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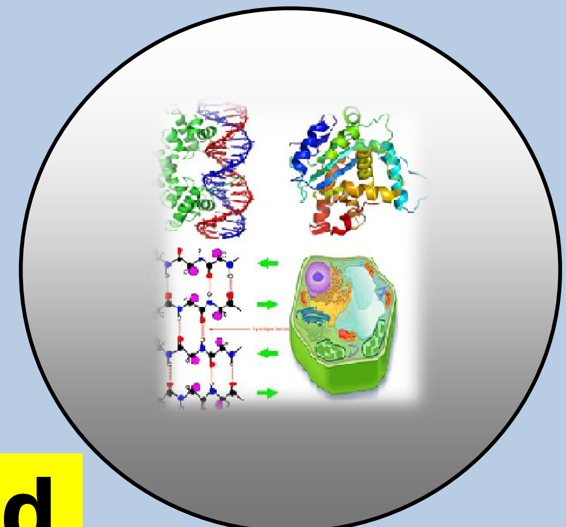

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Effects of Soil Sodicity on Growth, Biochemical Constituents and Zinc Content in Wheat Plants

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ABSTRACT

The soil from Jankipuram area (Lucknow district, U.P., India) was alkalized to prepare graded sodicity viz. Nil, 5.2, 19.8, 38.9 and 80 E.S.P. and used to grow wheat (Triticum aestivum L., var. H2829). Growth, biochemical constituents (pigments, enzymes and sugar) and tissue zinc were observed. Increase in Na levels in soil above E.S.P. 5.2 suppressed seed germination shoot length, tillering and exhibited visible symptoms of Zn deficiency such as stunted growth, chlorosis in young leaves, reduced size and fading of leaf lamina and brown spots on young leases were observed. Excess Na levels above E.S.P. 5.2 in soil inhibited dry matter yield, pigments and sugar contents. Also, suppressed the accumulation of Zn in wheat shoot up to a deficient level (<15 µg/g dry weight). Severity of visible symptoms and biochemical constituents was decreased with decrease in Na concentration in soil. Whereas low Na in soil (E.S.P. 5.2) showed promontory effects on above parameters estimated and tissue Zn in wheat.

Key words: Sodicity, Zn availability, Wheat, Bio Chemical Constituents, and Growth.

INTRODUCTION

In India, about 63851.35 Km^2 area are salt affected. Indogangatic plains in northern India (semi arid region) is a large tract of salt affected soils. The productivity of 6.73 Mha. land is limited by the salinity/alkalinity in India. Nutrient disorder is a major factor of poor plant productivity on halomorphic soil for increasing population, today. Sodic soils are mainly characterized by its high pH (> 8.5), exchangeable sodium content (> 15 percent), humus dispersion (Marschener, 1995) and poor availability of micronutrients (Sharma, 2006).

Sodic soils are rich in carbonate salts cause high soil pH, which brings poor availability of micronutrients (Pandey and Gautam, 2009). Zinc form a structural component of a large number of proteins with catalytic or regulatory functions. Zinc is a cofactor of large numbers of enzymes (Valee and Auld, 1990). Least information are available on the critical limit of micronutrient Zn both in soil and plants which leads various growth and biochemical disorders and decreases production in plants grown at sodic soils. Information may help at least in identification of limits of sodicity which can support wheat crop and management of such problem soils for improvement in crop produce. Therefore, present study was carried out to find the availability of Zn as micronutrient in soil and plants and their effect on growth and biochemical responses of wheat (*Triticum aestivum* L., var. HD 2829) grown in various levels of sodic soils.

MATERIAL AND METHODS

A composite surface soil (0-25cm) collected from the Jankipuram) area of Lucknow district (U.P. state, India) analyzed for some physico-chemical properties (Table 1). The collected soil was alkalized to prepare graded sodicity and rated viz. Nil, 5.2, 19.8, 38.9, 80.0 E.S.P. (exchangeable sodium percentage). Sodium carbonate, sodium bicarbonate and sodium sulfates were used to prepare soil with graded exchangeable sodium percentage. In the water saturation extract of soil prepared and sodium was estimated flame photometrically, calcium by versene procedure, carbonate and bicarbonate by titrimetric procedure and sulfate by Chesnin and Yien as described by Jackson, 1958. The exchangeable sodium percentage (E.S.P.) of the soil was determined according to formula:

$$E.S.P. = \frac{\text{Exchangeable Na in meq. 100g of soil x 100}}{\text{Total cation exchange capacity in meq. Na / 100g soil}}$$

