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ZINC AVAILABILITY TO WHEAT AT VARIOUS ZINC AND SOIL MOISTURE LEVELS

S. Mahmood Shah, Wisal Mohammad, Naseer H. Khan and M. Mohsin Iqbal

Nuclear Institute for Food and Agriculture, Peshawar

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The water regime of a soil exercises great influence on the availability of nutrient elements to plants. The availability of zinc applied to wheat, at three rates, was studied at different soil moisture levels representing high, low and optimum moisture contents maintained during the entire growth periods in a pot experiment. The results showed that maximum grain yield and uptake of zinc in wheat occurred at optimum (1.0 field capacity) moisture level. The moisture contents above or below this level caused a reduction in yield. The reduction was greater at above-optimum than at sub-optimum moisture levels. Zinc fertilization had a corrective effect on yield under saturated or waterlogged conditions. The influence of zinc rates was different at different moisture levels. The above-optimum moisture levels favoured more vegetative growth whereas optimum or slightly-stressed conditions favoured the production of more grain.

Key words: Zinc uptake; Waterlogging; Moisture stress.

INTRODUCTION

Next to nitrogen and phosphorus, zinc is an element which limits plant growth if present in inadequate amounts. The element has functions in biosynthesis of tryptophane and indole acetic acid and acts as an activator of a number of enzymes [8].

Zinc deficiency has been detected in most of the alkaline calcareous soils of Pakistan. Upto 85 % of the soils were found to be either deficient or within the marginal range of zinc content [4,9]. The deficiency has been severe in rice soils suggesting that zinc availability might have some relationship with the water regime of soil. According to a recent report [5], more than three-fourth of the rice area and 20-60 % of the wheat area needed attention to explore reasons for low zinc availability and to replenish with the element. Increasing crop intensity and use of major nutrient elements on these soils may aggravate the deficiency. The present experiment was therefore planned to study the availability of added zinc to wheat at different soil moisture levels representing high, low and optimum moisture contents during the entire growth period.

MATERIALS AND METHODS

In a preliminary study during 1983-84, the influence of two soil moisture levels (field capacity and 0.5 field capacity) was studied on the availability of zinc to wheat applied at the rates of 2.5, 5.0 and 7.5 kg Zn/ha [10]. Grain yield was reduced by 47 % and zinc uptake by 41 % when soil moisture was reduced by 50 % (half field capacity compared to field capacity).

In the furtherance of these results, the present experiment was conducted during 1984-85, using five soil moisture levels, viz, 2.0 field capacity (FC), 1.5 FC, 1.0 FC, 0.75 FC and 0.5 FC. The 1.0 field capacity represented the optimum moisture content whereas the first two levels represented the higher and the last two the suboptimum levels. Field capacity was estimated by determining the saturation percentage of the soil samples according to the saturation paste method and by dividing the values obtained by two [6]. The Zn levels were 0, 2.5, 5.0 and 7.5 kg/ha of zinc. They were applied in the form of $ZnSO_4.H_2O$ (35 % Zn). Basal doses of N and P at the rates of 150 and 100 kg per/ha respectively were applied to all the pots at the time of sowing.

Each pot contained 5 kg soil. Six presoaked wheat seeds were planted in each pot which, after stand establishment, were thinned to 3 plants per pot. The soil used was a fine-textured one with the following physicochemical characteristics: pH 8.0, EC 0.25 dS/m, saturation percentage 46.6 and DTPA-extractable Zn 0.97 mg/kg of soil. The pots were arranged according to the split plot design with water levels forming the main treatments and zinc levels the sub-treatments. There were 3 replications.

The desired water levels were maintained by weighing the pots and adding the required amounts of water to the pots on alternate days throughout the growth period.

Wheat was harvested at physiological maturity. The straw and grain yields were recorded at the time of harvest. Samples of plant shoot and grain were obtained to determine the zinc uptake. The plant samples were washed with 0.1N HCl, deionized water and finally with distilled water. After oven drying at 70°, the samples were ground in a Wiley Mill and digested in a diacid mixture, $HNO_3:HClO_4$, in the ratio of 5:1 and analysed for zinc using Atomic Absorption Spectrophotometer (Hitachi, Model 170).

