% with smooth witch-grass and 4% with Johnson grass (Lešnik 1995).

Slurry was applied to 95% of the infested fields at least once a year. In 1997, the weed survey of the same fields was repeated and it was established that already 25% of fields were infested with ragweed, 19% with tall panicum and 17% with Johnson grass (unpubl. obs.). Also a significant increase in average plant density of investigated three weeds was observed during the comparison of data from 1993 and 1997 weed surveys. On the basis of these findings it was anticipated that cattle slurry plays an important role in spreading of Johnson grass, ragweed and tall panicum to new habitats.

There are a few accurate data on survival rate of seeds of investigated weeds in silage and slurry in the literature. Most reports deal with results obtained on the basis of random sampling of slurry in which usually a few seeds of ragweed and Johnson grass were found, having a low percentage of germinability (Elema et al. 1990; Pleasant and Schlather 1994; Kellerer et al. 1996). Due to the fact that random samples of slurry usually contain weed seeds from various sources, which have been present in it for different periods of time, results from different farms can vary a lot (Cudney et al. 1992). Some scientists reported that a low percentage of seeds of investigated three weeds always survives the passage through the cattle digestive tract and the storage in manure or slurry (Harmon and Keim 1934; Atekson et al. 1934; Elema et al. 1990; Korsmo 1930; Kellerer et al. 1996).

Our study was aimed at presenting the changes in per cent germination of ragweed, Johnson grass and tall panicum seeds from the moment the seeds enter the silage to the moment when seeds are returned to the fields through the application of slurry. Therefore the experiments were designed in accordance with the production processes on farms.

MATERIAL AND METHODS

Collection of weed seeds

Seeds were collected between 20th and 25th September 1997 in the fields of north-eastern Slovenia from plants that had not been damaged by herbicides or diseases. The seeds were collected manually by shaking them out of inflorescences onto a tilt a few days before experiments started. The weight of 1000 seeds at, on average, 23.6% moisture content was 5.2–7 g at ragweed, 4.5–5.3 g at Johnson grass and 0.9–2.1 g at tall panicum.

Germination test procedure

The same germination procedure was applied for all seed samples taken from maize silage, cow dung, sand and cattle slurry. Germination tests were carried out in Petri dishes (9 cm diameter) placed in temperature-controlled growth chambers. First, filter paper was placed on the bottom of dishes, then it was covered with 0.5 cm layer of sand, on which seeds were dispersed evenly, and finally covered with 0.5 cm of fine sand. Afterwards, 10 ml of 0.03% propamocarb solution (Previcur 607 SL, 607 g a.i. L^{-1}, AgrEvo) and 10 ml 0.015% thiophant-methyl solution (Enovit-M, 70 g a.i. kg^{-1}, SIPCAM S.p.A.) was added to each Petri dish in order to prevent the development of fungi that were present on the seed coats.

The appropriate fungicides were selected on the basis of tests in which comparisons were made between per cent germination of disinfected and non-disinfected seeds that had not been stored in slurry. The tests showed that the applied fungicides did not have any inhibitory effects on seed germination of investigated weeds. Thus a higher degree of accuracy of results on per cent germination was assured.

During experiments, distilled water was added as needed to supply seeds with humidity. The temperature was kept constant at 25 °C (24 hours a day), relative air humidity was 80%. The chamber was illuminated 12 hours per day with fluorescent lamps providing Petri dishes with approximately 450 $mmol^{-1}$ m^{-2} photon flux. All the germination tests lasted three weeks. Seeds were considered to have germinated when essential structures of cotyledons appeared above sand surface. Such a seed testing protocol was used on the basis of our previous experience in testing germination of ragweed, Johnson grass and tall panicum seeds.

Investigation of time dependency of per cent germination of seeds stored in maize silage and sand

Our study started at the beginning of October 1997 and took 16 months. Seeds of all three weed species were mixed together and divided into two equal parts. The first part of seeds was placed into maize silage stored in 30 L plastic containers (treatment 1), and the other into the sand stored in 5 L plastic containers (control treatment 2). The moisture content of the sand was not sufficient for the seeds to germinate. The mixture of seeds and maize silage was prepared manually by mixing seeds with fresh maize silage taken off the silage combine. Seeds used in experiments did not pass through the silage combine. We prepared 160 plastic containers filled with silage containing mixture of seeds of investigated weeds and 160 plastic containers filled with sand containing seeds of ragweed, Johnson grass and tall panicum.

Each container was filled separately with mixture of 0.7 kg seeds and 15 kg of whole plants maize silage (grain and stover cut to 1 cm length). The dry matter content of the silage at the beginning of fermentation was 35–38%. The mixture was thoroughly pressed and the containers were air-tight.

The fermentation process was carried out at 20 °C. Silage pH was measured before each seed sampling. Silage pH during the first seven months decreased from 6.5 to 4.2, afterwards it increased slightly, so that at the end of the experiment it was 4.7. The mixture of sand and seeds was prepared by mixing 0.7 kg seeds with 3 kg sand. Plastic containers filled with mixture of seeds and sand were stored in the same place like the containers with maize silage and were not covered. Each two months during the16-month time period, ten containers of each experimental group were selected randomly, opened and the silage from the middle of each container was placed on a sieve from which seed samples (100 seeds for each weed species per container) were taken. In the same way and at the same time, samples of seeds stored in containers filled with sand were also taken. After sampling, seeds were used in germination tests and the silage was fed to cows in other experiments.

Investigation of time dependency of per cent germination of seeds stored in cattle slurry after storage in maize silage and passing through the cow digestive tract

The experiments aimed at establishing the time dependency of per cent germination of seeds in cattle slurry were conducted so that the digested seeds mixed with cow dung were placed into 30 L plastic containers which were immersed into slurry basins at the depth of 2 m. Surface access of air to slurry in basins was possible, since basins were covered only with concrete grates. The containers were suspended on a rope, so that they could be lifted up for each sampling. Before seeds were placed in slurry, they were fed to cows. The cow dung containing seeds of investigated weeds was collected afterwards and placed in containers which were then immersed into slurry.

Four cows were selected for the experiments. Two of them were four-year old Friesian breed cows, weighing approx. 550 kg, and two of them were five-year old Simmental breed cows, weighing approx. 650 kg. The animals were kept in a separate part of a cowshed with a concrete floor, which enabled us to collect all the dung. In all experiments, the same cows were fed with daily meals consisting of 20 kg of maize silage (silage from plastic containers), 25 kg of hay and 30 kg of feed concentrates. Seeds stored in sand were cleaned in water before feeding. The dung was always collected for two days (period from 48 to 96 hours after first intake of feed). Usually, 80 kg of dung from all four animals together was collected. The dung was mixed thoroughly and then divided into ten equal parts (10 × 8 kg). Next, 100 seeds of each weed species were taken from each dung part for the germination tests. Seed extraction from the dung was performed by wet-sieving. Seeds separated from the dung were taken one by one, as they appeared on the sieve, also seeds damaged by mastification were included. After the seed extraction, dung samples weighting approx. 4 kg were taken from each of ten 8-kg dung parts and were placed in bags from stretchy material, allowing slurry to pass through. Each bag containing mixture of dung and digested seeds was then placed in a separate plastic container. In each of ten containers, the seeds from different groups of experiments were kept in bags that were marked with plastic bands of different colours, which enabled us to distinguish seeds from different experiments.

