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THE EFFECT OF SOIL APPLICATIONS OF ZEOLITE, AGRISORB AND LIGNITE ON THE CHEMICAL COMPOSITION OF CLOVER-GRASS MIXTURES GROWN IN ARID CONDITIONS OF SOUTH MORAVIA

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Abstract

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The two-year field trial was established in May 2008 on light soil in the cadastre of Ratíškovice near Hodonín in an arid maize-growing production area. Prior to sowing selected soil conditioners were applied in experimental plots of an area of 864 m^2 as follows: zeolite (a mineral of high sorption capacity), lignite (the youngest coal containing humus substances) and the supplementary soil substance agrisorb (polymer organic compound capable of holding in its structure and subsequently releasing water) and they were incorporated into a profile of 0.15 m. Including the untreated control the experiment involved 4 treatments. The rates of the conditioners were as follows: zeolite – 3 $l.m^{-2}$, fraction used 1–2 mm; agrisorb – 20 $g.m^{-2}$; lignite – 1000 $g.m^{-2}$. Three types of clover-grass mixtures were sown: landscape mixture with an addition of leguminous plants (seeding rate 200 $kg.ha^{-1}$), regional mixture (100 $kg.ha^{-1}$) and annual mixture (70 $kg.ha^{-1}$). The aboveground biomass taken from an area of 0.05 m^2 was sampled in the stage of bud setting with three repetitions to each treatment.
In 2008 and 2009 the respective treatments did not significantly change the contents of N, P, K, Ca and Mg in the aboveground biomass of the clover-grass mixtures. The differences in the contents of the macro elements were significant only between the individual types of mixtures and were due to their different botanical composition. Between the years 2008 and 2009 no significant differences were discovered among treatments in terms of the contents of P and K in none of the mixtures, but the Mg content decreased in the second year in most treatments by 50 relative % and more. The contents of N and Ca increased significantly in the second year in the regional and landscape mixtures; in the annual mixture also the Ca content. The year-on-year differences however were seen also in the untreated control showing the apparent effect of the year. A longer period of monitoring is necessary if we are to achieve an objective evaluation of the effect of the applied preparations on the chemical composition of the aboveground biomass.

South Moravia, soil, arid conditions, zeolite, Agrisorb, lignite, chemical composition of plants

Soil is the most frequently used substrate for plant growing and is characterised by certain specific (physical, biological, chemical, physical-chemical and other) properties. The soil and agrochemical properties can considerably influence plant growth and development, particularly in arid conditions or during a deficit in precipitation. The capacity to absorb water and nutrients dissolved in the water is markedly worse in light soils than in soils with a higher proportion of clayey particles (medium and heavy). Therefore in light soils the danger of depletion of nutrients (NO_3^-, SO_4^{2-}, etc.) by washing out is more imminent (Mengel and Kirkby, 2001). That is the reason why plants on light soils suffer from drought-related stress much more (Lošák *et al.*, 2008).

To achieve adequate yields and quality of production it is necessary to comply with the principles of balanced plant nutrition (Marschner, 2002). An adequate supply of available macro- and micro-biogenic elements in the soil and in the plant is a prerequisite for plant growth and development. If these conditions are fulfilled with respect to the law of conservation of mass and Liebig's law of minimum we can work on the assumption that varied supplementary substances, preparations and soil conditioners will be exploited. A supplementary soil substance is a substance with no active amount of nutrients, which otherwise has a beneficial biological, chemical or physical effect, improves the condition of the soil and enhances the efficiency of fertilisers. A supplementary plant preparation is a substance without an active amount of nutrients, which otherwise has a beneficial effect on the development of cultural plants or on the quality of plant products (Law 156/1998 Coll.). If the supplementary substance or soil conditioner helps to increase the sorption of water or nutrients in the soil we can expect that plants are better supplied with available nutrients and that depletion of nutrients from the soil caused by washing out is reduced. Increased nutrient intake should have a subsequent effect also on the chemical composition of the plant biomass (Mengel and Kirkby, 2001).