DTPA extractable available micronutrients content (Zn, Cu, Fe, Mn) in soil was estimated by the method of Lindsay and Norwell (1978) presented in Table 1. The graded sodic soils above prepared were filled up in duplicate in polythene lined 10 Kg size clay pots and mixed with 5 0 ppm nitrogen, P_2O_5 and K_2O each. These graded soils used for sowing wheat (*Triticum aestivum* L. var. HD2829). Ten seeds in all pots were sown, and after emergence pots were thinned to 5 seedlings. Each pot top dressed by nitrogen at the rate of 50 ppm at tillering stage of growth. A visible effect of sodicity was observed periodically. Growth parameters such as emergence, shoot height, tillering and dry matter yield of plants were observed at day 45 of the growth. Test plants sampled at 45 days of growth were analyzed for tissue concentration of zinc. At day 45 of growth, soil sample from each pot of treatments were also analyzed for DTPA extractable available trace metals (Zn, Cu, Mn, Fe) by the method of Lindsay and Norwell, 1978. Pigments content was estimated by the method of Lichtenthalclr and Welburn, 1983. Sugar content by Dubois *et al.,* 1956, catalase by Euler and Josephson, 1959 and peroxidase activity by the method of Luck, 1963 were estimated. The digested plant samples (with nitric-perchloric acid) and 1:2 soil-DTPA extract (pH 7.3) was estimated on Atomic Absorption Spectrophotometer Parkin-Ulmer-250.

Data presented in the table are mean ± S.E. value (n=3) and statistically analyzed using student 't' test for significance. Also one-way ANOVA was used to determine statistical significance.

$F = MSB/MS_E$ Where:

MS_B = The mean square between group [explained variance].

MS_E = The mean square within groups [error various].

RESULTS

Growth and visible symptoms

At high levels of exchangeable sodium (EPS 38.9 and 80) seed germination was delayed and reduced. High Na in soil showed visible effects on plants such as reduced size and fading of leaf lamina, stunted plant growth and small brown necrotic lesions on the base of leaf were observed. The chlorosis gradually proceeding younger to older leaves. Severity of visible effects was less at E.S.P. 19.8 than higher E.S.P levels in soil (38.9 and 80.0). At these high levels of sodium decreased shoot length and tillering of wheat plants were also observed. The emergence of seedlings, shoot length and tillering were favored by low sodium levels in soil (E.S.P. 5.2). Low level of added sodium in soil promoted growth including dry matter yield than higher levels of Na in soil. Decrease in dry matter yield and severity of visible symptoms increased with increase in Na levels in soil above E.S.P. 5.2. Maximum reduction in seed germination, shoot length and dry matter yield by 50, 48 and 80% was observed respectively at high Na content in soil (E.S.P. 80).

Zinc in soil and plants

The tissue accumulation of Zn showed that, high levels of added sodium (ESP 38.9 and 80) markedly decreased the Zn uptake by wheat. At highest level of added sodium in soil (ESP 80) resulting highly dwarfed or dying seedlings accumulated a low level of Zn (< 12μg g^{-1} dry weight). Wheat plants showed increase in tissue concentration of Zn (22.5 μg Zn g^{-1} dry weight) grown at soil up to ESP 19.8 but tissue Zn was low as compared to wheat grown at soil with E.S.P. 5.2.

Pigments and total sugar content

A significant decrease was found in pigments content (Chlorophyll a and b) in wheat leaves grown at sodic soils have ESP greater than 5.2. reduction in chlorophyll 'a' content by 24, 35 and 69% at ESP 19.8, 38.9 and 80 in soil, respectively. The reduction in chlorophyll 'a' was more than the chlorophyll 'b' was observed. Inhibitory effects of sodic soil (ESP 80) on pigments content was found in wheat leaves showed low level of tissue Zn (8.2 μg g^{-1} dr. wt.)

Enzymes activity

Activity of catalase and peroxidase was found decreased in wheat at high sodium levels in soil (ESP 38.9 and 80.0). While, lower levels of sodic soils (E.S.P. 5.2 and 19.8) promoted these enzymes activity. Whereas further increase in sodium levels in soil decreased catalase activity in wheat leaves by 37 and 60% observed at ESP 38.9 and 80 respectively.

