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THE INFLUENCE OF SOIL REACTION ON THE EFFECTS OF MOLYBDENUM FOLIAR FERTILIZATION OF OILSEED RAPE

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Abstrakt

Thirty-three field trials have been carried out on soils of different acidity (pH=4.1-7.1) to investigate the effect of foliar fertilization with molybdenum on oilseed rape. Three rates of the element: 30, 60 and 120 g $Mo \cdot ha^{-1}$, were applied on two dates: in the spring, a few days after the growing season started, and during the early stem formation stage. In the group of trials on very acidic and acidic soils, seed yields were on average 0.08 $t \cdot ha^{-1}$ higher. The regression equation demonstrated that a relative seed yield increase obtained as a result of molybdenum fertilization depended on the concentration of manganese and percentage of the silt fraction in the soil. Oilseed rape grown on slightly acidic and neutral soils responded to molybdenum fertilization with an average seed yield increase of 0.02 $t \cdot ha^{-1}$. The rate of molybdenum had a significant effect on rape yields only in the group of trials set up on slightly acidic and neutral soils. No significant difference was found between 60 and 120 g $Mo \cdot ha^{-1}$. However, both of these rates were more effective than the lowest dose of 30 g $Mo \cdot ha^{-1}$. No evidence was found to support any relationship between the date of molybdenum application and seed yields or any interaction between Mo rates and application dates in either group of the trials.

Key words: Mo doses, time of application, yield increase, soil pH.

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WPŁYW ODCZYNU GLEBY NA EFEKTY DOLISTNEGO NAWOŻENIA RZEPAKU MOLIBDENEM

Abstrakt

Na glebach o różnej kwasowości (pH=4,1-7,1) przeprowadzono 33 doświadczenia polowe, w których badano efekt dolistnego nawożenia rzepaku molibdenem. Stosowano dawki 30, 60 i 120 g Mo·ha^{-1} w 2 terminach: wiosną, kilka dni po ruszeniu wegetacji, oraz na początku formowania łodygi. W grupie doświadczeń z glebami bardzo kwaśnymi i kwaśnymi uzyskano zwyżki plonów nasion, średnio 0,08 t·ha^{-1}. Według równania regresji, względna zwyżka plonów wskutek nawożenia Mo zależała od zawartości manganu oraz procentowego udziału frakcji pyłu w glebie. W grupie doświadczeń z glebami lekko kwaśnymi i obojętnymi rzepak reagował zwyżką plonów – średnio 0,2 t·ha^{-1}. Wielkość dawki molibdenu miała istotny wpływ na plonowanie rzepaku tylko w grupie gleb lekko kwaśnych i obojętnych. Nie stwierdzono istotnej różnicy między dawkami 60 g i 120 g Mo·ha^{-1}. Obie były jednak skuteczniejsze niż dawka 30 g Mo·ha^{-1}. Nie udowodniono wpływu terminu oprysku molibdenem na plony nasion ani współdziałania wielkości dawki Mo z terminem jej stosowania w obu grupach doświadczeń.

Słowa kluczowe: dawki Mo, terminy aplikacji, zwyżka plonu, pH gleby.

INTRODUCTION

Oilseed rape as a crop is gaining in economic importance all over the world. Its seeds are a valuable material for production of edible oil as well as biofuels. Oilseed rape is known to be a demanding crop in terms of macroelemental nutrition, but the information on microelements it requires remains scarce. The available literature focuses on *Cruciferae* family (Katyal, Randhawa 1983) and oilseed rape (Shorrocks 1990) being very susceptible to B and Mo deficit.

In Poland, about 60% of arable land consists of acidic soils, in which molybdenum availability to plants is limited. Countries in which soils are sandy and acidic (Gupta, MacLeod 2006), for example south-western Australia (Brennan 2006), struggle with a similar problem of limited molybdenum availability. There, many crops, particularly large wheat plantations, receive molybdenum fertilizers, as liming is not economically viable (Brennan, Bolland 2007). According to Finck (1998), oilseed rape should be fertilized with Mo under the low pH conditions and high nitrogen application. Sulphur application can also decrease the Mo uptake by oilseed rape (Balik et al. 2007).

Oilseed rape, which is not always cultivated on soils providing the crop with optimum reaction, is likely to suffer from insufficient molybdenum supply. The objective of our study has been to test the response of winter oilseed rape to foliar fertilization with molybdenum under the conditions of different soil pH.

MATERIALS AND METODS

The trails were performed on commercially grown winter oilseed rape plantations in 8 Polish provinces. In total, 33 testing sites had been selected. The soils were highly varied in soil reaction (4.1 to 7.1 pH in 1 mol $KCl \cdot dm^{-3}$). Most of the tests were performed on acidic and slightly acidic soils, characterised by various abundance in macroelements (Table 1).