In two-month intervals four separate experiments were carried out according to the same procedure, only the time of storage of seeds, before they were fed to cows, was different in each of four experiments. First, the seeds from maize silage, and three days later the seeds from sand were fed to cows. In the first experiment cows were fed with the seeds that had been stored in silage or sand for two months (AMART-ms2, AMART-sa2, PADIH-ms2, PADIH-sa2, SOHAL-ms2, SOHAL-sa2), in the second one, with the seeds that had been stored in silage or sand for four months (AMART-ms4, AMART-sa4, PADIH-ms4, PADIH-sa4, SOHAL-ms4, SOHAL-sa4), in the third one, with the seeds that had been stored in silage or sand for six months (AMART-ms6, AMART-sa6, PADIH-ms6, PADIH-sa6, SOHAL-ms6, SOHAL-sa6) and in the fourth experiment, with the seeds that had been stored in silage or sand for eight months (AMART-ms8, AMART-sa8, PADIH-ms8, PADIH-sa8, SOHAL-ms8, SOHAL-sa8). At the beginning of experiments, when seeds were prepared for storage in maize silage and sand, ten seed samples of each of three weed species were also placed in the ten 30 L plastic containers and sank into the slurry in the same way as other samples that were obtained from cow dung. These samples were aimed at studying the changes of germinability of undigested seeds stored in cattle slurry.

The slurry temperature in summer ranged between 14–16 °C, and in winter between 6–8 °C. The dry matter content in slurry was approx. 7%. All the containers were lifted from the slurry each month in the 8-month time period. The bags were opened and 0.2 L slurry was taken from each bag. The slurry samples were then sieved by wet-sieving procedure and sampling of seeds was performed. 100 seeds of each weed species from each bag were then subjected to germinability tests.

Statistical analysis

For all experiments a completely randomised design with ten replications was applied. Average per cent germination and standard errors of means (± SEM) were computed and the data were presented in graphs to show changes in per cent germination of weed seeds stored in maize silage, sand and cattle slurry. SEM are not shown in presented graphs.

RESULTS

Results of experiments on the changes of per cent germination of seeds stored in sand and maize silage

The time dependent changes in per cent germination of ragweed, tall panicum and Johnson grass seeds stored in maize silage, sand in cattle slurry (undigested seeds) are presented in Fig. 1. The per cent germination of seeds stored in maize silage and cattle slurry was increasing in first 3 months and started to decrease significantly afterwards. Per cent germination of seeds stored in sand was increasing all the time, only a slight decrease of per cent germination of tall panicum and Johnson grass seeds was observed at the beginning of experiment. Seeds of ragweed stopped to germinate after being stored in maize silage for 13 months, seeds of tall panicum after 10 months and seeds of Johnson grass after 9 months. Per cent germination of undigested seeds stored in cattle slurry decreased slightly faster than at seeds stored in maize silage. The seeds of ragweed stored in slurry remained germinable for 13 months, seeds of Johnson grass for 10 and seeds of tall panicum for 6 months.

Results of experiments on the changes of per cent germination of seeds stored in cattle slurry after storage of seeds in maize silage and passing through the cow digestive tract

Changes of per cent germination of the seeds, that were stored in cattle slurry after digestion by cows, are presented in Figs. 2, 3 and 4. The storage of seeds in maize silage prior feeding to cows had a significant impact on the degree of decrease of per cent germination of digested seeds stored in the cattle slurry. Seeds that were

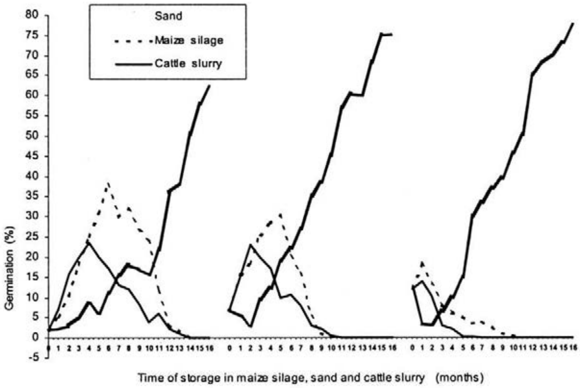

Figure 1. Changes of per cent germination of ragweed (left), Johnson grass (middle) and tall panicum seeds (right) stored in sand, maize silage and cattle slurry

stored in maize silage prior feeding to cows lost germinability faster than those stored in sand (compare left and right sets of curves in Figs. 2, 3 and 4). Also the time of storage of seeds in maize silage prior to feeding to cows had a significant impact on the degree of decrease of per cent germination of seeds stored in slurry. The longer the seeds were stored in maize silage prior to being fed to cows and storage in cattle slurry, the faster decreased percent germination of seeds stored in cattle slurry (compare curves ms2, ms4, ms6 and ms8 in Figs. 2, 3 and 4). Depending on the time of storage in maize silage, digested seeds of ragweed stored in cattle slurry remained germinable between 3 and 5 months, digested seeds of Johnson grass between 2 and 8 months and digested seeds of tall panicum between 1 and 4 months.

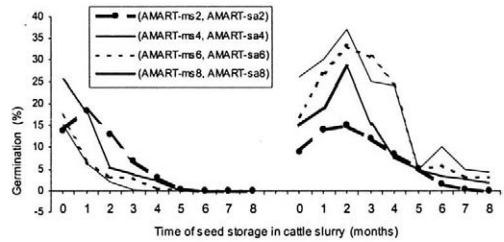

Figure 2. Changes of per cent germination of ragweed seeds stored in cattle slurry after digestion by cows and previous storage in maize silage (left) or in sand (right) for 2, 4, 6 or 8 months

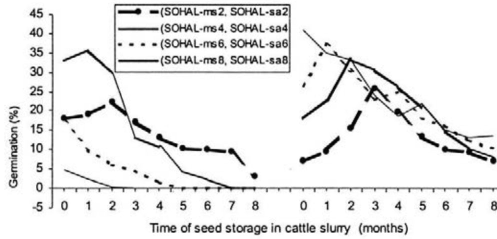

Figure 3. Changes of per cent germination of Johnson grass seeds stored in cattle slurry after digestion by cows and previous storage in maize silage (left) or in sand (right) for 2, 4, 6 or 8 months

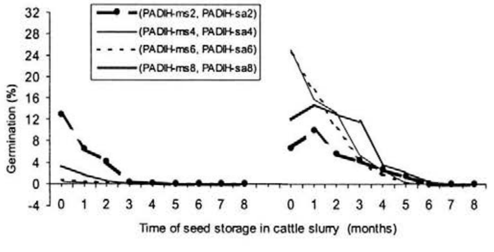

Figure 4. Changes of per cent germination of tall panicum seeds stored in cattle slurry after digestion by cows and previous storage in maize silage (left) or in sand (right) for 2, 4, 6 or 8 months

DISCUSSION

Changes of germinability of seeds stored in any kind of substrata (dry seeds in bags, seeds in the soil, seeds in the slurry etc.) depend a lot on seed age (maturity) at the beginning of the storage (Roberts 1978; Radosevich and Holt 1984). In order to simulate processes that affect seeds in the real production on the farms, in our experiments fresh seeds were used, therefore when analysing the results of germination tests in our experiments, we also have to take into consideration the above mentioned fact. In two similar experiments, seeds from the same source can be used, but if they are of different age (maturity), the results obtained will be different as well. It is possible that after their passing through the digestive tract, only a small percentage of seeds are germinable. If fresh seeds are fed to animals, it cannot be said whether the seeds really have been decayed or they are still dormant. In silage and slurry seeds are exposed to damages due to acids and gases, lack of oxygen and microbes, therefore it can be expected that under such conditions they would decay faster than in the soil, where they usually fall after weeds finish their development.

