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# THE EFFECT OF SULPHATE FERTILIZATION ON THE CHEMICAL COMPOSITION AND THE QUALITY OF WINTER WHEAT

THESES OF DOCTORAL DISSERTATION

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# 1. PRELIMINARIES AND OBJECTIVES

Sulphur, the fourth essential macroelement was a neglected nutrient element in agriculture in the past. As a result of numerous processes in the world and the increasing efficiency of environment protection the sulphur emission was reduced a lot, and this fact raised the necessity of sulphur replacement in agriculture.

Recognising the importance of this question we launched incubation and sulphur fertilisation experiments in order to study microbiological sulphur transformation in the soil and the reaction of winter wheat to sulphate fertilisation on a calcareous Danube alluvial soil.

In our experiments we tried to answer the following questions:

- How sulphate fertilisation influences the chemical composition and quality parameters of winter wheat on a Danube alluvial soil
- Can sulphate fertilisation efficiently improve yield and quality under similar climatic and geographical conditions
- Can experimental results efficiently be adapted to Hungarian conditions
- What is the relationship between sulphate content, N:S ratio, chemical composition of the plants and baking quality
- How N, P, K fertilisation and soil inoculation with *Thiobacillus sp.* influence the oxidation of elemental sulphur in the calcareous Danube alluvial soil used in the experiment
- Is elemental sulphur fertilisation and *Thiobacillus sp.* inoculation applicable for improving sulphur nutrition of cultivated plants

# 2. MATERIAL AND METHODS

## *2.1. Sulphur Oxidation Experiments*

For studying sulphur oxidation in the soil an experiment was launched that included sulphur fertilisation, N, P, K fertiliser application and bacterial soil inoculation.

In our incubation experiments the oxidation of increasing elemental sulphur doses was studied (*0,1; 1,0; 2,5; 5,0 and 10 g pot*$^{-1}$*, i.e. 50, 500, 1250, 2500 and 5000 kg ha*$^{-1}$).

In the 84 days long pot experiment the oxidation potential of the soil and the sulphur reducing micro-organisms *Thiobacillus ferrooxidans* and *T. thiooxidans* was studied among unfertilised and N, P, K fertilised soil respectively.

The experimental soil was collected at the field B/4 in SOLUM Crop Production Company Komárom, Hungary. The soil was gathered form the upper 5-30 cm layer in October 1999 prior to the primary tillage.

The nutrient status of the soil was as follows: N- medium supply, $P_2O_5$- excellent supply, $K_2O$- poor supply.

After mixing the elemental sulphur into the soil it was divided into two parts. The first part was not supplemented with N, P, K fertilisers, N, P, K fertiliser in an amount calculated according to “MÉM NAK” fertilisation system was given to the second part.

After this the two soil parts were separated into another three parts. The first part was not inoculated (N), the second part was inoculated with the bacterium strain *T. ferrooxidans* (DSM No. 583) (F) and the third part with *T. thiooxidans* (ATCC 8085), too. The inoculating solution contained

$1.5x10^8$ $ml^{-1}$ bacteria. The strains used for the experiment were obtained from the DSMZ. The solution was measured with DENSIMAT Biomerieux densitometer.

The experiment started on 24th February 2000 and the soils were inoculated at field capacity in a thermostat at a temperature of 22,8±0.5°C. This temperature practically equals the maximum temperature of the upper 10 cm soil layer of Hungarian fields.

After the incubation period the $pH_{H2O}$, the $pH_{KCl}$ and the $SO_4^{2-}$-values of the soil were measured.

### *2.2 Effect of Sulphate Fertilisation on the Chemical Composition and Quality Parameters of Winter Wheat*

In the field experiment the reaction of winter wheat to sulphate fertilisation was studied. We investigated the changes in chemical composition and in baking quality.

In this 3 years long experiment with randomised block design we studied the effect of the treatments on the chemical composition of the soil and the test plants respectively. The treatments of the experiment (*$NH_4NO_3$+MAP+$K_2SO_4$; $NH_4NO_3$+MAP+KCl; $(NH_4)_2SO_4$+MAP+ $K_2SO_4$; $(NH_4)_2SO_4$+MAP+ KCl; $CO(NH_2)_2$+MAP+$K_2SO_4$; $CO(NH_2)_2$+MAP+KCl, and untreated control*) were arranged in 3 blocks and carried out in 4 replications.

The three years long experiment was launched in September 1999. The N, P, K fertilisation rate was calculated according to the MÉM NAK fertilisation system.

The total amount of $P_2O_5$ (80 kg $ha^{-1}$) and $K_2O$ (75 kg $ha^{-1}$) fertilisers and the 42 % (80 kg ha-1, 0.16 kg $plot^{-1}$) was spread in the autumn. The rest of the

N fertiliser (111 kg $ha^{-1}$, 0.22 kg $plot^{-1}$) was applied as top dressing in springtime, evenly distributed at the phenological phases of Fe 2 and Fe 6.

### *2.2.1. Varieties, Soil tillage, Plant Protection*

In the first two years of the experiment (1999, 2000) the maturity group variety GK Csörnöc, in the third year (2001) the medium maturity Mv-Emma was grown. Sowing was done on October 7, October 15, October 2 in the first, second and third year respectively. The number of seeds sown was 6.2 million $ha^{-1}$, the depth of sowing 50 mm.