Total sugars content

Excess sodium (E.S.P. above 19.8) in soil decreased total sugar content in wheat leaves. Maximum reduction in sugar content by 75 percent was recorded in wheat at ESP 80 in soil. Whereas, low sodium level (E.S.P. 5.2) increased sugar content in wheat leaves by 17%. Sugar content followed similar trend as pigments content (chlorophyll a and b) in reduction induced by sodic soil with E.S.P. above 19.8 in soil.

DISCUSSION

At high levels of exchangeable sodium (EPS 38.9 and 80) seed germination was delayed and reduced. High Na levels in soil also showed visible effects on plants such as reduced size and fading of leaf lamina, stunted plant growth and small brown necrotic lesions on the base of leaf were observed. The chlorosis gradually proceeding younger to older leaves. These symptoms resembled with Zn deficiency as earlier described by Sharma *et al.,* 1971. In test plants, emergence of seedlings, shoot length and tillering were favored by low sodium levels in soil, these beneficial effects could be attributed due to the uptake of low sodium content and sufficient amount of Zn in wheat (Marschner, 1995). On the other hand, reduction in above mentioned growth parameters might be due to the effect of excess Na in soil which caused Zn deficiency in plants due to their low uptake and translocation to the shoot (Garg and Malhotra, 2008). Low level of added sodium in soil (E.S.P. 5.2) promoted dry matter yield, a beneficial effect of added sodium at its low level can to some extent be explained on the basis of its beneficial effect on Zn uptake has been reported by Mehrotra and Agrawala, 1979. Plants accumulate high content of Na grown in soil with high ESR reduces K^+, Zn, Cu and Fe uptake in plants (Prasad *et al.* 2006, Upadhyay and Pandey, 2011), these conditions may be a cause of reduction in seed germination, plant growth and tillering in wheat. Excess Na in soil also reduces uptake of N, P, sulphur, Zn and Fe contents may lead decrease in biomass production in wheat (Agarwala and Mehrotra, 1979). High levels of added sodium in soil with ESP 38.9 and 80 markedly decreased the Zn uptake by wheat showed low tissue concentration of Zn 11.5 and 8.2 µg g^{-1} dr. wt. respectively. At highest level of added sodium (EPS 80) resulting highly dwarfed or dying seedlings might be accumulated a high concentration of Na, it is possibly due to the loss of plants differential capacity of nutrient uptake (Blumwald, 2000). At low Na in soil caused passive uptake of zinc by wheat with metabolic control of their absorbing organs the root, finding was also in accord with Greenway, 1965. Wheat showed increase in tissue concentration of Zn grown at soil with ESP 5.2 (20.6 µg Zn g^{-1} dr.wt.) and ESP 19.8 (17 µg Zn g^{-1} dry weight) was in a sufficient range as 15-25 µg g^{-1} dry weight a critical sufficient range for most of the crop growth has been described (Sharma, 2006). A significant decrease was found in pigments content (Chlorophyll a and b) in wheat leaves grown in high sodic soils (ESP 19.8, 38.9 and 80) shown in Table 4. Decrease in chlorophylls content could be attributed due to disruption of fine structure of chlorophyll and instability of pigment-protein complex by excess accumulation of Na, in tissue (Upadhyay *et al.,* 2012). The antioxidative enzymes catalase and peroxidase activity was found decreased in wheat at high sodium leaves in soil (ESP 38.9 and 80.0) may be due to inhibitory effect of excess Na and deficient level of Zn in plant (Tiwari and Singh, 1999). While, lower levels of sodic soils promoted these enzymes activity. The increased activity of pigments and enzymes determined in wheat could be due to the sufficient accumulation of micronutrients and beneficial role of low Na in wheat (Marschner and Cakmak, 1989). Elevated Na content in soil low may cause Fe content in plant, which could decreased the activity of catalase and peroxidase in wheat leaves (Sijmons *et al.,* 1985). Maximum reduction in sugar content by 6, 17 and 75 percent was recorded in wheat at ESP 19.8, 38.9 and 80 respectively could be attributed by the reduction in photosynthesis with low uptake of Fe (Dai *et al*., 2000) and low chlorophyll concentration in wheat under the influence of elevated Na in tissue (Chereskin and Castelfraneo, 1982, Upadhyay *et al*., 2012).

Table 1. Physico-chemical properties of native composite soil used in the experiment.