We established that after storage in maize silage and slurry for some time period, seeds stopped to germinate, but we could not be sure whether the seeds had really decayed, since we did not carry out viability test, such as tetrazolium viability test. Viability tests enable us to get information on germination ability of seeds that do not germinate because of special ecological or physiological conditions. It is questionable if results about per cent germination of seeds stored in slurry established in this way in laboratory are comparable with per cent germination that would appear in nature. The results of the germinability tests conducted in Petri dishes in sand in conditions similar to natural ones (light, moisture, temperature, gases) show only germinability at the time of testing.

The results of viability tests (tetrazolium test, morphological test), on the other hand, show viability. The percentage of viable seeds is usually in dormant seeds much higher than the observed per cent germination, but in the case of the seeds stored in the manure or in the slurry sometimes also opposite results can be obtained (Roberts 1978; Rieder 1966).

During the passage of seeds through the digestive tract of cows and during storage in slurry, the seeds are exposed to different damages, which affect not only per cent germination during testing, but also seed survival rate at a later period when seeds are buried in the soil (time after slurry application), so that despite using exact laboratory tests we cannot provide a complete answer on seed survival rate in the natural conditions in the field. It is possible that seeds are viable immediately after sampling from slurry, but when in the soil, they can decay fast due to microbial infections or other causes. Thus, even if the test results on per cent germination obtained shortly before the application of slurry show that a certain percentage of seeds are still viable, we cannot be absolutely sure that this will lead to the establishment of new populations of investigated weeds in uninfested fields.

In Slovenia, the largest populations of ragweed, tall panicum and Johnson grass can be observed in the fields surrounding big cattle farms, what suggests that slurry plays an important role in the dissemination of those weeds to new habitats. But it has to be taken into consideration that another important factor for their successful development in these fields is excessive content of nitrogen and potassium in the soil, which is due to too high quantities of slurry applied to the fields. On Slovene cattle farms the maize silage is usually stored for 12 months, from October in one year to October in next year, when new silage is prepared. On the basis of the results obtained in experiments in which seeds of ragweed stored in maize silage remained germinable for 13 months, seeds of tall panicum 10 months and seeds of Johnson grass 9 months, it can be concluded that cows are almost always fed with silage which contains viable seeds of investigated weeds.

Cattle slurry is usually stored in basins under standing-floors in cowsheds (technology of cattle breeding on concrete grates). Other facilities for slurry storage are rare on most Slovene farms. Because of limited storage capacities the majority of Slovene farmers are not able to store slurry for more than 5 months. Our experiments showed that digested seeds stored in maize silage for 2 months before feeding to cows could remain germinable in slurry for 8 months in the case of Johnson grass, for 5 months at ragweed and 4 months in the case of tall panicum. When seeds are stored in maize silage for longer than two months prior to being fed to cows, they decay faster. According to the results of our experiments it is very likely that the applied slurry stored in basins under concrete grates for less than 5 months from end of October to April in the next year, will contain some viable seeds of all three species. In winter months (from November to March), when slurry contains the greatest amounts of germinable seeds, only a little part of whole year mass of slurry is dispersed on the fields (unfavourable conditions for application and prohibition of slurry application by law).

On the basis of our experiments it can be concluded that cattle slurry can be a source for dispersal of viable seeds of investigated weed species to uninfested fields, but on the other hand, according to the amount of germinable seeds in slurry and time of its application, it can be concluded also that other ways of weed seeds dispersal (zoochory, anemochory and other ways of antropochory) play more important role in fast spreading of ragweed, tall panicum and Johnson grass to new habitats throughout the Central and Eastern Europe.

REFERENCES

Ammon H.U. (1997): Weed control in transition – from weed eradication to vegetation management. Proc. 10th EWRS Symp. Poznan, Poland: 87–95.

Atekson F.W., Hulbert H.W., Warren T.R. (1934): Effect of bovine digestion and of manure storage on the viability of weed seeds. J. Amer. Soc. Agron., *26*: 390–397.

Cudney D.W., Wright S.D., Shultz T.A., Reints J.S. (1992): Weed seed in dairy manure depends on collection site. Californian Agric. May–June: 31–32.

Elema A.G., Bloemhard C.M.J., Scheepens P.C. (1990): Risk-analysis for the dissemination of weeds by liquid cattle manure. Med. Fac. Landb.-Wet. Rijksuniv. Gent, *55*: 1203–1209.

Győrffy B., Hunyadi K., Kádár A., Molnár J., Tóth A. (1995): Hungarian national weed surveys 1950–1992. Proc. 9th EWRS Symp. Budapest, Hungary: 1–10.

Harmon G.W., Keim F.D. (1934): The percentage and viability of weed seeds recovered in the feces of farm animals and their longevity when buried in manure. J. Amer. Soc. Agron., *26*: 762–767.

Kellerer C., Albrecht H., Pfadenhauer J. (1996): Ausbreitung von Pflanzen der landwirtschaftlichen Nutzflachen durch Rindergulle. Verh. Gesell. Ökol., 25. Jtag. Dresden, *26*: 729–736.

Korsmo E. (1930): Unkräuter in Ackerbau der Neuzeit. Berlin, Verlag von Julius Springer.

Lešnik M. (1995): A comparative analysis of weed communities in Dravsko and Ptujsko polje fields with intensive and extensive crop production. Master of Science Thesis, Biotechn. Fac. Agron. Dep. Univ. Ljubljana.

Pleasant J.M., Schlather K.J. (1994): Incidence of weed seed in cow (*Bos* sp.) manure and its importance as a weed source for cropland. Weed Technol., *8*: 304–310.

Radosevich S.R., Holt J.S. (1984): Weed ecology. New York, John Wiley & Sons, Inc.

Rieder G. (1966): Der Einfluß des Schwemmistes auf die Unkrautverbreitung und die Anwendung der Tetrazolium-Methode bei Unkrautsamen. [Dissertation.] Hohenheim, Landwirtsch. Hohsch.

Ries C. (1991): Überblick Über die Ackerunkrautvegetation Österreichs und ihre Entwicklung in neuerer Zeit. [Dissertation.] Wien, Bot. Inst. Univ. Bodenkult.

Roberts E.H. (1978): Viability of seeds. London, Chapman and Hall.

Received on June 28, 2000

ABSTRAKT

Změny klíčivosti semen plevelů *Ambrosia artemisiifolia*, *Panicum dichotomiflorum* a *Sorghum halepense* při skladování v kukuřičné siláži a kejdě

V letech 1997 až 1999 jsme ověřovali změny procenta klíčivosti semen ambrózie pelyňkolisté (*Ambrosia artemisiifolia* L.), prosa vidlicokvětého (*Panicum dichotomiflorum* Michx.) a čiroku halepského [*Sorghum halepense* (L.) Pers.] při skladování v kukuřičné siláži a kejdě. Klíčivost byla sledována ve třech stupních. Nejdříve jsme skladovali semena v kukuřičné siláži, kterou jsme použili jako krmení pro krávy. Po průchodu zažívacím traktem krav jsme semena uchovávali v kejdě. Při skladování v kukuřičné siláži si semena ambrózie udržela klíčivost 13 měsíců, semena prosa 10 měsíců a semena čiroku halepského 9 měsíců. Rychlost poklesu procenta klíčivosti semen skladovaných v kejdě závisí na době dočasného skladování v kukuřičné siláži. Semena ambrózie si při skladování v kejdě, v závislosti na délce doby skladování v siláži, uchovala klíčivost od 3 do 5 měsíců, semena prosa od 1 do 4 měsíců a semena čiroku halepského od 2 do 8 měsíců.