The crop management applied was identical to the crop management system of SOLUM Co.

Weed control was done with 2 litres $ha^{-1}$ Mecomorn, Granstar and Mecaphar in 2000, 2001 and 2002 as postemergent treatments respectively.
Tilt Premium, Alert-S and Eminent 125 SL fungicides were applied to control Fungi diseases (powdery mildew, fusarium) as aerial application.

In the 3 years of the experiment there was no need to protect the plants against insect pests.

Wheat harvest was done on the $26^{th}$, $27^{th}$ and $30^{th}$ of June in 2000, 2001, 2002 respectively.

### *2.2.2. Soil and Plant Analyses*

During the experiment the chemical composition of the soil and plant samples and the wheat grain was studied.
Soil samples were taken form the upper 30 cm soil layer twice a year, in early spring prior to the first top dressing and on the first day after harvest.
To monitor the nutrient absorption of winter wheat plant samples were taken also twice a year, firstly in the phenological phase of tillering (Fe 4-5), the

second time in the phase of milk ripeness. The first time the total aboveground green mass was collected and at milk ripening the still green flag leaves were gathered.

For measuring the yield and to collect grain samples for chemical analysis sample areas were assigned in each plot and the yield was harvested. The total sulphur content of the endosperm flour was measured in the laboratory of Crop Production Institute of UWH, Mosonmagyaróvár, the baking quality parameters in the Laboratory of Pannon Gabona Co.

### *2.3. Methods of Statistical Analysis*

The results were evaluated by analysis of variance and regression analysis by using Excel 7.0 for Windows and Statistica 4.5 for Windows.

## 3. RESULTS AND CONCLUSIONS

### *3.1. Evaluation of the Soil Inoculation Experiments*

In the experiment we established that as a result of the elemental sulphur given to the soil the available sulphur content increased in every case compared to the values that of treatments without sulphur application.

The bacterial soil incubation increased the oxidation rate of the soil to a great extent, which was displayed by the decreasing pH values. This effect was significant at 0.1% probability level. Among the two bacterium species used in the experiment the *T. thiooxidans* was more effective.

The increasing elemental sulphur doses stimulated the microbial sulphur oxidation that was also indicated by the increasing sulphate content of the soil.

The N, P, K fertilisation increased the oxidation of elemental sulphur significantly in every case. This significant relationship did not show a strong correlation with the pH values of the soil. Therefore we assume that numerous physico-chemical processes might play a role in the background that require further investigations.

The experiments carried out may serve a basis of the improvement of soil amendment methods, sulphur fertilisation and bioremediaton procedures that involve bacterial soil inoculation as well.

### *3.2. Sulphate Fertilisation Experiments*

The results were evaluated by means of analysis of variance and correlation analysis.

The soil samples taken at shooting and harvesting did not show any evidence and positive correlation between available sulphate content and the treatments used in the experiment.

On the basis of the plant analysis results we established that the amount of sulphur supplied by the experimental soil was sufficient to cover the sulphur requirement of the cultivated plants.

Studying the sulphur content of the plant samples taken at shooting we found that there was no significant relationship between the treatments and plant sulphur content. At the same time comparing the sulphur content of the control and the plants fertilised we established that the sulphur assimilation of the plants increased due to fertilisation.

The strong correlation between the raw protein content and the sulphur content of the samples refers to the basic role of sulphur in protein synthesis. Studying the sulphur content of flag leaves we could measure the highest values in the case of the $(NH_4)_2SO_4$ treatments. At the same time there was no significant difference in the raw protein content of the fertilised treatments.

Regarding the correlation between the two values it was found that the highest raw protein value was measured at the 0.24 % sulphur content of the flag leaf. The same sulphur concentration gave the best baking quality. Considering the quality parameters of flour there was no significant difference between the particular fertilised treatments.

During the 2001 flour quality studies the best baking quality was detected at *21:1* N:S ratio, that is considerably higher than that of can be found in the literature (*17:1*).

On the basis of the results obtained we established that among the described circumstances N had the highest influence on the quality parameters of winter wheat.

## *4. NEW SCIENTIFIC RESULTS*

1. In a soil inoculation experiment we proved that the original microbial population of the calcareous Danube alluvial soil has a significant ability to oxidise sulphur.

2. The applicability of *Thiobacillus sp*. inoculation on calcareous, alkaline soils was proved.

3. It was established that on the calcareous Danube alluvial soil the bacterium species *T. thiooxidans* oxidised sulphur the most efficiently.

4. In the sulphur fertilisation experiment we proved that the sulphur content of the soil was sufficient to fulfil the sulphur requirement of winter wheat.

5. The chemical analyses carried out proved that due to N, P, K fertilisation the S content of the plants increased.

6. The basic role of soil organic matter in S absorption of plants was proved.

7. The maximum raw protein content of the flag leaf was detected at 0.2 % S-content and 0.3 % S-content of the flag leaf and the tillering plant samples respectively. In case of higher sulphur content the raw protein content decreased.

8. The N:S ratio of flour samples was 20-21:1 which is higher than the results found in the literature (17:1).

9. The highest baking quality number and protein content was measured at the N:S =21:1 ratio which is higher than the corresponding data in the literature.

10. The highest wet gluten content of the flour was measured at 0.24 % S-content of the flag leaf.

## *5. PUBLICATIONS FROM THE TOPIC OF THE THESIS*

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