for the existence of a well-knit association between K+ content of leaf on one hand and the dry matter production on the other for the higher pod yield under moistures stress conditions.

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ZINC LEVELS IN RELATION TO GROWTH AND ZINC CONTENT OF WHEAT*

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Wheat (*Triticum aestrivum L.*) plants were grown in the greenhouse using a Zn deficient soil (Typic Torripsamment) treated with nine levels of Zn ranging from 0 to 100 ppm. The magnitude of Zn response was dependent on growth stage and Zn level. A dose upto 20 ppm Zn had no deterimental effect on yield. In early stage of growth, 2.5 ppm Zn was found better than the other levels tried. But, at later stages a higher rate of Zn (10 ppm) could meet the requirement of the crop. Concentration of Zn in different plant parts increased with the rate of its application and it was invaulable higher in lower leaves than in middle and upper ones. There was considerable build up in tissue Zn concentration at higher Zn levels without substantial difference in yield. The amount of DTPA extractable Zn decreased. With time primarily due to fixation in soil during crop growth as the total amount of Zn removed through shoot growth was only a small proportion.

Large tracts of land all over the world have been found to be deficient in one or the other micronutrient resulting in low productivity of soils. Among different micronutrients, the deficiency of Zn is widespread in Indian soils. Soil application of Zn in large amount has been found to exert an appreciable influence on crops and soils for a relatively long periods of time (Ellis *et al*, 1969) and its unplanned or excessive application may develop toxicity. Deb and Zeliang (1975) did not find any response to Zn application in terms of dry weight of wheat plants in a greenhouse experiment and Zn content of the plant was not affected by the treatment Gattani *et al*, (1976) round that dry matter yield of eight week old wheat crop increased upto 5 ppm Zn level and thereafter it decreased with increasing level of Zn.

Detailed information relating to changes that occur with age, in the content of Zn in different parts of plants is fragmentary. The present study was, therefore, undertaken to find out the effect of varying Zn levels on dry matter yield, Zn, concentration in different plant parts at three growth stages and available Zn in post harvest soil samples.

MATERIALS AND METHODS

A greenhouse experiment was conducted in polythylene lined clay pots (25 cm in diameter), filled with 4kg of Zn deficient sandy (Typic Torripsamment) soil of pH 8.3, EC 0.26 mmhos/cm, CEC 45 meq/100g, organic carbon 0.05%. The available N. P and K were 31.0, 4.2 and 63.0 ppm. respectively. The sand, silt and clay contents were 93.3, and 4% respectively. The DTPA extractable Zn (0.36 ppm) was determined according tothe procedure of Lindsay and Norvell (1978).Allthe soil properties were esti-

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mated by following the standard procedures as described by Jackson (1967). Wheat variety WH-147 was grown as test crop. The Zn was applied @ 0, 1.25, 2.5, 5, 7.5, 10, 20, 40 and 100 ppm $ZnSO_4$ $7H_2O$ The treatments were replicated nine times. A basal dose of N, P and K was applied @ 100, 50 and 50 ppm. respectively. Since soil was deficient in other nutrient elements, Mg, Fe Mn and Cu were also applied @10, 5, 5 and 1 ppm respectively. The pots were irrigated with distilled water as and when required.

Three replications out of nine were harvested at the tillering stage of growth. At second sampling, two whole plant tops at the boot stage were out at the ground surface and from the rest of the plants, younger (flag leaf), middle (2nd and 3rd) and older (all other leaves) leaves and stems were collected separately. The remaining three replications were harvested at earing stage.

Composite soil sample was also taken from each pot at every stage of sampling. after harvesting the plants, with a stainless steel tube auger. About 5-6 probes were taken from each container and mixed thoroughly to ensure representative sampling

Harvested plant samples were washed successively in acidified distilled and redistilled water and dried in an air draft oven at 70±2°. After recording the dry matter yields, the samples were ground in a Wiley-mill. Zinc was estimated in soil extracts and acid digests of various plant samples by atomic absorption spectrophotometry.

RESULTS AND DISCUSSION

Dry matter yield : A perusal of dry matter yield data (Tables 1,2,3) indicated that wheat var. WH-147 responded to Zn application and magnitude of response was dependent on growth stage and Zn level.

Maximum response was found with 2.5 ppm Zn at tillering stage. Addition of 40 and 100 ppm Zn led to a reduction in plant dry weight. At earing stage a maximum response of 40 per cent was noted at 10 ppm Zn.

Application of Zn upto 20 ppm had no detrimental effect on yield. This may be due to the tolerance of wheat to higher concentration of Zn. These results confirm to the findings of Takkar *et al.* (1975) and Singh and Singh (1979). It was further observed that in early stage of growth, 2.5 ppm Zn was found better or at par with other levels of Zn but at later stages of growth, a higher rate of Zn (10 ppm) could meet the requirement of crop. Significant increases in dry matter production for Zn additions were obtained at all 3 harvests Increase in yield due to application of Zn may be attributed to the fact that the initial status of available Zn (0.36 ppm) in the experimental soil was below the critical limit of 0.67 ppm DTPA extractable Zn as suggested by Gupta *et al.* (1981). Rathore *et al* (1978) also noted a significant response of wheat to the application of Zn in soils containing less than 0.46 ppm DTPA extractable Zn.