Klíčová slova: kukuřičná siláž; kejda; klíčivost semen; *Ambrosia artemisiifolia*; *Panicum dichotomiflorum*; Sorghum halepense

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Rostliny a zvyšující se koncentrace CO_2 v atmosféře Země

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Motýl dosedl na květ a roztáhl svoje křídla. Způsobil tím sotva znatelný pohyb vzduchu, který se však za nějakou dobu na úplně jiném místě projevil náhlou bouřkou, povichrem či jiným dramatickým klimatickým jevem.

Tak nějak všichni známe trochu poetické přirovnání citlivosti klimatu i na sebenepatrnější změny některého z mnoha faktorů, které ovlivňují aktuální stav počasí. Úplně stejné přirovnání bych rád vymyslel pro ilustraci nečekaných změn, které vyvolává poměrně nepatrné zvýšení koncentrace oxidu uhličitého v atmosféře Země o dvě až tři setiny procenta: nepřekvapí nás změna v růstu rostlin, ale většinou nedomýšlíme také změny ve spotřebě vody rostlinami až po zvýšení či pokles relativní vzdušné vlhkosti, oblačnosti a srážek. A jen málokoho napadne uvažovat o změně aktivity půdních mikrobů, což se může projevit změnou dostupnosti minerálních živin. A znovu se můžeme vrátit k motýlům. Mnohé porosty totiž s onou nepatrnou změnou koncentrace CO_2 přestanou být vhodné pro býložravé živočichy, zejména hmyz. Housenky se nestačí zakuklit a na rostlinách se objeví zcela nové druhy živočichů. A to vše způsobí ona nepatrná změna dvou či tří setin procenta CO_2 ve vzduchu.

Je obecně známo, že změna koncentrace skleníkových plynů v atmosféře Země vede ke změnám globálního klimatu, z nichž nejčastěji uváděnou změnou je zvýšení teploty o 2 až 5 °C a s tím spojené zvýšení hladin oceánů, změna geografického rozdělení srážek, zvýšení frekvence záplav, hurikánů apod. Pravděpodobnost změny klimatu je obecně přijímána. Neshody však panují v prognózách, kdy a v jakém rozsahu se tyto změny projeví. O vlivu těchto klimatických změn na rostliny se tento článek nezmiňuje. Zde se soustředím jen na to, co je mimo jakoukoliv diskusi: **je prokázáno, a obecně tedy přijímáno, že dochází k velmi rychlému zvyšování koncentrace CO_2 v atmosféře**. Obdobně je známo, že zvýšení koncentrace CO_2 má velký vliv na růst rostlin. Tento text se tedy pokouší přispět k pochopení základů uvedeného vlivu CO_2 na rostliny. Rád bych přitom pomohl pochopit celou problematiku v tom smyslu, že doslova tisíce prací věnovaných v posledních dvou desetiletích této tematice zdaleka nestačilo k dostatečnému popisu uvedeného vlivu. Snad to bude i další příspěvek k uvědomění si nesmírné složitosti a provázanosti všech jevů v přírodě i nebezpečnosti konání člověka, který tuto skutečnost velkopansky přehlíží.

Koncentrace CO_2 ve vzduchu

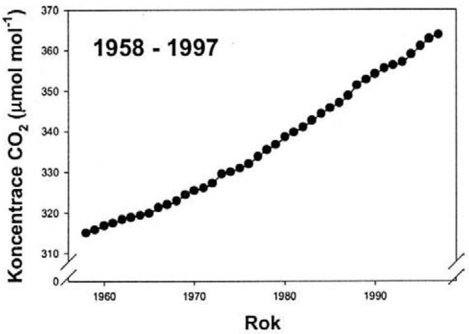
Ale po úvodním zjednodušujícím souhrnu nyní postupně a přehledněji. Ve vzduchu je asi 0,036 objemových procent CO_2. Toto množství se často vyjadřuje jako 360 μmol CO_2 na 1 mol vzduchu neboli 360 μl na 1 litr vzduchu čili 360 cm^3 na 1 krychlový metr. Také se používá k vyjádření obsahu CO_2 ve vzduchu hodnota jeho parciálního tlaku, která pro uvedenou koncentraci odpovídá 36 Pa. A konečně se můžeme setkat také s konstatováním, že při stávající koncentraci CO_2 ve vzduchu je v 1 m^3 720 mg CO_2. Přitom nejjednodušší je snad 360 ppm (pars per milion), tedy ony miliontiny. Protože žádný z uvedených způsobů vyjadřování koncentrace CO_2 v literatuře nepřevažuje, může být pro čtenáře vhodné tuto různorodost si připomenout.

Ostatně samotné vyjádření „současná koncentrace" je trochu zavádějící. Obsah CO_2 v atmosféře totiž systematicky vzrůstá. Před deseti lety bychom jako současnou koncentraci označili 350 ppm, dnes je to 366 ppm a nejmladší generace čtenářů tohoto příspěvku ještě zažije koncentrace 400 ppm a více. Systematická a velmi přesná měření koncentrace CO_2 se provádějí od roku 1958, a to na observatoři v Mauna Loa na Havajských ostrovech. Průběh těchto koncentrací udává obr. 1 (grafy a schémata – Nátr 2000), z něhož je patrný nejen rovnoměrný vzrůst, ale také určité sezonní kolísání v rámci jednoho roku, kdy minimum je v době pozdního léta a maximum v době pozdní zimy, a to podle ročních období severní polokoule (obr. 2). Geografické rozdíly v koncentraci CO_2 na Zemi jsou minimální, byť prokazatelné.

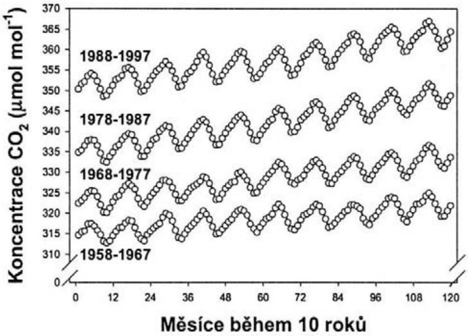
Příčiny soustavného zvyšování koncentrace CO_2, které začalo někdy v polovině minulého století, jsou obecně známy. Připomeňme proto základní údaje celkového koloběhu CO_2 mezi biosférou, atmosférou a oceány.