Table 1

Percent distribution of trials according to soil acidity and fertility

Soil fertility	P	K	Mg	Mo	Soil reaction	
Very low	7	7	18	-	very acid	12
Low	22	18	36	14	acid	36
Medium	43	47	36	75	slightly acid	36
High	21	14	10	11	neutral	16
Very high	7	14	-	-	alkaline	-

Strict experiments with 4 replications were set up on fields under winter oilseed rape. The experiments were established as two-factor split-plots with a single control object. The design of the experiments was as follows:

The control – no Mo fertilization

– factor I – date of fertilization with Mo 1) in spring, a few days after the onset of the growing season, 2) the early stem formation stage;
– factor II – molybdenum rates: 1) 30 g $Mo \cdot ha^{-1}$, 2) 60 g $Mo \cdot ha^{-1}$ and 3) 120 g $Mo \cdot ha^{-1}$.

Molybdenum was applied as an aqueous solution of ammonium molybdate which contained 54% Mo.

In spring, immediately before Mo fertilization, soil samples were taken. Oilseed rape seeds, in turn, were sampled during the harvest. Laboratory examination of the soil and plant material was carried out using the methods commonly applied at chemical and agricultural laboratory stations. Granulometric composition of the soils was examined according to the procedure described by Casagrande-Prószyński; soil pH was tested in 1 mol $KCl \cdot dm^{-3}$ and the available forms of phosphorus and potassium were determined by Egnar-Riehm method, while these of magnesium were assayed using Schachtschabel method. The results were processed statistically. Differences in seed yields between the fertilization objects were tested using analysis of variance for multiple experiments. The tables which compile yields and mean values for the first and second factor levels are set alongside the values of the so-called 'contrast', i.e. the difference in yields between the control and an average yield for molybdenum fertilized objects. Correlation and regression calculations, obtained with an aid of Statographics software, were used to draw conclusions.

RESULTS AND DISCUSSION

Certain pot experiments conducted in the 1980s and earlier in Poland demonstrated that oilseed rape grown on acid soils was lower in Mo with soil liming being capable of raising Mo concentration in plant tissues. It could be hypothesised that the response of oilseed rape to foliar fertilization with Mo would be more pronounced under low soil pH than on soils of the reaction closer to neutral one. The results of our studies, however, do not confirm this hypothesis. The analysis of variance for the yields showed that on very acidic and acidic soils (pH=5.5), an average seed yield rise attributed to molybdenum foliar sprays was 0.08 $t \cdot ha^{-1}$, thus being within the significance limit (Table 2).

Table 2

Average yields of oilseed rape ($t \cdot ha^{-1}$) from experiments on very acidic and acidic soils

Time of application (factor I)	Mo rate ($g \cdot ha^{-1}$) (factor II)			Average of factor I
	30	60	120	
1	2.91	2.92	2.96	2.93^{A}
2	2.90	2.92	3.00	2.94^{A}
Average of factor II	2.91^{a}	2.92^{a}	2.98^{a}	2.94
Average of control plots				2.86
Contrast				0.08*

*, **, *** – significance of differences at $\alpha < 0.05$; $\alpha < 0.01$; $\alpha < 0.001$
Different letters indicate significant differences at a 5% level according to Tukey's test, factor I – capital letter, factor II – small letter.

In the other group of trials, set up on slightly acidic and neutral soils, the effect of molybdenum fertilization was stronger than on soils of the reaction ≤=5.5. Statistically significant increase in seed yield in this group equalled 0.2 $t \cdot ha^{-1}$ (Table 3).

The rate of molybdenum had a significant effect on oilseed rape yields only in the group of trials on slightly acidic and neutral soils, where no significant differences were observed between the effects produced on seed yields by the fertilization rates 60 and 120 g $Mo \cdot ha^{-1}$, although they were both more effective than the rate of 30 g $Mo \cdot ha^{-1}$. No effect of the date

Table 3

Average yields of oilseed rape ($t \cdot ha^{-1}$) from experiments on slightly acid and neutral soils

Time of application (factor I)	Mo rate ($g \cdot ha^{-1}$) (factor II)			Average of factor I
	30	60	120	
1	2.93	3.05	3.09	3.02^A
2	3.01	3.05	3.05	3.03^A
Average of factor II	2.97^a	3.05^b	3.07^b	3.03
Average of control plots				2.82
Contrast				0.21 ***

*, **, *** – significance of differences at $\alpha < 0.05$; $\alpha < 0.01$; $\alpha < 0.001$
Different letters indicate significant differences at a 5% level according to Tukey's test, factor I – capital letter, factor II – small letter.

of molybdenum application on seed yields was found. Neither did we observe any interaction between the rate of the element and the date of the fertilization treatment in any of the two groups of the experiments.

Some research carried out in Australia showed that on very acidic soils it was possible to attain higher wheat yields when Mo fertilization had been applied. The actual yield increment depended on the concentration of molybdenum in seed material. The lower the Mo content in the seeds, the better the yield stimulating effect of Mo fertilization (Brennan, Bolland 2007). Rates of Mo between 35 and 140 $g \cdot ha^{-1}$ had a significant effect. Common bean has also been examined towards increasing the Mo concentration in seeds by using very high rates of Mo, between 90 and 720 $g \cdot ha^{-1}$, applied to leaves (Vieira et al. 2005). By enriching seed material with Mo, it is possible to do without later Mo fertilization treatments.

