Effect of Zinc Activities on Shoot, Root Biomass and Phosphorus Uptake in Wheat Gynotypes

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Abstract: An experiment was conducted to find out the variation in tolerance toward Zn deficiency among four different wheat genotypes using chelate-buffered nutrient solution of three Zn activities. The genotypes (NRL-1027, NRL-1241, NRL-1242 and NRL-1243) were transplanted to nutrient culture solution in a net house for 45 days to find the impression of various levels of Zn activity (2, 10 and 40 picomolar (pM)) on shoot and root biomass. Among all the wheat genotypes, “NRL-1242” exhibited the highest tolerance to Zn deficiency and hence categorized as Zn-efficient, whereas “NRL-1243” proved to be Zn-inefficient. The remaining two genotypes were medium in efficiency on the above criteria. Efficient wheat genotype “NRL-1242” showed less reduction in growth and accumulated higher P at all lower Zn activities. Thus on the basis of survival in low Zn availability genotypes “NRL-1242” may be used by the researchers to plan their breeding experiments and to set genotype specific recommendations to Zn deficient soils.

Key words: Wheat • Zinc • Deficiency • Phosphorous • Biomass

INTRODUCTION

Wheat is a main staple food in Pakistan. It is mainly planted on calcareous soil which has low plant available Zn [1]. Diethylenetriaminepenta acetic acid (DTPA) extractable Zn in the calcareous soil averages as 0.37 µg g⁻¹, whereas a critical value of 0.46 mg kg⁻¹ is required for optimal wheat growth [2]. The low level of Zn in soil has a negative effect on wheat yield and nutritional value [3]. In a global study initiated by FAO, it has been shown that about 30 % of the cultivated soil of the world contains low amount of Zn available to plant [4] and Zn deficiency is prominent in the crops grown on these soils.

Zinc acts as a functional, structural, or regulatory cofactor of over 300 enzymes and these are involved in cell division, nucleic acid and protein metabolism[5]. Zinc is component of plant CA and the presence of CA in the chloroplast of –C3 plants was considered evidence for its involvement in maintaining the internal bicarbonate pool of the chlorophyll or, possibly, its association with ribose biphosphate carboxylase in CO₂ fixation. In C4 plants, the CA present in the cytosol of mesophyll cells specifically catalyses the conversion of CO₂ to HCO₃⁻ which is then assimilated by carboxylase [6]. Even though wheat is classed as less sensitive to low available Zn and also showing[7] great genotypic variation to Zn deficiency but in Pakistan still extremely affected by this condition.

Soil Zn deficiency reduces both grain yield and quality [8] and may lead to human Zn deficiency, especially in developing countries where diets are abundant in cereal-based foods and deficient in animal protein [9,10]. Recent improvements in the technique of sing a nutrient solution with a buffer chelates micronutrients free ionic format appropriate levels low, it mimics the situation on the ground, has enabled the study of genotypic differences in micronutrient intake in a more realistic, while still maintaining all the advantages of solution culture system [11-13]. Early experiments have shown that the chelate-buffered nutrient solution system can be used to distinguish definitely different levels of Zn efficiency of wheat genotypes [14].

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Due to lack of information on the adaptation of the cultivars on Zn deficient soils, Zn deficient susceptible cultivars are cultivated which also intensify the problem of Zn deficiency in wheat. Wheat cultivars greatly differ in their adaptation to low Zn, therefore this study was initiated to screen four wheat genotype to classify it into various categories on the basis of their adaptation ability to varying zinc activities.

**MATERIALS AND METHODS**

An experiment was conducted to study effect of zinc activities on shoot, root biomass and phosphorus uptake in wheat genotypes in the net house of Nuclear Institute for Food and Agriculture (NIFA) Tarnab, Peshawar, Pakistan during the year 2012-2013. To select the “Zn-efficient and inefficient wheat genotypes”, seeds of 4 wheat genotypes (NRL-1027, NRL-1241, NRL-1242 and NRL-1243) were grown in chelate-buffered nutrient solution of three Zn activities i.e. 2 (deficient), 10 and 40 (adequate) pM of Zn activities were monitored daily basis and adjusted with 0.1M HCl or 0.1M KOH at pH 6.0 ± 0.01.

The experiment was conducted in the net house with the conditions set up to operate at minimum 2°C and maximum 18°C with mean value of 10°C. After 45 days of transplantation plant were harvested; three lots of deionised water were used to root and shoot samples, than wash with double deionised water. The washed samples were air dried with tissue paper and record a fresh weight. The air dried sample were then dried for 48 hours in force drought oven at 80 ± 1°C. The dried samples were stored in a desiccator. The oven dried samples of wheat (tops and roots) were then finely grinded in a mechanical grinder (MF 10 IKA, Werke, Germany) to pass through a 1 mm sieve. The grinded samples were then stored in paper bags labeled properly for further analysis. Total P was also determined by digesting the plant material in HNO₃:HClO₃ mixture prepared in 5:1 ratio. The digested material was analysed for total P by metavanadate yellow colour method as described by Jonathan [15]. Data were analyzed statistically using complete randomize block design and differences among treatments were evaluated [16].