Globální cyklus uhlíku na Zemi je tvořen relativně malým počtem zdrojů i sinků. Poměrně přesně stanovenými **zdroji uhlíku** jsou:

– 5,4 Gt $C.rok^{-1}$: spalování fosilních paliv (G, giga, 10^9, tedy miliardy),



Obr. 1. Průběh koncentrace CO_2 (ppm neboli µmol.mol^{-1}) v atmosféře Země podle přesných stanovení na lokalitě Mauna Loa v období od roku 1958; graf sestaven podle údajů Keelinga a Whorfa (1998)



Obr. 2. Průběh koncentrace CO_2 jako na obr. 1, ale s uvedením měsíčních hodnot v průběhu jednotlivých dekád

– 1,6 Gt.rok^{-1}: změny ve využívání půdy spojené především s odlesňováním.

Naproti tomu **hlavní sinky** představují:

– 2,0 Gt.rok^{-1}: pohlcování v oceánech,

– 3,2 Gt.rok^{-1}: zvyšování koncentrace v atmosféře.

Připomínám, že jako sink se označuje místo, kde dochází ke spotřebě nebo hromadění dané látky.

Ve výsledné bilanci tedy chybí sink asi pro 1,8 Gt.rok^{-1}. Toto je tzv. chybějící C, o němž se dosud přesně neví, kam se „ztrácí". Nasnadě je otázka, jakou roli zde hraje fotosyntéza rostlin. Odhaduje se, že globální roční fotosyntetická fixace dosahuje 100 Gt C.rok^{-1}. Přitom však prakticky stejné množství se vrací zpět do atmosféry jako důsledek dýchání rostlin (50 Gt C.rok^{-1}) a půdy (50 Gt C.rok^{-1}). Nejčastěji se spekuluje o tom, že právě rychlost fotosyntetické fixace CO_2 a následné uložení C ve vytvořené biomase jsou podceněny. Tento názor podporuje samotný vzestup koncentrace CO_2 v atmosféře, který působí pozitivně na rychlost fotosyntézy. Předpokládá se například, že globální zvýšení produkce sušiny suchozemských rostlin o pouhých 10 % by pokrylo současné emise CO_2 vytvářené spalováním fosilních paliv. Ovšem ani tato představa není zcela jednoznačná.

Ten „chybějící článek" v neúplné bilanci je samozřejmě v popředí zájmu vědců. Snad nás překvapí, že nejvíce je zatím předmětem studia otázka, do jaké míry jednotlivé typy suchozemských ekosystémů představují zdroj CO_2, to znamená, že do atmosféry uvolňují v celoroční bilanci více CO_2, než samy pohlcují, nebo sink, kde by převládal příjem a fixace CO_2 nad celkovým výdejem.

Metody studia vlivu koncentrace CO_2 na rostliny

Pro lepší pochopení výsledků studia vlivu zvýšené koncentrace CO_2 na rostliny je vhodné, abychom si alespoň velmi stručně připomněli, jakými metodickými postupy se tyto výsledky získávají.

Ve většině případů, kdy se zmiňuji o vlivu zvýšené koncentrace CO_2 na rostliny, mám na mysli koncentrace v rozsahu 600 ppm až 700 ppm ve srovnání se stávajícími či nedávno ještě existujícími 350 ppm až 370 ppm CO_2 ve vzduchu. Očekává se, že uvedené zvýšené koncentrace CO_2 budou v atmosféře Země dosaženy někdy v polovině příštího století.

Základním principem metod měření vlivu zvýšené koncentrace CO_2 na rostliny je umístění části rostliny, celé rostliny nebo skupiny rostlin (části porostu) do prostředí, kde je tato zvýšená koncentrace CO_2 udržována trvalým průtokem vzduchu obsahujícím příslušnou koncentraci CO_2. Přitom bývá někdy řízena i teplota vzduchu, případně záření (světlo). Po době expozice, která trvá dny, týdny, ale i roky, se srovná hmotnost sušiny či jiné parametry takto exponovaných rostlin s parametry těch rostlin, které po uvedenou dobu rostly ve srovnatelných podmínkách, ale při okolní koncentraci CO_2. Můžeme rozlišit následující skupiny metod:

(1) **Malé kyvety nebo vaky**, v nichž je umístěna část rostliny, nejčastěji větev nebo jiná část prýtu. Je to nejjednodušší postup, kdy expozice trvají několik dnů. Tento způsob je vhodný zejména pro studium některých dílčích problémů.

(2) **Velké uzavřené kyvety či komory**, v nichž jsou exponovány celé rostliny nebo mladé stromky. Expozice většinou trvá celou vegetaci. Rostliny bývají zasazeny v nádobách s různým substrátem.

(3) **Velké kyvety s otevřeným stropem** (anglicky „open-top chambers"). Konstrukcí a způsobem provedení se podobají předchozímu typu, avšak chybějící stropní stěna vytváří příznivější podmínky pro udržení mikroklimatu srovnatelného s volnou přírodou. Navíc se tento velmi rozšířený typ kyvet velmi dobře uplatňuje i v přirozených porostech, kde tedy nemusejí být rostliny přesazovány z volné půdy do nádob.

(4) **Systém FACE** (z anglického „Free Air CO_2 Enhancement"), který označuje obohacování volné atmosféry

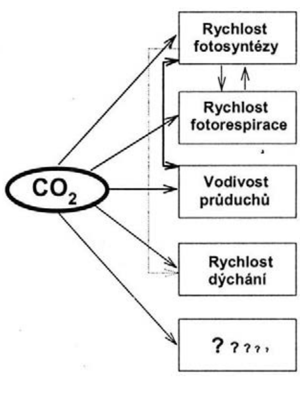
oxidem uhličitým. Je to patrně nejlepší současný systém, který umožňuje studium částí porostů zemědělských i vzrostlých lesních plodin. Přitom prakticky nedochází k narušení přirozeného mikroklimatu. Jeho podstatu tvoří systém trubic, které na obvodu kruhu o průměru asi 20 m přivádějí vzduch se zvýšenou koncentrací CO_2. Podle síly a směru větru se vzduch přivádí především do trubic na určité straně pokusného kruhu, a to v závislosti na údajích o koncentraci CO_2 monitorované v exponovaném porostu. Je to technicky, a tedy i finančně neobyčejně náročný systém, jehož asi osm současných instalací, především v USA, již poskytlo obrovskou spoustu poznatků, které jsou například pro lesní porosty jinak nedosažitelné. Jen pro zajímavost připomínám, že obdobný typ pokusného uspořádání realizoval již počátkem 20. let tohoto století Lundegårdh. Jeho zařízení bylo technicky mnohem primitivnější, což bylo zřejmě příčinou i nejednotných výsledků, které Lundegårdh získal.

(5) **Přirozené výrony CO_2** poskytují pozoruhodnou příležitost sledovat vliv opravdu dlouhodobého (až po staletí) působení zvýšené koncentrace CO_2 na růst rostlin. Existují zajímavé pokusné práce především z Islandu a Itálie.

