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ORIGINAL ARTICLE

Sustainable Ways of Zinc Management to Improve Growth and Metabolic Constituents in Wheat

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ABSTRACT

The effect of various ways of sustainable zinc management in soil to improvethe growth of plants (length and dry weight), some biochemical parameters (pigments and protein contents, and the activity of catalase and peroxidase) in wheat was studied.A clay pot experiment was conducted. The amendment of zinc was made as I- nil (control), II- Zn-enriched compost extract (40%), III- Green synthesized Zn nanoparticles, IV- Zn + EDTA, and V- $ZnSO_4$ fertilized in the soil to find out the best sustainable way of Zn fertilization.The experiment was conducted in triplicates. Maximum dry weight (+50%), pigments, and protein contents (+36.8%) were found when Zn-enriched compost extract (40%)was applied tothe soil. A single application of $ZnSO_4$ also increased all the determined parameters in wheat, but the effect was less than the Zn-enriched compost extract. Among all treatments, Zn-EDTA showed the least promotery effects on wheat vegetative growth, but the effect was maximum at reproductive yield (length and weight of inflorescence and grains weight).

KEY WORDS: Alluvial soil, Micronutrients, Soil, Wheat, Zinc sulfate.

INTRODUCTION

Micronutrient zinc (Zn) plays vital rolein the growth and metabolism of plants, as being activator of many enzymes (Sharma, 2006; Lv *et al*., 2023), and also important to human health (Kavian *et al*., 2022). In India, the agricultural area deficient in zinc is spread over 50% (Assche *et al*., 2003). Zinc plays a role in the regulation and protection of cellular metabolism and other many physiological processes in plants (Marschner, 2011; Pandey, 2020), whichgreatly influencecrop production (Verma & Pandey, 2020). Zinc plays role in the structural integrity of cellular membranes, in the expression of genes and regulatory functions of various biochemical reactions in cell (Andreini *et al*., 2006; Sadeghzadeh, 2013). Photosynthesis of C_4 plants has an enzyme system carbonic anhydrase fixes the CO_2 at first step Thus, have a significant role in the photosynthesis of C_4 plants. (Sharma, 2006). Zn is the main activator of this carbonic anhydrase enzyme described (Pandey, 2018). Also, the role of Zn in tryptophan biosynthesis as the precursor of indole-3-acetic acid (IAA) has been described (Sharma, 2006). At Zn deficiency in adverse soil conditions, (such as alkaline pH, sandy soil texture, low organic matter content etc. availability of Zn to plants is very poor (Cakmak 2000; Marschner, 2011). Therefore,a deficiency of Zn causes negative effects onthe growth and reproductive development of crops via reducing metabolic activities (Krouma, 2023). It has been observed that there is a frequent deficiency of Zn in North Indian Plains of alluvial soil (Pandey & Gautam, 2009; Malviya & Pandey, 2023). Management of soil through sustainable ways of zinc can solve the zinc deficiency problem in crops. At the immature plant growth stage,the application of Zn-nanoparticles may be apossible tool of zinc supplement to the crops. For the efficient availability of Zn in soil use of EDTA chelates has been documented (Dhaliwal *et al*., 2022) but it may cause adverse soil health effects.

The least work is available on the application of zinc in soil by a single use of $ZnSO_4$, EDTA-chelated Zn and green synthesized Zn-nanoparticles (reduced size of Zn<100 nm)sources. Therefore, a comparative study was made on the effectiveness of these ways of Zn applications

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in soil and their effect on growth, biochemical status and reproductive yield of wheat (*Triticum aestivum* L.).

MATERIALS AND METHODS

Clay Pot Experiment

A claypot experiment was conducted in the glasshouse condition to study the various measures of Zn supply in the soil to find a sustainable and effective way to improve growth (length, dry weight), biochemical constituents (pigments, protein, catalase, and peroxidase activity) and reproductive yield of wheat (*Tritcum aestivum* L.).

Soil Analysis

Soil analysis was carried out for pH, texture, and organic matter by the method described by Piper (1962). Organic matter content was determined by the Walkley-Black method (1934) as described in Piper (1962). Available Zinc (DTPA-extractable) in soil was determined by Lindsay and

Table 1: Physico-chemical properties of the soil (Badshahbagh area, Lucknow district)

Soil Texture	pH	O.M. (%)	Bulk density (g/cc)	EC dS/cm	$CaCO_3$ (%)	Zinc (ppm)
Sandy loam	7.8	0.4	1.41	0.47	1.41	0.56

Table 2: Various ways of Zinc fertilization (as $ZnSO_4$) in wheat and their effect on growth and some biochemical constituents.