RESULTS AND DISCUSSION

Yield. The results obtained on the grain and straw yield as influenced by various moisture and zinc levels are presented in Table 1. The maximum grain yield was obtained at the field capacity (optimum) moisture content at all levels of zinc. The moisture contents above or below this level caused a reduction in yield. The magnitude of reduction was greater at the moisture levels higher than field capacity (35-50 %) than those lower than field capacity (19-37 %). These results are in conformity with findings of other workers. Waterlogging, which is analogous to 2.0 field capacity moisture content in our studies, was shown to reduce the yield of winter wheat by 24 and 21 % on clay and sandy loam soils respectively [2]. Similarly, moisture stress significantly reduced the crop yield compared to normal moisture content [1,3].

Zinc fertilization significantly increased the grain yield compared to no fertilization (Table 1). The maximum average grain yield was obtained at the highest zinc rate (7.5 kg/ha) followed by 5.0 and 2.5 kg Zn/ha which were statistically not different from each other. Zinc water interaction showed that addition of zinc had a corrective effect on grain yield at 2.0 field capacity moisture level which corresponds to saturated or waterlogged conditions. Even the lowest zinc rate at this moisture level led to a significant (more than twofold) increase in yield compared to no-zinc treatment. The maximum yield at field capacity was produced by 5 kg Zn/ha whereas at the other moisture levels by 7.5 kg Zn/ha.

The picture for straw yield (Table 1) is slightly different from that for grain yield. The significantly highest straw yield was produced at 1.5 field capacity at almost all levels of zinc as against the highest grain yield at field capacity. The moisture levels above field capacity produced comparatively more straw than the lower moisture levels. Cannell *et al.* [2] however observed that winter water-logging caused more reduction in the yield of winter wheat than drought. Zinc fertilization led to a slight increase in the straw yield (compared to no-zinc) at all water levels but there was little difference among various zinc levels in increasing the yield.

Tissue zinc concentration. The average zinc concentration in grain and straw (data not given) generally increased with increasing levels of zinc. The moisture levels had no effect on zinc concentration in grain. In straw, the concentration was decreased at above-optimum moisture contents. This was probably due to a dilution of the zinc caused by the greater straw yields produced at the higher soil moisture levels.

Zinc uptake. Water levels had a significant effect on zinc uptake by wheat grain (Table 2). The maximum uptake occurred at field capacity (optimum) moisture level. The moisture excess as well as moisture stress caused a significant reduction in the uptake. The reduction was greatest (50 %) at both the extremes, i.e., 2.0 FC and 0.5 FC.

Zinc addition caused a significant increase in the average zinc uptake by grain compared to no-zinc but at individual moisutre levels, zinc was taken up differently.

Table 1. Grain and straw yields of wheat (g/pot) as influenced by various moisture and zinc levels.

Moisture level	Zinc level (kg/ha) 0	2.5	5.0	7.5	Mean
		Grain yield			
2.0FC*	6.65	14.70	12.75	15.33	12.36 d[1]
1.5 FC	15.90	15.85	15.15	16.36	15.82 c
1.0 FC	23.10	24.23	24.90	24.42	24.17 a
0.75 FC	16.60	19.63	20.76	21.50	19.62 b
0.5 FC	14.33	14.73	15.03	16.33	15.16 c
Mean	15.36 c	17.83 b	17.72 b	18.79 a[1]	
		Straw yield			
2.0 FC*	20.90	23.60	22.85	25.50	23.21 b[1]
1.5 FC	23.85	27.40	25.06	22.80	24.78 a
1.0 FC	21.50	22.40	22.93	21.73	22.14 b
0.75 FC	12.75	15.50	16.53	14.90	14.92 c
0.5 FC	8.75	9.67	10.53	11.66	10.15 d
Mean	17.55	19.71	19.58	19.32	

LSD (5 %)	Grain	Straw
Moisture levels	0.91	1.47 g/pot
Zinc levels	0.85	N.S "
Moist. x Zinc	1.78	N.S "

*FC = Field capacity moisture content.

1 Values followed by different letters, within a set of means, differ significantly (P <.05) by Ducan's Multiple Range Test.

Table 2. Zinc uptake in wheat grain and straw (μg/pot) as influenced by various moisture and zinc levels.

Moisutre level	Zinc level (kg/ha) 0	2.5	5.0	7.5	Mean
		Uptake in grain			
2.0 FC	225.1	612.7	488.8	564.1	472.7 d[1]
1.5 FC	524.3	602.7	556.0	754.0	609.3 c
1.0 FC	843.8	927.1	1006.6	1005.4	945.8 a
0.75 FC	555.9	704.1	893.9	795.8	737.4 b
0.5 FC	407.0	481.8	388.2	571.8	462.2 d
Mean	511.2 c	665.7 b	666.7 b	738.2 a[1]	
		Uptake in straw			
2.0 FC	420.4	509.1	648.9	663.5	560.5 b[1]
1.5 FC	407.9	624.4	620.7	604.5	564.3 b
1.0 FC	511.0	519.7	796.2	779.6	651.6 a
0.75 FC	285.4	350.9	544.4	533.4	428.5 c
0.5 FC	181.5	251.3	303.5	402.2	284.6 d
Mean	361.2 c	451.1 bc	582.7 ab	596.6 a[1]	

LSD (5 %)	Grain	Straw
Moisture levels	64.8	65.4
Zinc levels	45.3	136.6
Moist. x zinc	100.4	N.S.