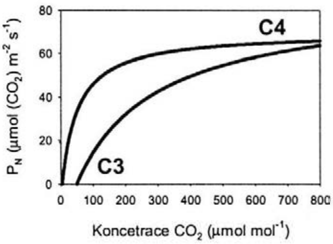
Přímé účinky CO_2 na rostliny

Přímé působení CO_2 na rostliny zasahuje jen málo procesů. Podle obr. 3 rozlišujeme přímý vliv CO_2 na:

1. **Rychlost fotosyntézy** nebo snad přesněji: rychlost fixace CO_2 karboxylačními enzymy rostlin. Tato závislost je ilustrována na obr. 4, kde jsou rozlišeny rostliny na skupinu C3 a C4. Samotná charakteristika těchto skupin rostlin je velmi zajímavou tematikou, která snad bude popsána v jiném příspěvku. Pro pochopení vlivu CO_2 zatím postačí konstatování odvozené i z uvedeného obr. 4, podle něhož jsou rostliny C4 (kukuřice, cukrová třtina aj.) stávající koncentrací CO_2 prakticky nasyceny,



Obr. 3. Znázornění přímých účinků CO_2 na fyziologické procesy rostlin



Obr. 4. Průběh závislosti rychlosti čisté fotosyntézy (P_N) na koncentraci CO_2 u rostlin C3 a C4

zatímco rostliny C3 (obilniny, cukrová řepa aj.) na současné zvyšování koncentrace CO_2 reagují zvýšením rychlosti fotosyntézy.

2. **Rychlost fotorespirace**. Opět jen velmi stručně připomeňme, že karboxylační enzym ribulóza-1,5-bisfosfát-karboxyláza, zkráceně rubisco, působí také jako oxygenáza. To znamená, že na příslušný substrát je schopná vázat nejen molekulu CO_2, ale také kyslíku, O_2. Při současné koncentraci CO_2 (viz výše) a současných 21 % kyslíku ve vzduchu je u rostlin C3 při fixaci asi tří molekul CO_2 fixována vždy jedna molekula O_2, což představuje pokles rychlosti fotosyntézy, a tedy i množství vytvořených asimilátů. Uvedená fotorespirace se týká prakticky jen rostlin C3, protože u rostlin C4 je vzhledem k odlišnému systému fixace CO_2 zanedbatelná. A právě zvyšující se koncentrace CO_2 inhibuje fotorespiraci, a tím přispívá ke zvýšení rychlosti fotosyntézy.

3. **Vodivost průduchů**. Oxid uhličitý se z atmosféry do buněk v listech dostává difuzí. Ne však celým povrchem listů, protože kutikula je pro CO_2 prakticky nepropustná, ale jen průduchy, které jsou vytvářeny dvěma svěracími buňkami. Čím více se svěrací buňky od sebe oddálí, tím větší je průduchová štěrbina, a tím více CO_2 může difundovat z okolního vzduchu do intercelulárních prostorů a posléze až do chloroplastů buněk mezofylu. Stejnými průduchy difunduje do listů kyslík (v noci) a z listů také vodní pára, jejíž únik představuje stomatální transpiraci. Otevřenost průduchů stoupá při poklesu koncentrace CO_2. To tedy znamená, že současné zvyšování koncentrace CO_2 ve vzduchu vyvolává přivření průduchů. Tak dochází k omezení výdeje vody z rostliny. Na rychlost fotosyntézy, tedy na rychlost difuze CO_2 do listů však toto přivření vliv nemá, protože se zároveň zvyšuje rozdíl koncentrací CO_2 mezi atmosférou a intercelulárami listů. A rychlost fotosyntézy je přímo úměrná tomuto gradientu koncentrací CO_2 mezi atmosférou a vzduchem v intercelulárách.

4. **Rychlost dýchání**. Jako všechny živé organismy také rostliny dýchají, to znamená, že spotřebovávají zejména cukry, které za spotřeby kyslíku rozkládají na CO_2 a vodu a vytvářejí různé meziprodukty potřebné k zabezpečení jednotlivých funkcí celého organismu. Rostliny dýchají zejména v noci, ale tento proces neustává ani na světle.

Vliv CO_2 na dýchání rostlin není dosud jednoznačně vysvětlen. Domnívám se však, že zejména literatura posledních let poskytuje dostatek experimentálních dokladů pro tvrzení, že zvyšující se koncentrace CO_2 snižuje rychlost dýchání.

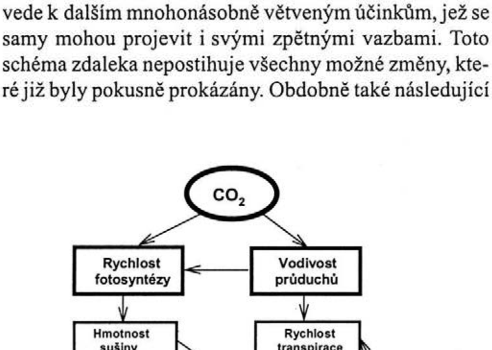
5. **Dosud neznámé mechanismy**. Z některých experimentálních prací lze odvodit, že existují ještě další procesy, na které změna koncentrace CO_2 působí přímo. Nepovažuji za nutné tyto pokusy zde rozvádět. Zdá se mi však potřebné upozornit, že naše poznání přímého vlivu CO_2 na rostliny ještě pořád není konečné.

Podíváme-li se na uvedený přehled procesů, které jsou zvyšující se koncentrací CO_2 přímo ovlivněny, nezdá se být tato problematika nikterak složitá. **Prostě můžeme očekávat zvýšení rychlosti fotosyntézy, tj. tvorby biomasy, omezení fotorespirace i spotřeby vody a patrně také pokles rychlosti dýchání.** To vše jsou důsledky, které jsou člověku – a vlastně všem heterotrofním organismům – příznivé, protože **vedou k růstu primární produkce organických látek.**

V čem je tedy problém a kde zůstali třeba oni motýli zmiňovaní v úvodu? To by měla nastínit následující kapitola.

Nepřímé vlivy zvyšující se koncentrace CO_2 na rostliny

Obr. 5 ukazuje několik sekvencí změn, k nimž dochází v rostlinách při změně koncentrace CO_2 v okolním vzduchu. Naznačeny jsou pouze primární účinky CO_2 na rychlost fotosyntézy a vodivost průduchů, jejichž změna vede k dalším mnohonásobně větveným účinkům, jež se samy mohou projevit i svými zpětnými vazbami. Toto schéma zdaleka nepostihuje všechny možné změny, které již byly pokusně prokázány. Obdobně také následující



Obr. 5. Znázornění nepřímých účinků zvýšené koncentrace CO_2 na procesy a struktury rostlin. Z přímých vlivů je uvedeno jen působení CO_2 na rychlost fotosyntézy a vodivost (otevřenost) průduchů

text přináší jen vybrané příklady postupností změn indukovaných změnami procesů, na něž CO_2 působí přímo.