Zeolites are crystal alumina silicate that has negative charge, which is balanced by one or two valence positively charged cations (Mumpton, 1999). Other properties of zeolites contain high absorption level, water retaining and releasing, high cation exchange capacity (CEC) and high buffering against to change of pH. Zeolite changes media pH and influences element absorption (Allen and Ming, 1995). High exchange potential of cation NH_4^+ and K^+ has been considered as an important property of zeolites (Maloupa *et al.*, 1999). Physical and chemical properties of zeolite: specific gravity: 2.17 gr/cm^3; bulk density: 1.14 gr/cm^3; total porosity: 57.23 %; water porosity: 42.4 %, air porosity. 14.83 %; CEC: 170 meq/100g; pH: 8.13; EC: 3.01 (Ghazvini *et al.*, 2007).

For a long time lignite was the youngest mined coal used as fuel and for energetic purposes in the area of south Moravia. In terms of energy however (heating value, total heat value) the quality of lignite as coal is not high. Isolation of humic acids from brown coal is relatively frequent, but experience with and knowledge of direct application of natural lignite to soil is only minimal. Such an application should also be more economical because it does not pose costs for extraction and recycling or processing of the used agents. Naturally, humic substances contained in lignite have a different genesis than humic substances in the soil (Pekař *et al.*, 2009). Analyses comparing the elementary composition of humic acids isolated from lignite and some soil types indicate that in terms of the content of C, H and proportion of aromatic and aliphatic carbon the lignite acids are very close to chernozem acids. They differ in a lower content of nitrogen (Pekař *et al.*, 2005). The advantage of humus is its high ion-exchangeable capacity which ensures binding of nutrients in the soil and reduces their leaching. It reacts with the mineral colloid soil fraction and improves the physical and physical-mechanical soil properties, regulates the soil water and air regime, binds xenobiotic pollutants in the soil etc. (Kolář *et al.*, 2008). Some technologies use lignite as a substrate for the growth of micro-organisms decomposing various organic pollutants (Rethmeier and Jonas, 2003). In many cases lignite reduces the content of heavy metals in plant tissues what is attributed to the sorption capacity of lignite not only towards metal ions (Pekař *et al.*, 2009, Klučáková and Omelka, 2004). On the basis of long-term investigations Honěk *et al.* (2001) give the average composition of lignite from south Moravia (mass %) converted either to dry matter (ash, S) or dry state free of ash (C, O, H, N) as follows: humidity 40–50 %, ash 8–50 %, C 64–68 %, O 22–29 %, H 5–6 %, N: 0.1–1.5%, S 1–4 %. The pH value ranges between 5 and 6 (Pekař *et al.*, 2009).

The objective of field trials lasting several years was to evaluate the possibility of applying soil conditioners and supplementary soil substances to light soil in arid conditions of south Moravia to increase the sorption of water and nutrients (and reduce losses due to washing out) which should be reflected in the chemical composition of the biomass of various clover-grass mixtures.

MATERIALS AND METHODS

The two-year field trial was established in May 2008 on light soil in the cadastre of Ratíškovice near Hodonín in an arid maize-growing production area of south Moravia. We used the method of random blocks in 3 repetitions. The size of one block was 10,368 m^2, the dimension of each experimental plot (treatment) was 36 × 24 m = 864 m^2. In the experimental plot prior to sowing the mixture we applied soil conditioners zeolite (Z) and lignite (L) and supplementary soil substance agrisorb (A) using several types of applicators.

Zeolite minerals are crystalline hydrated aluminosilicates of alkali or alkaline-earth metals, structured in three-dimensional rigid crystalline network, formed by the tetrahedral AlO4 and SiO4, which come together to compose a system of canals, cavities and pores (Ming and Mumpton, 1989).

Lignite is the youngest coal and considering its composition it can also be used in agriculture – as a source of organic carbon or humic substances and also as an *in situ* soil remedial agent.

Agrisorb is a polymer organic compound whose structure is capable of retaining water and supplying the roots during vegetation. The gel that is formed from the preparation protects the ultra-fine root system (root hairs) against damage by drought and the effects of transplanting. After plant root treatment and following planting the presence of Agrisorb accelerates contact with the surrounding soil and in this way helps to overcome shock. Gel produced from 1 g can bind as much as 300 g of water (Straková *et al.*, 2009).

