Patterns of Zinc Accumulation by Maize and Its Yielding Responses

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INTRODUCTION

The harvested yield of a given crop plant and its yielding components reflect *ex post* conditions of dry matter (DM) accumulation over the growing season. The decisive effect of N on plant growth is well known, but its use efficiency is low even for maize, which is not a high N demanding crop**.** It is well recognized, that Zn exerts a great metabolic effect on N plant economy. However, the most difficult problem is to find answers to three basic questions: what kind of Zn fertilizer? how much? and when to be applied? Plant growth analysis seems to be reliable for obtaining usable answers. The main objective of this study was to describe the patterns of Zn uptake by maize to determine its effect on grain yield.

METHODS

Field trials were carried out in 2001, 2002, 2003 growing seasons on a private farm at Nieczajna (25 km North of Poznań, Poland; 52.40 ^{o}N, 16.90 ^{o}E) on a neutral pH loamy sand soil rich in available P, K, Zn. Plants were fertilized with 135 kg N ha^{-1}. One factorial experiment with maize (covariety *Bachia*) consisted of four rates of Zn (0, 0.5, 1, 1.5 kg ha^{-1}) with three replications. Zinc in the form of oxysulphate (45% of ZnO and 5% of $ZnSO_4$) was applied onto the foliage at the 5/6 leaf stage. Crops were harvested on 14 m^2. Studies of the dynamics of DM growth and nutrient accumulation in maize plants were conducted in 2002 and 2003. For this purpose 8 plants were sampled out at 10 consecutive stages of maize growth (BBCH stages: 14, 17, 19, 39, 59, 67, 75, 83, 87, 89). Nitrogen and Zn contents of plant tissues were determined using the Kjeldahl method (Kjeltec Auto Destillation) and Flame Atomic Absorption Spectrometry (FASS), respectively. Results are expressed on a DM basis. The growth analysis methodology was applied to determine Absolute Accumulation Rate (AAR) and Relative Accumulation Rate (RAR) of Zn (Hunt 1978). The obtained data were subjected to conventional analysis of variance and simple regression.

RESULTS AND DISCUSSION

The grain yield of maize harvested on the control, i.e. fertilized with 135 kg N ha^{-1} only, was high (Table 1). The effect of Zn fertilizer was significant and consistent despite the seasonal weather variability. The highest yield increase was 1.62 t ha^{-1}, i.e. 20% of the control yield. Plants responded to consecutive Zn rates up to 1 kg ha^{-1} despite the naturally high availability of Zn that is confirmed by the highest uptake on the control at harvest.

Table 1. Zinc fertilizer effect on maize yielding characteristics at harvest

Zn applied (kg ha^{-1})	Grain yield (t ha^{-1})	Ear length (cm)	Kernels per ear (No.)	TKW (g)
0.0	8.03	13.88	27.76	253.4
0.5	8.83	15.37	29.20	266.1
1.0	9.52	15.62	31.69	264.3
1.5	9.65	15.19	29.37	275.0
$LSD_{0.05}$	0.484	0.424	2.319	9.74

At harvest, plants fertilized with 1 kg Zn ha^{-1} had taken up 45.1 kg N ha^{-1} more than those grown on the control. Therefore, based on the specific N uptake for 20,1 or 33,6 kg t^{-1} of grain + straw in accordance with the World Fertilizer Use Manual data set and our own data, this amount (i.e. 45.1 kg N ha^{-1}) allows to produce an extra grain yield of 2.244 or 1.342 t ha^{-1}, respectively. The yield increase, as explained by means of the applied path analysis, was due to higher length of cobs, i.e. higher number of kernels per cob. The obtained results are in agreement with the main thesis of Subedi and Ma (2005), who stressed the decisive effect of the N nutritional status of maize at early stages on grain yield.

The analysis of the time growth course of maize for the Zn AAR and RAR allows indicating critical stages of Zn uptake. According to AAR analysis, Zn accumulation patterns were highly dependent on the amount of applied Zn rates. Plants in Zn-unfertilized plots showed elevated Zn uptake at BBCH 19, 75 and 89, but those fertilized with Zn only at the first two stages were twice as high (details available by the authors). The patterns of Zn uptake, as shown by RAR analysis, were similar for all Zn treatments. The periods most decisive for plant growth were the periods between BBCH 17 and 19, i.e. from 7 to 9 leaves. As in the case of AAR, the rate of Zn accumulation by plants fertilized with Zn was much higher in comparison to the control plots at those particular stages (Fig. 1). As a result, the higher RAR at BBCH-17 and the highest Zn concentration (Zn_{con}) can be expected as shown by the developed equations:

$$Zn_{con} = 236.3\ RAR_{Zn0.0} + 14.53 \qquad \text{for } n = 9 \text{ and } R^2 = 0.85$$

$$Zn_{con} = 593.7\ RAR_{Zn1.0} + 17.90 \qquad \text{for } n = 9 \text{ and } R^2 = 0.87$$

Therefore, at BBCH 17, the optimum Zn concentration for the maximum yield ranges from 75 to 85 mg kg^{-1} DM. The calculated ranges, by means of RAR analysis data, were much higher than those found in agronomic papers (Shulte and Kelling 2000).

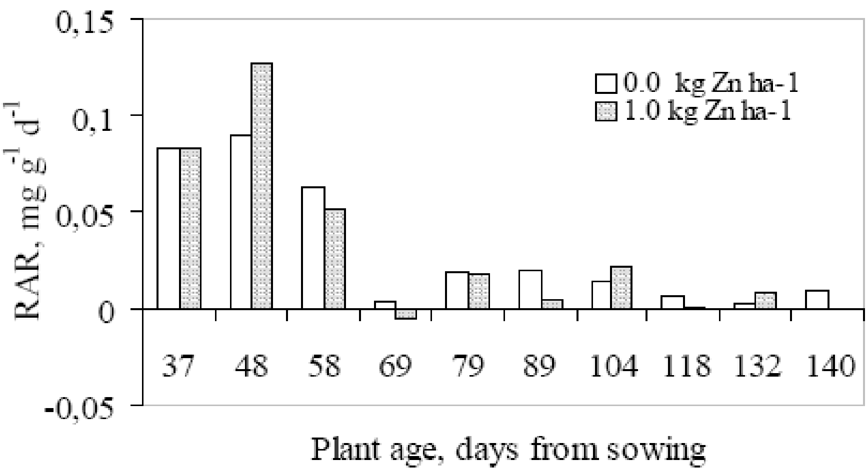

Fig. 1. Patterns of the effect of Zn application rates on Zn accumulation by maize.

CONCLUSIONS

An effect of Zn on maize grain yield can be expected provided that a correction of the nutritional Zn status and in turn N uptake would be managed at early growth stages. The nutritional Zn status of maize at the stage of 7 leaves is of great prognostic value with respect to the final grain yield. The frequently used ranges of the nutritional Zn status need to be corrected based on the analysis of plant growth as a methodological tool.

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