Treatments					
Parameters	I	II	III	IV	V
Dry weight(g)	10.1±0.5(0.0)	15.2±0.9(+50.0)	10.1±0.8(+0.09)	13.3±1.1**(+31.7)	14.4±1.1(+41.8)
Length (cm)	61.5±1.1(0.0)	68.5±1.4(+11.3)	60.5±1.3(-1.6)	66.0±2.0(+7.3)	64.0±1.4(+4.0)
Chlorophyll a (mg g^{-1} fr. wt.)	2.1±0.14(0.0)	2.9±0.17**(+38.0)	2.3±0.14(+9.5)	1.6±0.17(-23.8)	1.7±0.14(-19.0)
Chlorophyll b (mg g^{-1} fr. wt.)	1.0±0.17(0.0)	1.7±0.17(+70.0)	1.2±0.11*(+20.0)	0.8±0.14(-20.0)	0.7±0.17(-30.0)
Total chlorophyll (mg g^{-1} fr. wt.)	2.0±0.01(0.0)	4.5±0.1(+125)	2.0±0.02(0.0)	1.5±0.01(+725.0)	3.5±0.01(+75.0)
Carotenoids (mg g^{-1} fr. wt.)	1.4±0.11(0.0)	2.0±0.14**(+42.8)	1.9±0.14(+35.7)	1.6±0.14(+14.3)	1.6±0.32(+14.3)
Peroxidase (µmol H_2O_2 decomposed mg^{-1} protein)	51.1±1.4(0.0)	69.9±1.5**(+36.7)	58.2±1.4(+13.8)	53.0±1.1(+3.7)	63.6±1.4(+24.4)
Catalase (mMol H_2O_2 decomposedfr.wt./100mg)	360.0±1.1(0.0)	640.0±2.0(+77.7)	620.0±1.4(+72.2)	640.0±2.0*(+77.7)	600.0±1.4(+66.6)
Protein (µg g^{-1} fr. wt.)	94.1±1.4(0.0)	123.7±1.1**(+36.8)	114.5±1.7(+21.6)	105.5±2.0(+12.03)	128.9±1.7*(+31.3)

Treatments: I–Nil (native soil), II–Zn-enrichedcompost extract, III–Green synthesized Zn nanoparticles, IV–Zn +EDTA, and V– $ZnSO_4$ fertilization before flowering. Parenthesis indicates percentage decrease (-) or increase (+) over control.±S.E. (n = 3); *- value significant at p< 0.05 level and **- value significant at p< 0.01 levels.

Table 3: Various ways of Zinc fertilization (as $ZnSO_4$) on reproductive yield of wheat.

Treatments					
Parameters	I	II	III	IV	V
Inflorescence length (cm)	10.5±1.0(0.0)	12.0±1.4(+14.3)	12.2±1.4(+2.0)	13.5±1.1**(+12.5)	12.5±1.0(+4.1)
Inflorescence weight (g)	6.82±0.1(0.0)	17.5±2.0(-17.1)	14.5±1.4(-61.0)	24.47±1.7**(+259.0)	15.6±1.4(-10.8)
Weight of 20 grains (g)	0.6±0.05(0.0)	0.8±0.01(-3.8)	0.5±0.02(-42.3)	0.9±0.02**(+4.4)	0.8±0.01(-5.4)

Treatments: I–Nil (native soil), II–Zn enriched compost extract, III–Green synthesized Zn nanoparticles, IV–Zn +EDTA, and V– $ZnSO_4$ fertilization before flowering. Parenthesis indicates percentage decrease (-) or increase (+) over control. ± S.E. (n = 3); *- value significant at p< 0.05 level and **- value significant at p< 0.01 levels.

Norwell (1978). 20 g of air-dried soil was weighed and transferred in a 125 ml Erlenmeyer flask and to it 50 ml of DTPA extracting solution was added and each flask was covered with stretchable parafilm and placed on a reciprocating shaker. The solution was shaken at a speed of about 176 cycles/min for 2 hours and filtered through Whatman filter paper number 42. The filtrate was analyzed by atomic absorption spectrophotometer (Shimadzu AA 7000).

Growth Observations

Growth (length and dry weight) and visible symptoms on plants at each treatment were observed, periodically. The length and dry weight were observed at the time of harvesting of the wheat plant. Soil was determined deficient in Zn (Agarwala & Sharma, 1979).