Including the untreated control the experiment comprised 4 treatments. The applications were as follows: zeolite – 3 l/m^2, i.e. 30 m^3/ha; the used fraction 1–2 mm; Agrisorb – 20 g/m^2, i.e. 200 kg/ha; lignite 1000 g/m^2, i.e. 10 tons/ha and the rate was specified with regard to the coarser soil texture; lignite was applied in the form of the preparation TerraClean. Single incorporation of supplementary soil substances into a profile of 0.15 m was performed with a compactor.

Three types of clover-grass mixtures were proposed for the following sowing: landscape mixture with an addition of leguminous plants (seeding rate 200 $kg.ha^{-1}$); regional mixture (100 $kg.ha^{-1}$) and annual mixture (70 $kg.ha^{-1}$).

The first cut was conducted late to allow natural seeding of the main species. Prior to the first cut the aboveground biomass from an area of 0.05 m^2 was sampled in three repetitions for each treatment. Sampling was conducted in the stage of bud setting on 20 August 2008 (due to the late sowing on 27 May 2008) and on 16 June 2009. The samples were weighed and then analysed for the individual groups: grasses, leguminous, herbs, and the not sown species – weeds. In these groups we determined the weight proportion in the green matter of the sample. The samples were then dried and again weighed to determine hay yields. The dried samples were homogenised.

The content of macrobiogenic elements in the plant biomass was assessed after wet mineralization (H_2SO_4+H_2O_2). The N content was assessed according to Kjeldahl, colorimetry was used to assess P, and the AAS method to assess K, Ca and Mg (Zbíral, 1994).

The content of available nutrients in soil samples prior to the establishment of the trial (Tab. I) was assessed by the method used in agrochemical testing of agricultural soils (AZZP) in extract Mehlich III (NH_4F, NH_4NO_3, CH_3COOH, HNO_3, EDTA). Available P was assessed from the soil extract by spectrophotometry as phospho-molybden blue; available K was assessed from the extract by atomic emission spectrometry (AES) in acetylene-air flame and available Ca and Mg were assessed from the extract after adding lanthanum by atomic absorption spectrometry (AAS) in acetylene-air flame. The exchangeable soil reaction was assessed with the method used for AZZP in a soil extract of 0.01 M $CaCl_2$ Zbíral (2002).

The results were processed statistically using variance analysis followed by testing according to Scheffe (P = 95%).

RESULTS AND DISCUSSION

a) Agrochemical characteristics of the soil before establishment of the trial

Tab. I shows the results of analyses of the light soil before establishment of the experiment. The exchangeable soil reaction was strongly acid, the content of phosphorus very high, the content of potassium satisfactory and the content of calcium and magnesium low.

In terms of the nutrient content this soil does not provide optimum conditions for plant growth and development. Absolutely surprising is the very high content of phosphorus (the category "very high" equals more than 185 $mg.kg^{-1}$) and it is very difficult to find out the reason. However a number of factors limit the utilisation of phosphorus by plants of which the soil reaction value (pH) is crucial. In acid soils P yields to chemo-sorption and after reaction with Fe and Al passes into insoluble compounds which in fact the plants cannot utilise (Marschner, 2002; Mengel and Kirkby, 2001). In the matter of the remaining nutrients in the soil (K, Ca, Mg) it would be suitable to fertilise with mineral fertilisers although it is very likely that they would suppress the effects of the applied soil conditioners and supplementary soil substances; that is the reason why we did not take this into account and also with regard to the extent of the experiments.

b) Results of chemical analyses of plants of the individual species of the clover-grass mixtures

Tabs. II–IV give the results of chemical analyses of the clover-grass mixtures for the content of macrobiogenic elements (N, P, K, Ca, Mg) after treatment with the respective preparations. Three different types of clove-grass mixtures were used in the experiment: regional mixture (RM), landscape mixture (LM) and annual mixture (AM). The botanical composition of these mixtures is different.