Soil properties	Average value
Texture	Silty loam
Exchangeable sodium percentage	2.8
pH (1:2.5 soil and water)	7.6
Organic matter (%)	0.3
$CaCO_3$ (%)	1.50
Carbonate (meq. /L)	0.5
Electrical conductivity (mS/cm at 25^{o}C)	0.62
Bicarbonate (meq./L)	1.5
Available Zn (ppm)	0.28
Available Cu (ppm)	0.20
Available Mn (ppm)	0.35
Available Fe (ppm)	5.6
Sulfate ions (meq./L)	0.8

Table 2. Effect of graded soil sodicity in soil on Zn content in soil (DTPA extractable) and plant (wheat).

Parameters	**Soil sodicity [ESP]**				
	Nil(2.8)	5.2	19.8	38.9	80.0
Soil (µg Zn g^{-1} soil)	0.28 ±0.01	0.29 ±0.05	0.31 ±0.05	0.16 ±0.01	0.15 ±0.01
Shoot (µg Zn g^{-1} dr. wt.)	14.5 ±0.5	20.6 ±0.2	17.0 ±0.1	11.5 ±0.1	8.2 ±0.5

Table 3. Effect of sodic soil on growth of wheat (*Triticum aestivum* L. var. HD 2829).

Parameters	**Soil sodicity (ESP)**				
	Nil(2.8)	**5.2**	**19.8**	**38.9**	**80.0**
Germination (%)	**40 ±1.5 (0.0)**	**45 ±2.0 (+12.5)**	**35±2.0 (-12.5)**	**35 ±1 (-12.5)**	**20 ±1.0 (-50)**
Shoot length (cm)	**30.5 ±1.0 (0.0)**	**34.6±6.9(+13.4)**	**29.0 ±1.5 (-5)**	**25.2 ±1.0 (-17.4)**	**15.8 ±1.0(-48)**
Tillering / plant	**1.2**	**2.0**	**2.0**	**1.0**	**0**
Dry weight (g)	**0.25±0.01 (0.0)**	**0.32±0.01 (+28)**	**0.20±0.01(-20)**	**0.18±0.02(-28)**	**0.05±0.01(-80)**

Low sugar content and reduction in catalase and peroxidase activities is an indication of loss of defense system against free oxygen radicals, which may caused due to low Zn level in wheat under Na stress conditions (Cakmak, 2000, Cakmak and Marschner, 1988). Reduction in chlorophylls content and dry matter yield in test plants might be also resulted due to low Zn and other essential micronutrients content in the tissues induced by excess Na content in soil and their accumulation in wheat plants (Shrotri *et al*., 1980; Sharma, 2006). Zinc deficient plants show low activities of catalase has also been reported earlier by Marschner and Cakmak (1989). In addition, low activity of catalase may be due to the iron deficiency in plants and high pH of soil (Bertamini *et al*., 2002).

Table 4. Effect of sodicity in soil on biochemical responses of wheat (*T. aestivum* L.var. HD2829).

Parameters	Soil sodicity (ESP)					LSD CD=0.05
	Nil (2.8)	**5.2**	**19.8**	**38.9**	**80**	
Catalase (µ moles H_2O_2 Split/100 mg fr.Wt.)	2460 (0.0)	2575 (+5)	2975 (+21)	1550 (-37)	980 (-60)	985
Peroxidase (µ moles H_2O_2 Split / 100 mg fr.wt.)	10.3 (0.0)	11.5 (+12)	9.2 (-11)	6.5 (-37)	4.6 (-55)	1.2
Chlorophyll 'a' (mg g^{-1} fr.wt.)	1.62 (0.0)	1.85 (+14)	1.23 (-24)	1.06 (-35)	0.50 (-69)	0.6
Chlorophyll 'b' (mg g^{-1} fr.wt.)	0.80 (0.0)	0.95 (+19)	0.65 (-19)	0.50 (-38)	0.40 (-50)	0.50
Total sugars (µg sugar/100 mg fr.wt.)	180 (0-0)	210 (+17)	170 (-6)	150 (-17)	45.0 (-75)	35.0

CONCLUSION

Therefore, study concluded that excess sodium in soil inhibited plant growth and suppressed biochemical constituents in wheat, and retarded uptake and translocation of Zn with exhibition of some visible symptoms of Zn deficiency. Such soils need Zn fertilization and reclamation. Wheat plants in such soil with E.S.P. below than 19.8 may give normal growth.

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