Biochemical Responses

The biochemical parameters were determined by the prescribed standard methods: Pigments (Lichtenthaler & Welbern, 1983), Catalase, (Euler & Josephson, 1927), Peroxidase (Luck, 1963) and Protein (Lowry *et al*., 1951).

Statistical Analysis

Data were statistically analyzed with standard error (n=3) for their significance by the student '*t*' test method.The data presented in the table are mean values.

RESULTS AND DISCUSSION

Growth (dry weight and length), some biochemical constituents (pigments, protein and activity of catalase and peroxidase) and crop reproductive production (weight and length of inflorescence, grain weight) were determined in wheat (*T. aestivum* L.) in response to various ways of Zn management in the soil to find out an effective sustainable way of Zn-management to optimize wheat production. Data are presented in tables 2 and 3.

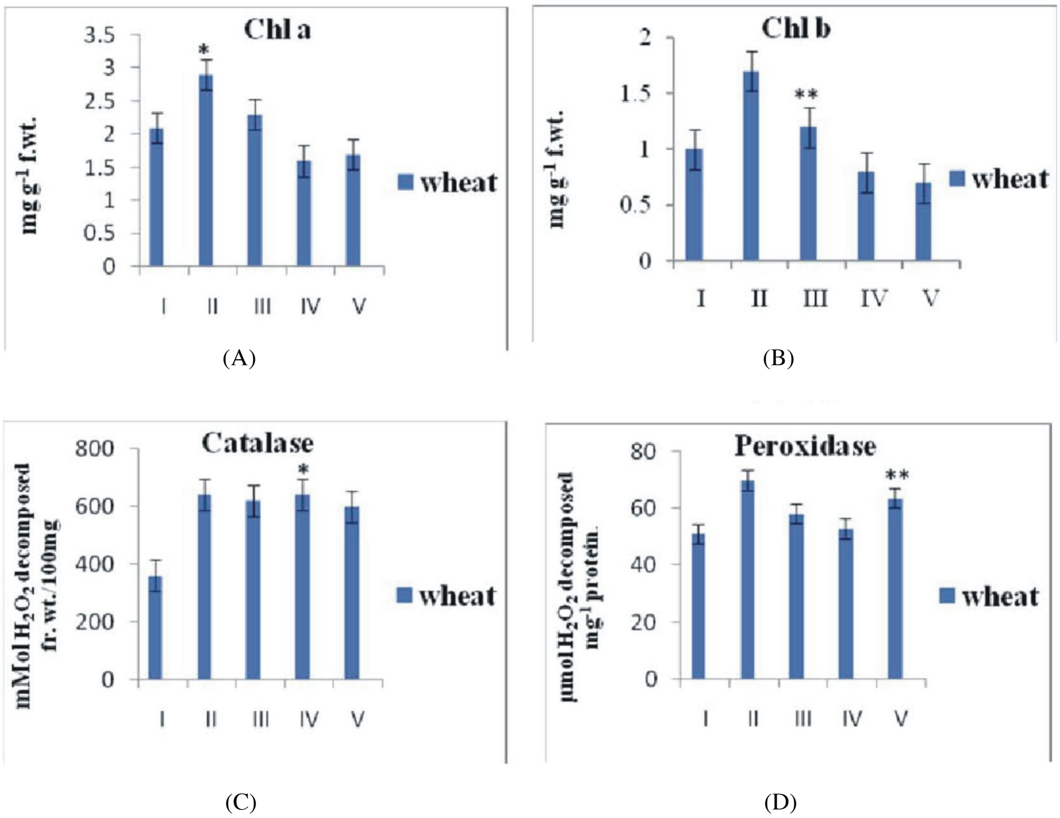

Fig. 1. Various ways of Zinc fertilization (as $ZnSO_4$) in soil and their effects onchl. a (A), and chl. b (B), catalase activity (C) and peroxidase activity (D) in wheat. Treatments: I– Nil (native soil), II–Zn-enriched compost extract, III–Green synthesized Zn nanoparticles, IV–Zn +EDTA, and V–$ZnSO_4$ fertilization before flowering.