In 2008 no significant differences among treatments 1–4 (Tab. II–IV) in the contents of the macrobiogenic elements (N, P, K, Ca, Mg) were discovered. Nevertheless in terms of statistical evaluation of the entire locality we monitored significant differences in the nutrient contents between some

I: *Agrochemical characteristics of soil prior to trial establishment, April 2008 (Mehlich III)*

pH/$CaCl_2$	**$mg.kg^{-1}$**			
	P	**K**	**Ca**	**Mg**
4.54	222	148	365	30
strongly acid	very high	satisfactory	low	low

II: *Content of macro elements in the regional mixture (RM) in 2008 and 2009 (% in dry matter)*

Var. No.	Indication	N	P	K	Ca	Mg
				2008		
1	Control	0.85 a	0.29 a	2.55 a	0.20 ab	0.21 a
2	Zeolite	0.99 a	0.34 a	2.52 a	0.21 ab	0.21 a
3	Agrisorb	0.83 a	0.28 a	2.58 a	0.17 ab	0.20 a
4	Lignite	0.86 a	0.28 a	2.18 a	0.14 a	0.21 a
				2009		
1	Control	1.97 b	0.33 a	3.29 a	0.50 b	0.10 b
2	Zeolite	1.68 b	0.28 a	2.37 a	0.53 b	0.11 b
3	Agrisorb	1.79 b	0.31 a	3.04 a	0.50 b	0.10 b
4	Lignite	1.90 b	0.31 a	2.76 a	0.53 b	0.11 b

Different letters (a, b) in columns indicate significant differences among treatments between 2008 and 2009

III: *Content of macro elements in the landscape mixture (LM) in 2008 and 2009 (% in dry matter)*

Var. No.	Indication	N	P	K	Ca	Mg
				2008		
1	Control	0.97 a	0.29 a	3.07 a	0.26 a	0.23 a
2	Zeolite	0.82 a	0.30 a	2.53 a	0.15 a	0.18 a
3	Agrisorb	1.03 a	0.31 a	2.87 a	0.23 a	0.22 a
4	Lignite	0.94 a	0.32 a	2.85 a	0.18 a	0.25 a
				2009		
1	Control	2.37 b	0.29 a	2.50 a	0.50 b	0.09 b
2	Zeolite	1.92 b	0.29 a	2.37 a	0.62 b	0.11 b
3	Agrisorb	2.22 b	0.32 a	2.79 a	0.55 b	0.12 b
4	Lignite	2.14 b	0.30 a	2.79 a	0.55 b	0.11 b

Different letters (a, b) in columns indicate significant differences among treatments between 2008 and 2009

IV: *Content of macro elements in the annual mixture (AM) in 2008 and 2009 (% in dry matter)*

Var. No.	Indication	N	P	K	Ca	Mg
				2008		
1	Control	0.86 a	0.24 a	1.95 a	0.12 a	0.17 a
2	Zeolite	0.98 a	0.28 a	2.00 a	0.10 a	0.16 a
3	Agrisorb	0.83 a	0.26 a	2.06 a	0.12 a	0.15 a
4	Lignite	0.79 a	0.26 a	2.12 a	0.09 a	0.18 a
				2009		
1	Control	1.32 ab	0.28 a	2.81 a	0.63 b	0.09 b
2	Zeolite	1.30 ab	0.25 a	2.04 a	0.46 b	0.09 b
3	Agrisorb	1.45 b	0.28 a	2.63 a	0.55 b	0.09 b
4	Lignite	1.02 ab	0.28 a	2.66 a	0.49 b	0.08 b

Different letters (a, b) in columns indicate significant differences among treatments between 2008 and 2009

of the grass mixtures, specifically as follows: between LM-AM in the phosphorus content; between RM-AM in the content of potassium; between RM-AM in the calcium content; and between RM-AM and LM-AM in the magnesium content.

It was the same in 2009 when no significant differences in the contents of macrobiogenic elements among treatments 1–4 (Tab. II–IV) were monitored. Just the same as in the previous year the differences in the contents of nitrogen between RM-AM and LM-AM were significant. Hence in both years the botanical composition of the stand influenced the content of the respective nutrients in the aboveground biomass.