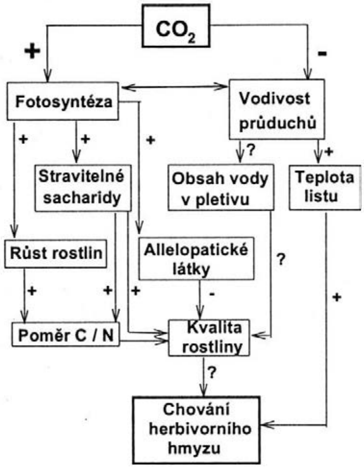
Zvýšení rychlosti fotosyntézy vede k **větší tvorbě cukrů**, tedy sloučenin obsahujících převážně uhlík a neobsahujících žádný dusík. Zvýšené množství asimilátů se může transportovat do jiných částí rostliny zejména v případě, že je dosti „spotřebitelů", tedy sinků pro tyto látky. To znamená, že rostlina s dostatečným větvením či odnožováním nebo s intenzivně rostoucími kořeny může vytvářený přebytek spotřebovat na růst těchto rozvíjejících se orgánů. Často se však stává, že růst nových orgánů je limitován nedostatkem minerálních živin, nejčastěji dusíku. V tom případě zůstává většina asimilátů v listech a dochází ke zvýšení hodnoty poměru uhlíku k dusíku, tedy **C/N v biomase.** Samotné zvýšení obsahu cukrů v listech však zcela v souladu s intuitivním očekáváním začne zpětnovazebně působit na snížení rychlosti fotosyntézy. Vnější faktory – dostatek záření a zvýšená koncentrace CO_2 – mohou být příznivé pro fotosyntézu, ale vnitřními faktory je její rychlost omezována. Mechanismů pro toto omezování je patrně více. Účastní se i genetický aparát v tom smyslu, že hromadící se cukry inhibují přepis genů kódujících fotosyntetické enzymy. Omezí se tedy množství enzymů, které zajišťují fotosyntetickou fixaci CO_2, která tím rovněž klesá. Obrazně řečeno, celý systém má sice dostatek energie (sluneční záření) a surovin (CO_2), ale chybí mu „strojní vybavení" pro jejich zpracování. A tak vědci trochu překvapivě zjišťují, že při dlouhodobé kultivaci rostlin v podmínkách se zvýšenou koncentrací CO_2 dochází k postupnému poklesu jejich rychlosti fotosyntézy. Tedy k procesu, který je obecně označován jako aklimace fotosyntézy.

Ovšem v případě dostatku vody i minerálních živin je vytvářený nadbytek asimilátů využit na stavbu například mohutnějšího kořenového systému. Ten je schopen zajistit větší množství živin i vody, a tak podpořit účelné využití dalších asimilátů. Kromě toho se zvyšuje celková biomasa rostlin. Větší listová plocha dále zesiluje pozitivní účinek zvýšené koncentrace CO_2, takže celková produkce asimilátů jednou rostlinou nebo porostem se ještě zvýší.

Uvedenými dvěma alternativami – dostatek či nedostatek vody a minerálních živin pro rostliny pěstované při zvýšené koncentraci CO_2 – pak lze dobře vysvětlit enormní rozdíly v reakci jednotlivých rodů, druhů i kultivarů na zvýšenou koncentraci CO_2. Tyto rozdíly byly v počátcích výzkumu trochu překvapivé, protože se obtížně vysvětlovalo, proč jeden kultivar pěstovaný při dvojnásobné koncentraci CO_2 zvyšuje svou produkci hmoty o 10 %, zatímco jiný i o 100 %. Přitom nejčastěji se setkáváme se zvýšením produkce rostlin za celou dobu jejich vegetace o 20 až 30 %.

Ale ještě si všimněme dalších důsledků naznačené změny poměru C/N v sušině rostlin pěstovaných při zvýšené koncentraci CO_2. Začněme jedním konkrétním příkladem (obr. 6).

Bylo studováno 49 interakcí mezi hmyzem a rostlinami v podmínkách zvýšené koncentrace CO_2. Ve 36 případech



Obr. 6. Schéma nepřímých vlivů zvýšené koncentrace CO_2 na chování herbivorního hmyzu. Naznačeno je zvýšení (+), snížení (–) nebo neznámé (?) působení;. upraveno v návaznosti na Bezemera a Jonese (1998)

nebyl zjištěn žádný vliv. Ovšem v deseti případech došlo k urychlení vývoje hmyzu, avšak ve třech případech k jeho zpomalení. Přitom u samotných rostlin může dojít k urychlení nebo naopak ke zpoždění doby kvetení. To může dokonale **„odpojit" opylovače od jejich rostlinných druhů** s následky jak pro rostlinu, tak i pro příslušný hmyz. Přitom právě hmyz patří k rozhodujícím složkám mnoha ekosystémů, a to pokud jde o celkovou biomasu i druhovou četnost. Změny chování nebo dokonce výskytu některých druhů hmyzu jsou často prvními rozeznatelnými indikátory i velmi mírných změn klimatu. Například rašení pupenů mnoha druhů dřevin mírného pásma vyžaduje období chladu, po němž následuje výrazné oteplení. Některé druhy stromů vyžadují poměrně dlouhé období chladu a každé omezení počtu chladných dnů silně zvyšuje termální čas, který je nezbytný pro rašení pupenů (připomeňme, že termální čas se nejčastěji vyjadřuje součtem průměrných denních teplot zmenšených o určitou teplotu bazální). Tím překvapivě i v teplejším klimatu dojde k pozdějšímu rašení pupenů. Naopak u stromů, jejichž požadavek na nízké teploty je menší, může zvýšená teplota rašení pupenů urychlit. Zcela obdobná je situace u mnoha druhů hmyzu, který pro kladení vajíček vyžaduje jisté období chladu následované obdobím s vyšší teplotou. Dobrým příkladem je píďalka podzimní (*Operophtera brumata*), která parazituje na dubech i dalších rostlinách. Rašení dubů je dobře korelováno s termálním časem, který se zkracuje s prodloužením délky dne. Protože fotoperioda zůstává konstantní, tak teplejší klima může urychlit rašení pupenů u dubu (jak bude patrné z dalšího textu, tak zvýšená koncentrace CO_2 může zvyšovat teplotu listů). Lze si proto snadno představit, že doba rašení a kladení vajíček bude „rozfázována" s kritickými následky pro tento druh hmyzu. Přitom se tento vliv projeví i na vyšších úrovních trofického řetězce, který bude ovlivněn menší četností hmyzích larev, které jsou základní potravou některých ptáků.

Uvedené příklady naznačují mechanismus, který může v podmínkách zvýšené koncentrace CO_2 ovlivnit složení a strukturu jednotlivých ekosystémů. Nejde už o hypotetické úvahy, ale o závěry mnoha konkrétních pokusů.

Uvedu ještě jeden příklad důsledků zvýšení hodnoty poměru C/N u rostlin pěstovaných při zvýšené koncentraci CO_2. Listy těchto rostlin se sníženým obsahem N tvoří hlavní složku opadu. Tím také **půdní organická hmota** je systematicky obohacována cukry, což umožní větší rozvoj půdních mikrobů. Ty však mohou vázat zvýšené množství minerálních živin, tedy je imobilizovat, což dále omezí jejich dostupnost pro rostliny. Výsledkem je ještě výraznější zvýšení obsahu cukrů v listech rostlin, tedy zesílení celého jevu. Ale v závislosti na vnějších podmínkách, především teplotě a dostatku vody, může v určité fázi dojít k odumření a rozkladu onoho zvýšeného množství mikrobů, tím se uvolní větší množství minerálních živin, které jsou nyní pro rostliny přijatelné. Zvýšený příjem živin pak umožní rychlejší růst rostlin a nakonec povede k poklesu obsahu cukrů v listech, tedy k jistému poklesu obsahu C/N.

Naznačené sekvence dějů mohou působit trochu zmatečně a navodit dokonce představy o jakýchsi uměle konstruovaných komplikacích. Nikoliv. To vše jsou prvé výsledky mnoha experimentů mnoha autorů na celém světě. Snad to pomůže objasnit ještě jeden příklad.