In Germany, a study based on 70 field experiments showed that there was no relationship between soil reaction and the response of oilseed rape to Mo foliar fertilization (Finck, Sauermann 1998). Very few cases of seed yield increase occurred when the Mo concentration in rape leaves was below the optimum level, which is 0.4 mg $Mo \cdot kg^{-1}$ d.m. (Bergmann 1992). However, a fertilization rate of 40 Mo $g \cdot ha^{-1}$, which was applied in the reported study, seems to be too low for oilseed rape. According to the Australian data, application of comparable rates of molybdenum to another crop such as grapevine made the yields increase by 70-750% (Williams et al. 2005).

In our own studies, small increase in oilseed rape yields as a result of Mo fertilization which occurred only on very acid and neutral soils could be explained by the fact that on such soils there are a number of yield limiting factors (Brennan et al. 2004). These include low availability of Mo as much as toxicity of Al and Mn, limited availability of P and inhibited uptake of Ca and Mg. In a situation where several yield-determining factors occur on a minimum level, rising one of them up to the optimum position may not suffice to guarantee higher yields (WALLACE 1984). On soils characterised by a higher pH, the factors which inhibit the growth and development of crops are eliminated, which explains a more pronounced effect of foliar application of molybdenum.

Simple correlation calculations, computed on the basis of the data from the whole set of the experiments, did not show any relationship between the value of soil pH and yield increase obtained as a result of Mo fertilization (Figure 1). Within the whole range of soil pH values, there were both yield increases and decreases caused by Mo fertilization, but on soils of the pH ≤=5.5 yield the increments were smaller while declining yields occurred more often and were sometimes bigger than on soils of higher reaction.

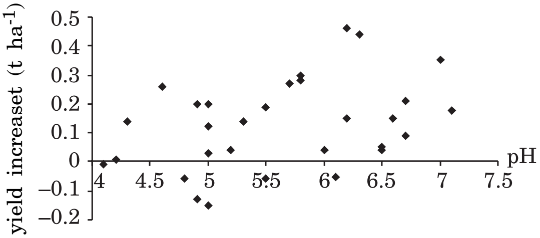

Fig. 1. Relationship between seed yield increase after Mo application and soil pH

In both groups of trials, regression correlation was searched between a relative yield increase obtained on molybdenum fertilized objects versus the control and some physicochemical properties of soil, such as abundance of available forms of macro- and microelements in soil or the content of floatable particles and silt fractions. For the soils characterised by pH ranging within 5.6-7.1 we were unable to create a regression model with the above variables as the population we investigated was uniform in this respect. The relationship for the trials established on very acidic and acidic soils was defined with the following regression function:

$$y = 1.106015 - 0.004865 \text{ silt} + 0.000801 \text{ Mn} \quad R^2 = 0.731^{***}, n = 14$$

where:

y = relative yield increase for 120 g Mo·ha^{-1} versus the control (%),

silt – content of silt fraction in soil (%),

Mn – concentration of available Mn in soil (mg·kg^{-1}).

With this function it was demonstrated that on the soils of pH up to 5.5. the effect of molybdenum fertilization on yield increase was negatively correlated with the silt fraction but positively correlated with the percentage of available manganese in soil. A review of the relevant references indicated that higher yields could be obtained owing to some interactions between nutrients (Fageria 2001). Manganese can impede the uptake of molybdenum (Kabata-Pendias 2001). In the above equation, increased Mn concentration in soil was accompanied by a stronger response of oilseed rape to molybdenum fertilization, which reflects the Mn – Mo antagonism. Excess of manganese in soil, which impedes the uptake of molybdenum by plants, was responsible for their stronger response in yields to Mo foliar fertilization.

The negative effect of the silt fraction in soil on oilseed rape yield increase stimulated by Mo fertilization is difficult to explain. Most probably, there is some indirect relationship. The silt fraction exerts quite strong effect on water and air ratios in soil, which are associated with the oxidation / / reduction potential as well as molybdenum availability to plants.

CONCLUSIONS

1. Despite the commonly held opinion that molybdenum fertilization is a recommendable measure only on acidic soils, the highest winter oilseed rape yield increases stimulated by molybdenum foliar application were obtained on soils of pH > 5.5. On acid and very acidic soils, the effects of Mo fertilization were much lower and sometimes even negative, which meant that the seed yield was depressed.

2. On soils of pH > 5.5, the best results were obtained when 60-120 g $Mo \cdot ha^{-1}$ was applied, irrespective of the fertilization date (a few days after the vegetative season had begun or during the early stem formation stage). This seems to suggest that the exact date for Mo fertilization can be adjusted to combine it with a specific plant protection treatment.

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