In terms of the individual types of treatment of the stand (C, Z, A, L) in 2009 in all the types of mixtures it was discovered that treatments with agrisorb (A), lignite (L) as well as the control (C) had a significant effect on the N content in the biomass between LM-AM in the entire locality.

We compared the content of macro elements in the biomass of the regional mixture (RM) (Tab. II) of all the treatments (zeolite, agrisorb, lignite) and we discovered that the N content increased significantly in 2009, to more than double that of 2008. A similar trend was monitored also in the content of Ca; nevertheless a significant increase was reported in 2009 in all treatments only against the lignite treatment in 2008. Also Gul *et al.* (2005) reported an increased N content in tissues of head-lettuce from 2.90 to 3.37% after the application of zeolite. These results support the previous report of Harland *et al.* (1999) submitting that zeolite acts as a reservoir, holding elements in its structure for slow release to the substrate solution or directly to plant roots. Challinor *et al.* (1995) report that zeolite is highly selective for potassium and ammonium nitrogen. In a pot trial with maize and carrot Pekař et al. (2009) reported that the Cd and Pb contents decreased in the plant biomass with increasing content of lignite in the soil; however in vetch the Cd content did not change after lignite application.

In the second year of the experiment the Mg content decreased in all the treatments of all three mixtures approximately to one half of the content in the first year (Tab. II–IV). Gul *et al.* (2005, 2007) reached the same conclusions; they reported that after the application of zeolite the Mg content decreased in the aboveground biomass of lettuce from 0.45 to 0.37%. The reason for this decrease in the Mg content in plants may be its lower amount in the nutrient solution because it was absorbed due to the effect of the applied preparations.

No significant differences between the two years were monitored in the contents of P and K in none of the mixtures (Tab. II–IV). Neither Gul *et al.* (2005) found differences in the phosphorus content after the application of zeolite in lettuce leaves and Ghazvini *et al.* (2007) in strawberries. On the contrary Kavoosi (2007) reported that after the application of zeolite at rates of 8–24 $t.ha^{-1}$ the content of soil-available potassium and its uptake by rice straw increased.

The trends of the year-on-year differences in the regional mixture (Tab. II) are the same also for the landscape mixture (Tab. III). The content of Ca (as well as the N content) increased significantly in 2009 in all treatments compared to 2008. Ghazvini *et al.* (2007) likewise reported that the concentration of Ca in strawberry tissues increased from 0.08 to 0.20% after the application of zeolite. Calcium absorption and movement are related to water content of media. Applied zeolite enhanced water retention and Ca^{2+} (Ghazvini *et al.*, 2007). Cell membranes can be protected by Ca^{2+} on substrates with high level of EC (Turhan and Atilla, 2004). In the annual mixture (Tab. IV) the content of nitrogen increased significantly only after treatment with Agrisorb in 2009 as compared to all the treatments of 2008.

SUMMARY

In 2008 and 2009 the individual treatments did not significantly change the contents of N, P, K, Ca and Mg in the aboveground biomass of the respective clover-grass mixtures. A significant difference in the contents of macroelements was discovered only between the individual mixtures; this is due to their different botanical composition. No significant differences in the contents of P and K were observed between the years 2008 and 2009 in none of mixtures, but the Mg content decreased in the second year, in many cases by more than 50%. The N and Ca contents increased significantly in the second year in the regional and landscape mixtures and the Ca content increased also in the annual mixture. The year-to-year differences however appeared also in the untreated control and showed evidence of the effect of the year. To be able to evaluate objectively the effect of the applied preparations on the chemical composition of the aboveground biomass a longer period of investigations will be necessary.

The economic factor will decide about whether the various supplementary soil substances and soil conditioners will be used in practice and whether their properties are suitable for concrete site conditions (pH preparations and soil etc.). There is no doubt that their absorption capacity will reduce losses of nutrients caused by washing out but the object of future research will be e.g. investigations into the strength of the bond of nutrients in the soil (a kind of sorption) to make the bound biogenic elements (nutrients) available for the plants.