Zvýšení koncentrace CO_2 snižuje vodivost průduchů, a tím se omezí výdej vody transpirací z rostliny. Výsledkem je to, že na jednotku vyprodukované sušiny se spotřebuje méně vody, tedy zvýší se účinnost využití vody rostlinami. To je poznatek, který je velmi příznivý, protože úbytek vody použitelné v zemědělství k závlahám je obecně znám. Ale opět nastupují další důsledky. Menší výdej vody transpirací sníží také ochlazování listů, takže teplota rostlin se zvýší. Tím se zvýší rychlost dýchání, tedy rozklad organických látek na CO_2 a vodu. Současně lze očekávat pokles relativní vlhkosti vzduchu kolem rostliny. Tento pokles spolu se zvýšenou teplotou listů však může výdej vody rostlinami pěstovanými při vyšší koncentraci CO_2 zvýšit, takže původní pozitivní vliv na účinnost využití vody se anuluje. A pokud současně dojde k větší produkci biomasy a listové plochy, tak se může výdej vody rostlinami ve zvýšené koncentraci CO_2 dokonce zvýšit, čímž se zejména na přirozeném stanovišti vyčerpají zásoby vody dříve, než tomu je v podmínkách současné koncentrace CO_2. Záleží tedy na řadě ostatních faktorů, jaký bude sled dějů indukovaných poklesem vodivosti průduchů. Jakkoliv můžeme očekávat obecné zvýšení účinnosti využití vody, tak v konkrétních podmínkách můžeme být svědky úplně opačného výsledku.

Právě uvedená podmíněnost změn kvantitativních vazeb mezi mnoha parametry vnějšího prostředí a rostlinami je příčinou, že přes ony tisíce publikovaných prací neexistuje dosud obecně platná představa o sledu procesů indukovaných zvýšenou koncentrací CO_2. Zdá se, že teprve další poznatky, kvantitativně popisující reakce jednotlivých druhů a kultivarů rostlin na zvýšenou koncentraci CO_2, přinesou dostatek podkladů pro konstrukci modelů, které budou respektovat i ono symbolické chvění motýlích křídel. Do té doby musíme jednotlivé pokusy vyhodnocovat s velkou pečlivostí, abychom obecné závěry nevyvozovali na úkor neúměrného zjednodušení.

V 50. a 60. letech tohoto století by možná nikoho nenapadlo věnovat se studiu vlivu zvýšené koncentrace CO_2 na rostliny, protože vše se zdálo být průhledně jasné. Teprve uvědomění si důsledků růstu skleníkových plynů, zejména CO_2, iniciovalo pokusy, jimiž měla být stanovena míra stimulace růstu jednotlivých druhů rostlin v jednotlivých podmínkách. A tyto pokusy se staly základem pro mnohem rozsáhlejší výzkum, jehož cílem je dosáhnout poznání zákonitostí, jimiž zvyšující se koncentrace CO_2 působí na rostliny. Teprve potom bude možné jednak určit funkci jednotlivých ekosystémů, zejména lesů, v koloběhu uhlíku na Zemi a jednak připravit lidstvo na změny zemědělských a přirozených ekosystémů vyvolaných stoupající koncentrací CO_2.

Zvyšující se koncentrace CO_2 v atmosféře, k níž došlo od poloviny minulého století, se nesporně podílela také na **zvyšování výnosů polních plodin**. Stejně tak všechny zmíněné vlivy nárůstu koncentrace CO_2 v blízké budoucnosti budou silně modifikovat rostlinnou produkci. Je proto žádoucí, abychom uvedeným změnám správně porozuměli. To umožní zejména zemědělcům vhodně reagovat na probíhající změny a podle možností je využít i pro racionalizaci pěstování kulturních rostlin.

LITERATURA

Bezemer T.M., Jones T.H. (1998): Plant-insect herbivore interactions in elevated atmospheric CO_2: quantitative analyses and guild effects. Oikos, *82*: 212–222.

Keeling C.D., Whorf T.P.: Atmospheric CO_2 concentrations (ppmv) derived from *in situ* air samples collected at Mauna Loa Observatory, Hawaii. http://cdiac.asd.ornl.gov/ftp/maunaloa-CO2/maunaloa.co2.

Nátr L. (2000): Koncentrace CO_2 a rostliny. Praha, ISV.

Došlo 12. 6. 2000

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XVII. Biochemický sjezd

Mezi významné události ve vědeckém životě uskutečněné v roce 2000 u nás bude jistě patřit XVII. biochemický sjezd, který se konal ve dnech 7. až 10. září 2000 v Praze. Pořadateli tohoto významného vědeckého sympozia byly Česká společnost pro biochemii a molekulární biologii a Slovenská spoločnosť pre biochémiu a molekulovú biológiu při SAV ve spolupráci se Společností klinické biochemie ČZS JEP. Sjezd probíhal v moderním areálu teoretických ústavů Fakulty architektury ČVUT v Praze-Dejvicích. Organizačně a technicky byl do všech detailů velmi dobře zabezpečen. Zúčastnilo se ho celkem 492 registrovaných biochemiků, většinou vědeckých a pedagogických pracovníků z vysokých škol, ústavů AV ČR a SR, rezortních výzkumných ústavů i jiných institucí.

Na sjezdu bylo vybranými specialisty prezentováno pět plenárních přednášek a 361 ústních sdělení nebo posterů. Pracovní jednání sjezdu probíhalo ve 14 odborných sekcích:

1. Molekulárně biologické techniky a jejich aplikace v základním a aplikovaném výzkumu
2. Peptidy a proteiny – struktura, vlastnosti
3. Enzymologie
4. Sacharidy
5. Regulační procesy, intra- a extracelulární signalizace, biologické membrány
6. Bioenergetika
7. Patobiochemie a klinická biochemie – nové imunochemické techniky a jejich aplikace
8. Reaktivní formy kyslíku a dusíku, antioxidační systémy
9. Biotechnologie, potravinářská chemie
10. Xenobiochemie
11. Ekologie
12. Biochemie a molekulární biologie rostlin
13. Technické algoritmy inspirované biologickými procesy
14. Varia

Podrobná abstrakta všech přednášek i posterů v anglickém znění včetně jmenného autorského rejstříku jsou vhodně uspořádána v obsáhlém sborníku sjezdu, který vyšel jako samostatná náplň monotematického čísla 8 Chemických listů 2000, v rozsahu stran 489–760.

Doc. RNDr. Ing. Josef Zahradníček, CSc.

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In this institute scientific journals dealing with the problems of agriculture and related sciences are published on behalf of the Czech Academy of Agricultural Sciences. The periodicals are published in English with abstracts in Czech.

Journal	Number of issues per year	Yearly subscription in USD Europe	Yearly subscription in USD overseas
Rostlinná výroba (Plant Production)	12	195,-	214,-
Czech Journal of Animal Science (Živočišná výroba)	12	195,-	214,-
Agricultural Economics (Zemědělská ekonomika)	12	195,-	214,-
Journal of Forest Science	12	195,-	214,-
Veterinární medicína (Veterinary Medicine – Czech)	12	159,-	167,-
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A change of publication language in Scientific Journals of the Czech Academy of Agricultural Sciences

As recommended by Board of Publishers of the Czech Academy of Agricultural Sciences all papers in **Rostlinná výroba** (Plant Production) will be published **solely in English** since 1st January 2001.

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ROSTLINNÁ VÝROBA PLANT PRODUCTION

Volume 47, No. 1 January 2001

OBSAH – CONTENTS

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Podávání novinových zásilek povoleno Českou poštou, s. p., Odštěpný závod Střední Čechy, č. j. NOV-6596/00-P/1 dne 9. 5. 2000