Zinc concentration : It is apparent from the data (Tables 1, 2, 3) that Zn concentration in various parts of wheat plants at different growth stages increased with increasing rate of Zn application. Similar results were reported by Rathore *et al.* (1978) and Singh and Singh (1979) zinc concentration in the various plant parts generally decreased with age and was invariably higher in lower (old) than in middle and upper (young) leaves. The decrease in Zn concentration of shoot ranged from 9.5 to 26.4, 3.9 to 68.2 ppm from tillering to boot growth and boot growth to earing stage, respectively, depending on Zn level. The decrease could partly be attributed to dilution effect of more dry matter accumulation with advancement of plant age.

There was considerable build-up in tissue Zn concentration at higher levels of applied Zn without any relationship with the yield. This indicated that once the minimum requirement of plant is met with, the accumulation of Zn in large quantities may take place till it is in excess to cause depression in growth. Several workers (Amber and Brown, 1969; Shukla and Raj, 1980) also reported accumulation of applied Zn by different crop plants without substantial change in yield.

An important observation cited by Agarwala and Sharma (1979) regarding appearance of Zn deficiency symptoms in the middle and lower leaves of wheat under Zn stress conditions could be explained from the Zn concentration data presented in Table 2. It is quite evident that, at low rates of added Zn, specifically upto 1.25 ppm, its concentration was very low in middle and lower leaves in comparison to upper leaves. Zinc is apprently re-translocated from lower to upper leaves where active metabolism takes place. With further increase in Zn rate from 2.5 to 100 ppm, the situation is reversed. The lower leaves had the highest Zn concentration followed by middle and upper ones. This reduction in concentration in the successive leaves from base to top of the shoot, would probably indicate little or no distribution in the plant at higher leaves of applied Zn and it gets accumulated in the lower leaves which may not be all active. *Soil Zn* : The amount of post harvest DTPA- extractable Zn in soil samples obtained at three stages of wheat growth are shown in table 1, 2, 3. It is evident from the data that a greater proportion of added Zn was fixed in the soil. At tillering stage, less than 40 per cent was DTPA extracable. The amount of DTPA extractable Zn decreased with time. Dev (1973) also found increased Zn fixation with time. The minimum and maximum decrease in extractable Zn in soil from tillering to earing stage ranged from 15 to 43 per cent of the amount available at tillering stage. The proportionate decline in extractable Zn was the minimum at the highest level of Zn and maximum in control. This decrease was primarily due fixation in soil during crop growth as the total amount of Zn removed by the crop through shoot growth was only a small proportion Reddy and Perkins (1974) concludad that Zn was fixed as a result to precipition, physical entrapment in clay lattice wedge zones and/or strongly adsorbed at the exchange sites. A

Table 1 Effect of varying Zn levels on dry weight of shoot, Zn concentration in different plant parts of wheat and soil available Zn at tillering stage

Zinc levels (ppm)	Dry weight of shoot (g/pot)	Post-harvest available soil Zn (ppm)	Zinc concentration (ppm)	
			Shoot	Leaf
0.00	2.25	0.35	21.9	22.9
1.25	2.53	0.67	54.3	57.2
2.50	2.61	1.12	75.8	83.0
5.00	2.52	2.15	100.1	100.1
7.50	2.51	3.03	120.1	120.1
10.00	2.46	3.98	128.7	134.4
20.00	2.31	8.58	157.3	162.1
40.00	2.20	15.58	197.3	197.4
100.00	2.07	39.37	235.2	332.6
S. Em ±	0.05	0.20	3.32	5.93
C. D. (5%)	0.15	0.60	9.87	17.61

Table 2 Effect of varying Zn levels on shoot dry weight, post-harvest available Zn in soil and Zn concentration in different plant parts of wheat at boot growth stage

Zinc levels (ppm)	Dry weight of shoot (g/pot)	Post-harvest available soil Zn (ppm)	Zinc concentration				
			Leaves (ppm)			Stem	Shoot
			Upper	Middle	Lower		
0.00	11.12	0.32	21.0	12.4	12.9	8.6	12.4
1.25	13.28	0.55	30.5	23.8	25.2	20.0	27.2
2.50	14.11	0.92	34.3	32.5	42.9	27.2	35.7
5.00	14.26	1.87	37.6	46.5	70.6	52.0	51.5
7.50	14.97	2.52	44.8	52.7	83.0	54.8	58.1
10.00	14.91	3.25	48.2	61.0	99.2	64.3	72.9
20.00	15.12	8.41	52.4	87.8	160.2	98.7	103.4
40.00	15.37	15.24	70.6	132.5	205.0	133.0	133.5
100.00	13.35	38.12	109.2	229.4	241.5	195.1	208.8
S. Em ±	0.30	0.23	2.50	2.92	3.37	2.50	2.62
C. D. (5%)	0.90	0.68	7.43	8.69	10.01	7.42	7.77

Table 3. Effects of varying Zn levels on dry weight post harvest available zinc in soil and zinc concentration in shoot of wheat at earing stage.

Zinc levels (ppm)	Dry weight of shoot (g/pot)	Post harvest available soil Zn (ppm)	Zinc concentration (ppm)
0.00	18.4	0.20	8.53
1.25	22.8	0.55	20.00
2.50	23 5	0.92	34.20
5.00	24.0	1.83	40.50
7.50	25.0	2.28	47.70
10.00	25.8	3.22	60.37
20.00	24.2	7.08	80.10
40.00	22.9	12.66	113.93
100.00	21.7	30.42	140.63
S.Em±	0.39	0.41	2.72
D.C. (5%)	1.18	1.20	8 09

general observation could be made from these resuls regarding changes in DTPA extractable Zn after cropping. All the Zn treatments showed a general decrease in extractable Zn after cropping Different rates of Zn application have build-up different levels of residual available Zn and significantly increased Zn content from deficient to sufficient levels.

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