SOUHRN

Efekt půdní aplikace zeolitu, agrisorbu a lignitu na chemické složení jetelotravních směsí v aridních podmínkách jižní Moravy

Víceletý polní pokus byl založen v květnu roku 2008 na lehké půdě v katastru obce Ratíškovice u Hodonína, v aridní kukuřičné výrobní oblasti. Na pokusné parcely o velikosti 864 m^2 byly ještě před výsevem směsí aplikovány vybrané půdní kondicionéry zeolit (minerál s vysokou sorpční schopností), lignit (nejmladší uhlí s obsahem humusových látek) a pomocná půdní látka agrisorb (polymerní organická sloučenina, schopná do své struktury vázat a následně uvolňovat vodu), a zapraveny do profilu 0,15 m. Včetně neošetřené kontroly zahrnoval experiment čtyři varianty. Aplikované dávky byly následující: zeolit – 3 l.m^{-2}, použitá frakce 1–2 mm; agrisorb – 20 g.m^{-2}; lignit – 1000 g.m^{-2}. Pro následný výsev byly navrženy tři typy jetelotravních směsí: krajinná směs s přídavkem jetelovin (výsevek 200 kg.ha^{-1}), regionální (100 kg.ha^{-1}) a jednoletá směs (70 kg.ha^{-1}). Odběr vzorků nadzemní biomasy byl realizován ve fázi butonizace z plochy 0,05 m^2 ve třech opakováních z každé varianty. V jednotlivých ročnících 2008 a 2009 se jednotlivé druhy ošetření průkazně neodrazily na změnách obsahů N, P, K, Ca, Mg v nadzemní biomase jednotlivých jetelotravních směsí. Průkazný rozdíl v obsazích makroprvků byl zjištěn pouze mezi jednotlivými druhy směsí, což je dáno jejich odlišným botanickým složením. Mezi roky 2008 a 2009 nebyly zjištěny u všech směsí mezi jednotlivými variantami průkazné rozdíly v obsazích P a K, ale obsah Mg druhým rokem poklesl u většiny variant o 50 i více relativních %. Obsahy N a Ca signifikantně narostly ve druhém roce u regionální a krajinné směsi a v případě Ca i u jednoleté směsi. Popisované meziroční diference se ovšem projevily i u neošetřené kontroly, z čehož je patrný vliv ročníku. Pro objektivní posouzení efektu použitých přípravků na chemické složení nadzemní biomasy je nezbytné dlouhodobější sledování.

jižní Morava, půda, aridní podmínky, zeolit, agrisorb, lignit, chemické složení rostlin

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REFERENCES

ALLEN, E. R. and MING, D. W., 1995: Recent progress in the use of natural zeolites in agronomy and horticulture. *Nat. Zeolites,* 93: 477–490.

CHALLINOR, P. F., LE PIVERT, J. M. and FULLER, M. P., 1995: The production of standard carnations on nutrient-loaded zeolite. *Acta Horticulturae*, 401: 293–299.

GHAZVINI, R. F., PAYVAST, G. and AZARIAN, H., 2007: Effect of clinoptilolitic-zeolite and perlite mixtures on the yield and quality of strawberry in soil-less culture. *International Journal of Agriculture & Biology*, 9: 885–888.

GUL, A., EROGUL, D., ONGUN, A. R., 2005: Comparison of the use zeolite and perlite as substrate for crisp-head lettuce. *Scientia Horticulturae*, 106: 464–471.

GUL, A., EROGUL, D., OZTAN, F., TEPECIK, M., 2007: Effect of growing media on plant growth and nutrient status of crisp-head lettuce. *Acta Horticulturae*, 729: 367–371.

HARLAND, J., LANE, S. and PRICE, D., 1999: Further experiences with recycled zeolite as a substrate for the sweet pepper crop. *Acta Horticulturae*, 481: 187–194.

HONĚK, J., SCHEJBAL, C. a STANĚK, F., 2001: Jihomoravský lignitový revír. Komplexní studie. In: Sborník vědeckých prací VŠB-TU Ostrava, řada hornicko-geologická, monografie 3, 47, 272 s. (in Czech).