**RESULTS AND DISCUSSION**

The significant \( P \leq 0.05 \) effects of genotypes and Zn activities were observed on dry weight of shoots and roots, length of shoots and roots, phosphorus and micronutrients (Zn, Fe, Cu and Mn) uptake in shoots and roots, Zn efficiency, growth reduction. The data are presented and discussed below:

**Shoot and Root Dry Matter:** Different Zn activities in solution had a significant impact on the growth of wheat plants (Fig. 1). As Zn activities in the culture solution were increased, the growth of the plants was increased and plants yielded higher dry matter production. Some genotypes showed better growth at 20 pM Zn activities than others and even some produced more dry matter at 40 pM Zn than others. This variation in the growth of genotypes at different Zn activities was exploited for the calculation of Zn efficiency. Higher dry weight of shoot (7.6 g pot⁻¹) is observed in genotype “NRL-1243” at 40 pM Zn activity and the lowest shoot dry matter yield (2 g pot⁻¹) was produced by the same genotype at 2 pM Zn activity. Due to low shoot dry matter production at Zn-deficiency conditions (2 pM Zn⁻²),
Fig. 1: Effect of Zn\(^{2+}\) activity on shoot dry matter

Fig. 2: Effect of Zn\(^{2+}\) activity on root dry matter

Fig. 3: Effect of Zn\(^{2+}\) activity on Zinc-efficiency

Fig. 4: Effect of Zn\(^{2+}\) activity on growth reduction

genotype “NRL-1243” proved to be Zn-inefficient and genotype “NRL-1242” showed higher dry matter production at 2pM Zn\(^{2+}\) activity, proved to Zn-efficient. The “NRL-1027” and “NRL-1241” has been considered Zn-medium genotypes. As with the shoot dry matter, Zinc activity in the solution also affected the production of root dry matter by different genotypes, as Zn activity in solution was increased, the root dry matter production by
Table 1: Shoot and root Phosphorus uptake in different wheat genotypes

<table>
<thead>
<tr>
<th>Genotypes</th>
<th>P (mg pot$^{-1}$)</th>
<th>P (mg pot$^{-1}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Shoot</td>
<td>Root</td>
</tr>
<tr>
<td></td>
<td>2pM</td>
<td>10pM</td>
</tr>
<tr>
<td>NRL-1027</td>
<td>28.0 abcd</td>
<td>37.9 a</td>
</tr>
<tr>
<td>NRL-1241</td>
<td>28.1 abcd</td>
<td>28.8 abcd</td>
</tr>
<tr>
<td>NRL-1242</td>
<td>29.8 abcd</td>
<td>37.3 ab</td>
</tr>
<tr>
<td>NRL-1243</td>
<td>28.3 abcd</td>
<td>34.2 abc</td>
</tr>
<tr>
<td>LSD(&lt;0.05)</td>
<td>14.20</td>
<td>1.7</td>
</tr>
</tbody>
</table>

Means with different letter(s) in rows and columns are statistically significant at $P \leq 0.05$

Phosphorus Uptake: The different Zn$^{2+}$ activities have significant effect on shoots P uptake by wheat plants. Phosphorus uptake was higher in the Zn-inefficient than Zn-efficient genotype (average of three Zn$^{2+}$activities). It was observed from the data (Table 1) that P uptake was increased statistically with increasing Zn treatment from 2 to 10 pM Zn$^{2+}$ and further increase in Zn treatment decreased P uptake significantly. The high P uptake 37.9 mg pot$^{-1}$ was observed in genotype “NRL-1027” and lowest in Zn-efficient genotype “NRL-1242” which is 19.9 mg pot$^{-1}$ at 40pM Zn$^{2+}$ activity. The shoot P uptake varied between genotypes from 19.9 to 37.9 mg pot$^{-1}$. The average P uptake in the roots of the plants is lower in genotype not tolerant to Zn compare to Zn-efficient genotypes. The P uptake varied between cultivars from 1.2 to 5.6 mg pot$^{-1}$ (Table 1). These results are in agreement to those of Zeinab et al. [21], who observed that P uptake was higher in Zn-sufficient plants compare with Zn-deficient plant and the lack of enhanced P uptake may have been due to a period of Zn$^{2+}$ deficiency to which the plants had been exposed. In Zn deficient plant high uptake of P is caused by improper mechanisms to control the release of P from root cells into the xylem and the distribution of P from shoots to roots affected and lead to higher accumulation or toxic concentrations of P in the leaves of plant showing Zn deficiency [22].

CONCLUSIONS

Significant interaction among genotypes and Zn activity for dry matter production and Zn contents indicated large genetic variations which can be exploited to select more Zn efficient wheat genotypes. The cultivar “NRL-1242” proved to be Zn efficient which accumulated higher Zn and more biomass production at Zn deficient level compared to the Zn-inefficient genotypes. It is recommended that Zn efficient genotypes may be cultivated which grow and yield well under Zn deficient condition and reduce the requirement for Zn fertilizer.
REFERENCES