Soil Fertility Status

An evaluation of soil fertility status (Table 1) indicated low organic matter content (0.4%) (Brady and Weil, 2017) and Bioavailable Zn (< 0.8 ppm) in the soil (Agarwala & Sharma, 1979). The low Zn could be due to the low organic matter content and alkaline pH range of the soil (Pandey, 2020). In addition, more sandy soil textural proportion lowered available Zn (Brady & Weil, 2017). Soil bulk density (1.41 g/cc) indicated moderate compactness of the soil. The presence of calcium carbonate (lime) and clay fraction in the soil makes compactness in the soil (Brady & Weil, 2017).

Growth

All the ways of Zinc-management promoted the growth of wheat. Without Zn management, wheat showed poor growth and exhibited some visible symptoms such as stunted shoot length, reduced size of leaf lamina, yellow spots in the interveinal areas and browning of leaf tip etc. resembled deficiency symptoms of zinc as reported earlier (Sharma, 2006; Pandey, 2020). Maximum length (+11%), dry weight (+50%) were observed at Zn-enriched compost extract (40%) as compared to control and Zn-EDTA treated wheat plants (Table 2). Compost extract in combination with Zn might be improved soil conditions facilitating Zn availability in the soil resulted in improved wheat growth (Marschner, 2011; Brady & Weil, 2017).

Biochemical Responses

Some important biochemical constituents were determined in wheat leaves such as pigments (chlorophyll a, b and total chlorophyll) and protein contents showed maximum increase in plants grown at Zn-enriched compost extract (40%) appliedto soil. These enhanced results followed at the soil treated with $ZnSO_4$ @ 25 mg/kg soil. The results might be due to the adequate Zn availability to the wheat and normal regulation of Zn-related cellular metabolism (Cakmak *et al*., 2023). Among the pigments determined, the maximum enhancement was in total chlorophyll (+125%), followed by chlorophyll a (+38%) and chlorophyll b (+70%). The increase in chlorophyll b content was more as compared to chlorophyll a. Pigments content could be supported by the Zn and minerals in the compost extract which supported the biosynthetic pathway of pigments (Maoka, 2020). Protein content in wheat alsoincreased at Zn-enriched compost extract as well as a single application of $ZnSO_4$ (@ 25 mg/kg soil) in the soil. Zn-EDTA application in the soil also showed promotery effects on both pigments and protein contents in wheat but was less effective than the above two applications in the soil. Maximum protein content was observed at Zn-enriched compost extract by 36% (Treatment-II) followed by single $ZnSO_4$ applications by 31.3% (Table 2). These could be attributed to the Zn supply to the wheat tissues (Maoka, 2020), Zn-facilitated biosynthetic pathways in cellular metabolism (Lv *etal*., 2023) and being essential constituents of biomolecules involved in pigments and protein synthesis (Pandey, 2018).

Antioxidative Enzymes

All the supplements of Zn sources in the soil showed promotery effects on antioxidative enzymes catalase and peroxidase. However,the effectiveness of promotery effect was more on the activity of catalase compared to the peroxidase and carotenoids content in wheat (Table 2, Fig. 1). Maximum enhanced activity of catalase (+77%), peroxidase(+36%), and carotenoids content (+42.8%) was determined at Zn-enriched compost extract (40%) as compared to the other applications of the Zn sources in the soil. These results might be indicative of the significant protective role of Zn in plants (Khan*et al.*, 2022). Zinc as an important constituent in antioxidative enzymeshas been reported earlier (Sharma, 2006; Cakmak*et al*., 2023).

Reproductive Production

Zinc application through various ways in soil promoted reproductive yield (weight and length of the inflorescence, grains weight) of wheat. Maximum increase was observed in the inflorescence length (+12.5), weight (+259) and grains weight (+4.4%) at Zn-EDTA application in the soil over control (Table 3). An effective increase was also observed at Zn-enriched compost extract (40%) application in the soil increased inflorescence length by +14.3 and weight by +157.4%. The promotery effect of Zn-EDTA supplement could be due to the facilitation of Zn transportation in wheat shootsup to the apical portion of plants (Pandey, 2020). But Zn-enriched compost extract application (40%) also increased reproductive yield of wheat by promoting the growth as well as biochemical constituents (Mani *et al*., 2019) in wheat. Role of Zn in reproductive yield have been reported earlier (Sharma, 2006; Sharma *et al.,* 2013).

Therefore, study was conducted that Zn-enriched compost extract (40%) promoted growth, biochemical constituents determined and wheat grains production. Although, Zn-EDTA supplement showed more reproductive production but Zn-enriched compost extract (40%) promoted over all above parameters determined in wheat resulted sustainable way of Zn fertilization in soil to optimize wheat production than chemical sources of Zn applications.

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