KAVOOSI, M. 2007: Effect of zeolite application on rice yield, nitrogen recovery, and nitrogen use efficiency. *Communations in soil science and plant analysis*, 38: 69–76.

KLUČÁKOVÁ, M. and OMELKA, L. 2004: Sorption of metal ions on lignite and humic acids. *Chem. Pap.*, 58: 170–175.

KOLÁŘ, L., KUŽEL, S., PETERKA, J., ŠTINDL, P. and PLÁT, V., 2008: Agrochemical value of organic matter of fermenter wastes in biomas production. *Plant, Soil, Environment*, 54: 312–328.

LOŠÁK, T., HLUŠEK, J., ŽALUD, Z., TRNKA, M., SEMERÁDOVÁ, D. a DUBROVSKÝ, M., 2008: Výživa rostlin v podmínkách měnícího se klimatu. In: *Bulletin*. Brno: ÚKZÚZ Brno, 5–10 (in Czech).

MALOUPA, E., SAMARTZIDIS, C., COULOUMBIS, P. and A. KOMNIN, A., 1999: Yeild quality and photosynthetic activity of greenhouse- grown "Madelom" Roses on Perlite- Zeolite Substrate mixtures. *Acta Hort*., 481: 97–9.

MARSCHNER, H., 2002: *Mineral nutrition of higher plants*. 2nd edition. London: Academic Press, 889 p.

MENGEL, K. and KIRKBY, E. A., 2001: *Principles of Plant Nutrition*. 5th Edition, Kluwer Academic Publishers, Dordrecht / Boston / London, 849 p.

MING, D. W. and MUMPTON, F. A., 1989: Zeolites in soils. In: Dixon JB, Weed SB, ed. Minerals in soil environments. 2nd ed. Madison: Soil Science Society of America, 873–911.

MUMPTON, F. A., 1999: Uses of natural zeolites in agriculture and industry. *Proc. Natl. Acad. Sci. U.S.A.*, 96: 3463–3470.

PEKAŘ, M., KLUČÁKOVÁ, BARANČÍKOVÁ, G., MADARAS, M. and MAKOVNÍKOVÁ, J., 2005: Afinity of soil and lignitic humic acids for Cu(II)

and Cd(II) ions. In Humic substances. Molecular details and applications in land and water conservation. E. Ghabbour, G. Davies, Eds. New York: Tailor and Francis, 14: 211–223.
PEKAŘ, M., KLUČÁKOVÁ, M., KUČERÍK, J. a KISLINGER, J., 2009: Lignit a jeho možné zemědělské použití (z pohledu chemika). In: konference Trávníky 2009, Hodonín, 61–66 (in Czech with English abstract).
RETHMEIER, J. and JONAS, A., 2003: Lignite based oil binder mats: a new absorbent strategy and technology. *Spill Sci. Technol. Bull.*, 8: 565–567.
STRAKOVÁ, M., SALAŠ, P., KOHUT, M. PEKAŘ, M., ŠEVČÍKOVÁ, M. a PELIKÁN, J., 2009: Modelový projekt zamezení biologické degradace půd v podmínkách aridního klimatu. In: Konference Trávníky 2009, Hodonín, 4–9 (in Czech with English abstract).
TURHAN, E. and ATILLA, E. 2004: Effect of chloride application and different growth media on ionic composition in strawberry plant. *J. Pl. Nut.*, 27: 1653–1665.
ZBÍRAL, J., 1994: *Jednotné pracovní postupy. Analýza rostlinného materiálu*. ÚKZÚZ Brno. (in Czech).
ZBÍRAL, J., 2002: *Jednotné pracovní postupy analýza půd I.* 2. vydání. ÚKZÚZ Brno, 197 s. (in Czech).
ZÁKON č. 156/1998 Sb. ze dne 12. června 1998, o hnojivech, pomocných půdních látkách, pomocných rostlinných přípravcích a substrátech a o agrochemickém zkoušení zemědělských půd (zákon o hnojivech), ve znění pozdějších předpisů (in Czech).

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