

The effect of zinc fertilization on the yield and element content of ryegrass

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ABSTRACT

The effect of Zn fertilization on the yield and Zn, N, P, K, Mg and Mn content of ryegrass was studied in a greenhouse experiment for 8 chernozem soils with three replicates under uniform NPK supply and irrigation. The applied Zn rates were 0, 2.5 and 5 mg/kg Zn. Due to Zn doses the yield increased significantly. Zn fertilization increased the plant Zn content and decreased the plant P and Mn content significantly. For N, K and Mg there was no significant effect.

INTRODUCTION

The appropriate nutrient supply is one of the most important factor of the success for intensive plant production. Beside the three most important macroelement (NPK) fertilization, the micronutrient replacement is also of great importance.

In Hungary 40-45% of agricultural areas is Zn deficient (Elek et al., 1984), thus it is reasonable to supply NPK fertilizers with Zn, especially for those cultures that are sensitive to Zn deficiency (e.g. maize). The most important soil factor associated with zinc deficiency is pH, as Zn availability is markedly reduced with increasing soil pH. Other soil factors affecting Zn availability are high available phosphorous, low total Zn status, high humus content and other nutrient deficiencies (Armour et al., 1993).

Chernozem soils in Hungary have adequate total Zn content, however intensive phosphorus fertilization can cause zinc deficiency. Csathó et al. (2009) observed zinc deficiency in chernozem soil over 150 kg/ha P₂O₅ dose for maize. In accordance with it Kincses et al. (2005) experienced decrease in zinc content for maize and wheat by 140 mg/kg P₂O₅ dose in case of calcareous chernozem soil. High pH can also occur on chernozem soils as a result of large lime content.

In our paper we studied the Zn supply of chernozem soils. Balla et al. (2005) observed yield increase for 10 mg/kg Zn dose on calcareous chernozem soil under greenhouse circumstances. Now we extend the examination for eight different chernozem soil samples. The soil samples were collected from Hajdú-Bihar County in Hungary. In a greenhouse experiment we examined the effect of zinc fertilization on the yield and on the element content (Zn, P, N, K, Mg and Mn) of ryegrass.

MATERIALS AND METHODS

A pot experiment was conducted using 8 chernozem arable soils. Pots were filled with 2250g air dry soils. The treatments included NPK application, NPK + 2.5 mg/kg Zn and NPK + 5mg/kg Zn levels with three replicates. Each pot received uniform application of 100 mg N/kg soil as NH₄NO₃, 80 mg P₂O₅/kg soil as KH₂PO₄ and 120 mg K₂O/kg soil as KH₂PO₄ and KCl. The zinc was applied as ZnSO₄·7H₂O solution. Soils were kept at constant moisture by daily irrigation, which was 75% of maximum water capacity of the soils. The experimental plant was ryegrass (*Lolium perenne* L.). 1.7 g seeds were sown in the soils per pots. After the first (33 day) and second (53 day) harvest 100 mg/kg N was added to the pots as NH₄NO₃ solution.

For the initial soils total-N, phosphate, potassium and pH values were measured from 0.01 molar CaCl₂ soil extract that was prepared according to Houba et al. (1990). The total-N and phosphate content were measured with SKALAR Continuous Flow Analyzer. Calcium and magnesium content was determined from ammonium-lactate soil extract. The Zn content was measured from CaCl₂-DTPA solutions. The most important soil properties for the initial soils are summarised in Table 1.

The plants' zinc, phosphorus, nitrogen, potassium, magnesium and manganese - contents were analysed as follows:

The plant samples from the first cut were digested with cc. H₂SO₄- cc. H₂O₂. and cc. HNO₃-cc. H₂O₂.

Zinc, manganese and magnesium content were measured from nitric acid digestion by AAS technique (Varian Spectr. AA-20). Potassium content was measured from sulphuric acid digestion with flame photometer (UNICAM SP95B). The phosphorus content was determined from the sulphuric acid digestion with vanadate-yellow spectrophotometric method. The total nitrogen was determined with CNS element analyser. The data were evaluated with two variable variance analysis.

Table 1 Main soil characteristics of the initial soil samples.