1 Values followed by different letters, within a set of means, differ significantly ($P < .05$) by Ducan's Multiple Range Test.

The most pronounced effect of zinc fertilization was at 2.0 FC where about threefold increase in uptake occurred at the lowest zinc level.

In straw, the zinc uptake trend was somewhat similar to that in grain (Table 2). The highest uptake occurred at the field capacity; the moisture contents above or below this level caused a significant decrease in uptake. The reduction tanded to be lower at moisture stress (suboptimum moisture) as compared to moisture excess (above-optimum moisture). Zinc fertilization led to a significant increase in zinc uptake but the influence of zinc rates was different at different moisture levels. Trought and Drew also reported that waterlogging affected the nutrient uptake by wheat seedlings under laboratory conditions [11]. In another experiment with rice, the uptake was found to be higher in non-flooded pots compared to flooded pots [7].

The level of chemically available nutrients and their uptake by plants is usually modified by variations in soil water supply. Due to excessive water or waterlogging the growth of existing roots ceases and they may die within a few days. In contrast, shoot growth continues at similar or somewhat higher rate for several days [11]. This leads to higher dry matter production, as was observed in our study. Cessation of root growth and root respiration leads to a drastic drop in the uptake and transport of mineral nutrients to shoots. Because the shoot weight continues to increase, the nutrient concentration in the shoot declines by dilution [11]. Our results showing lower concentrations of zinc in the 2.0 field capacity treatment are in conformity with these observations. Such inhibited nutrient uptake in the waterlogged soil in normally responsible for nutrient deficiency. Also, the formation of sparingly soluble sulphides by reduction of sulphates to H_2S in these soils decrease the solubility of zinc leading to its deficiency [12]. This can be prevented by the application of zinc to soil. In our experiment application of 2.5 kg Zn/ha to the 2.0 field capacity pots increased the yield and zinc uptake by factors of 2 and 3 compared to no-zinc treatments respectively.

In water-stressed soils, on the other hand, mechanical impedance is the dominant factor which lowers the supply of mineral nutrients to plants, although other factors may be involved such as the shrinkage of root and soil particles as they dry resulting in loss of soil-root contact [13]. For the same reason, the addition of nutrients to a dry soil may not help increase the yield and uptake to the same extent as expected in a waterlogged soil.

REFERENCES

1. B.D. Boss, R.W. Pearson and T. Roger, Agron. J., **66**, 297 (1974).
2. R.W. Cannell, R.K. Belford, K. Gales, R.J. Thomson and C.P. Webster, Plant and Soil, **80**, 53 (1984).
3. O.T. Denmead and R.H. Shaw, Agron. J., **52**, 272 (1960).
4. M.A. Kausar, S.M. Alam, M. Sharif and M.I. Parvez, Pakistan J. Sci. Ind. Res., **22**, 156 (1979).
5. NARC, *Soil Status and Scope of Micronutrients in Pakistan Agriculture*, Pakistan Agr. Res. Council, Islamabad (1986).
6. NFDC, *Proceedings of Soil Laboratory Training Course*, Nat. Fert. Dev. Centre. Govt, of Pakistan, Islamabad (1986).
7. A.J. Obermueller and D.S. Mikkelson, Agron. J., **66**, 627 (1974).
8. V. Sauchelli, *Trace Elements in Agriculture*, (Van Nostrand Reinhold Company, New York, 1969).
9. S.M. Shah, W. Mohammad and M.M. Iqbal, Pakistan J. Sci. Ind. Res. **29**, 288 (1986).

10. S.M. Shah and N. Hussain, *In 'Environmental Stress and Plant Growth'*, At. Energy Agr. Res. Cent., Tandojam, (1986).
11. M.C.T. Trought and M.C. Drew, Plant and Soil, **54**, 77 (1980).
12. F.N. Ponnamperuma, Adv. Agron., **24**, 29 (1972).
13. S.M.A. Faiz and P.E. Weatherley, New Phytol., **92**, 333 (1982).