Nr.	Soil Type	*K _A	Hu%	pH _{CaCl2}	Total N mg/kg	PO ₄ ³⁻ mg/kg	K mg/kg	AL-Ca mg/kg	AL-Mg mg/kg	Zn DTPA mg/kg
1	Leached chernozem	43	2.7	5.86	17.5	1.78	51.6	8180	559.4	1.9
2	Meadow chernozem	45	3.2	7.29	68.6	0.86	47.0	8960	1018.3	0.9
3	Meadow chernozem	42	2.7	7.21	53.4	0.97	56.3	12060	284.4	0.6
4	Meadow chernozem	46	2.7	7.40	30.8	1.16	65.8	23189	564.1	1.1
5	Meadow chernozem	42	2.1	7.45	45.4	1.06	83.2	13170	419.4	1.3
6	Calcareous chernozem	42	2.8	7.45	36.4	0.74	35.8	10940	703.0	0.6
7	Meadow chernozem	43	3.1	7.36	29.7	1.17	53.9	7660	609.5	2.3
8	Calcareous chernozem	43	3.0	7.18	58.9	1.03	187.3	1164	129.7	2.2

* K_A is the water amount taken up by soil to plasticity capacity (cm³/100g soil)

RESULTS AND DISCUSSION

The average dry matter production ryegrass at the first cut is summarized in Table 2. Significant positive relationship was found between Zn application and the dry matter production. Between the soils and dry production there was also significant relationship.

Based on the data of Table 1 and Table 2 the positive effect of Zn fertilization is characteristic even for those soils with high Zn content.

Table 2 Mean dry weight of ryegrass at the 1st cut

Soil sample	Mean dry weight (g/ pot)			mean	Difference between treatments in dry weight	
	Zn doses (mg /kg soil)					
	0	2.50	5.00		2.5-0	5-0
1	3.70	4.00	4.73	4.14	0.30	1.03
2	4.00	4.40	5.03	4.48	0.40	1.03
3	3.03	3.97	4.33	3.78	0.93	1.30
4	3.33	4.10	4.17	3.87	0.77	0.83
5	5.43	6.07	5.87	5.79	0.63	0.43
6	2.83	2.50	3.33	2.89	-0.33	0.50
7	4.60	5.10	5.40	5.03	0.50	0.80
8	4.80	5.07	4.73	4.87	0.27	-0.07
mean	3.34	3.89	4.40	3.88	1.07	2.10

SD_{5%} between Zn treatments = 0.25

SD_{5%} between soils = 0.41

SD_{5%} between any two combinations = 0.71

The results of variance analysis for the plant Zn content are represented in Table 3. The significant effect of Zn fertilization on the Zn content of the plants is manifested. The zinc content increment for the 2.5 mg/kg zinc treatment ranges from 1.94 mg/kg to 13.62 mg/kg. For sample 1 and 8 the increments were relatively small. These soils are less zinc deficient, that is indicated with the soil dissolved zinc content by DTPA, which was relatively high.

For sample 7 in spite of the high dissolved zinc content from the soil (2.32 mg/kg), the zinc content and the dry matter of plant increased markedly for zinc treatment. It can be explained with the high pH (pH = 7.36) and high phosphate content (1.17 mg/kg) of the soil. Further zinc content increment can be observed for the 5mg/kg zinc treatment. Though the degree of the enhancement was less in most of the cases.

Table 3 Mean Zn content of ryegrass , 1st cut

soil sample	Zn content of plant (mg/kg)			mean	Difference between treatments in dry weight	
	Zn doses (mg/ kg soil)				2.5-0	5-0
	0	2.5	5			
1	44.4	46.4	49.1	46.6	2.0	4.8
2	26.9	39.6	46.7	37.7	12.7	19.7
3	25.8	39.4	45.7	37.0	13.6	19.9
4	31.9	42.6	43.0	39.2	10.7	11.1
5	27.4	39.7	48.9	38.7	12.4	21.6
6	15.2	25.2	31.4	23.9	10.0	16.2
7	25.3	37.4	43.7	35.5	12.1	18.4
8	41.2	43.1	48.0	44.1	1.9	6.8
mean	29.8	39.2	44.6	37.8	9.4	5.4

SD_{5%} between Zn treatments = 3.73

SD_{5%} between soils = 2.28

SD_{5%} between any two combinations = 6.48

In Table 4 the plants' P content can be seen in (mg/g). In case of control treatments it ranges from 3.0 to 5.3. All soils (the control soils as well) got (100 mg P₂O₅)/kg soil fertilization, but the initial P status of the soil is somewhat reflected by the results. For example on soil sample 6 and sample 2 grew the plants with the lowest P content. Accordingly the dissolved P content was the smallest for these soils in the initial state.

It can be stated from the results that the zinc fertilization decreased the plant phosphorous content significantly.

In case of 2.5 mg/kg zinc treatment this negative effect can be observed for four soils, and in case of 5 mg/kg zinc treatment for six soils. It is well documented from the literature that there is antagonism between phosphorous and zinc (Gartel,1969). The antagonism was reported in case of phosphorous fertilization, when the overdose of phosphorous caused the lack of zinc. Our results show that even zinc, as a microelement can decrease the phosphorous content of plant. Zinc and phosphorus form precipitate in soil, which is one of the reason for the antagonism of these elements. However the antagonism has mainly plant physiological explanation (Stukenholz, 1965). The decrease in P content of the plants was averagely 24% for 5 mg/kg Zn fertilization.

Table 4 Mean P content of ryegrass , 1st cut

Soil sample	P content of plant (mg/g)			mean	Difference between treatments in P content	
	Zn doses (mg/ kg soil)				2.5-0	5-0
	0	2.5	5			
1	4.9	4.2	3.8	4.3	-0.7	-1.1
2	3.1	2.9	2.6	2.8	-0.2	-0.5
3	4.0	3.9	3.5	3.8	-0.1	-0.5
4	4.2	3.8	3.3	3.8	-0.4	-0.8
5	3.9	3.9	3.9	3.9	0.0	0.0
6	3.0	3.0	2.2	2.7	0.0	-0.8
7	5.3	4.8	4.8	5.0	-0.5	-0.5
8	6.7	6.5	6.7	6.6	-0.2	0.0
mean	4.4	4.1	3.9	4.1	-0.3	-0.2

SD_{5%} between Zn treatments = 0.24

SD_{5%} between soils = 0.39

SD_{5%} between any two combinations = 0.68

Table 5 shows the Mn content of the ryegrass. The Mn content varies between 38.7 and 90.3 mg /kg. Most of the cases the Mn content decreased significantly as a cause of zinc fertilization. Manganese and zinc have competition interactions, the increased zinc content of the soil inhibited the plant manganese uptake.

Table 5. Mean Mn content of ryegrass , 1st cut

soil sample	Mn content of plant (mg/kg)			mean	Difference between treatments in Mn content	
	Zn doses (mg/ kg soil)				2.5-0	5-0
	0	2.5	5			
1	51.3	45.7	38.7	45.2	-5.7	-12.7
2	72.3	73.7	65.3	70.4	1.3	-7.0
3	90.3	81.3	76.0	82.6	-9.0	-14.3
4	57.3	62.3	52.3	57.3	5.0	-5.0
5	64.0	62.3	67.3	64.6	-1.7	3.3
6	50.3	44.3	47.0	47.2	-6.0	-3.3
7	63.4	54.3	58.7	58.8	-9.0	-4.7
8	56.3	50.3	53.0	53.2	-6.0	-3.3
mean	63.2	59.3	57.3	59.9	-3.9	-5.9

SD_{5%} between Zn treatments = 4.5

SD_{5%} between soils = 7.6

SD_{5%} between any two combinations = 13.1

There were not significant effects of zinc fertilization on nitrogen, potassium and magnesium content of the plants. The nitrogen content of the dry matter ranged from 3.6 to 4.2 %. Potassium content varied from 5.3 to 10.2 %, and magnesium from 0.26 to 0.32%.

CONCLUSIONS

In our paper we studied the effects of zinc fertilization on the yield of ryegrass under greenhouse circumstances for eight chernozem soils. It can be stated that the zinc fertilization increased the yield, however ryegrass is not sensitive to zinc deficiency. It draws attention to the fact that zinc fertilization can be reasonable in chernozem soils, especially for zinc demanding cultures such as maize.

We also investigated how zinc fertilization influence the uptake of several elements. These are zinc, potassium, magnesium, nitrogen, phosphorous and manganese. We concluded that zinc fertilization increased the zinc content of plants. The increment was more than 30% in most of the cases for 2.5 mg/kg zinc dose. The zinc fertilization decreased phosphorus and manganese content of the plants. The decrease in P content of the plants was in average 24% for 5 mg/kg Zn fertilization. The decrease in Mn content of the plants in average 9%.

We did not find significant interactions between zinc fertilization and the potassium, nitrogen and magnesium content of plants.

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