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Improving Zinc Efficiency through Tillage Practices for Wheat Productivity and Soil Properties

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ABSTRACT

Due to Rapid response and high sensitivity, soil biological properties including microbial enzymatic activities are appropriate indicators of soil quality, under different agricultural systems. Hence the study was conducted to investigate the zinc efficiency through tillage practices for wheat productivity and soil properties, at New Developmental Research Farm (NDRF) at the University of Agriculture Peshawar during 2012-13. Three different tillage practices were allotted to main plots and five zinc levels to sub plots and were trialed in Randomized Complete Block design (RCBD) having three replications. Wheat variety Atta Habib was sown in the 3rd week of November, using 120 kg ha^{-1} seed rate. The results showed that Rotavator had significantly improved soil bulk density (1.30 g cm^{-3}), zinc content (0.51 mg kg^{-1}), organic matter (0.95 %), total nitrogen (0.45 g kg^{-1}), phosphorous (3.34 mg kg^{-1}) and potash (93.22 mg kg^{-1}). Lower soil bulk density (1.31 g cm^{-3}), higher soil zinc content (0.44 mg kg^{-1}), organic matter (0.93 %), phosphorous (3.39mg kg^{-1}), and potash (91.06 mg kg^{-1}) were recorded in soil depth of 0-15cm. However, maximum soil zinc content (0.78 mg kg^{-1}) and organic matter (0.92 %) were recorded in plots received Zn 10 kg ha^{-1}. Thus it is suggested that 7.5 kg ha^{-1} zinc will be useful under rotavator tillage practices for improved wheat productivity and soil physical and chemical properties.

KEY WORDS: Zn, Tillage, Wheat, Organic matter, Total nitrogen\

INTRODUCTION

Wheat (*Triticumaestivum*) is the most essential food across the globe. It occupies the largest crop area, and giving more yield comparatively to any other cereal crop. In Pakistan it is grown on about 65 % of the total area under cultivation, producing an average yield of 2834 kg ha^{-1}showed its importance [1]. It contains proteins and nutrients required by the body and also provides 60% of the calories in the average diet [2].

The quality and production of wheat crop might be influenced by the management of crop grown in the previous year but is highly dependent to the management practices of the recent year [3]. The capricious factors i.e. amount of seasonal rainfall [4], weed infestation [5], low availability of micronutrients [6], loss of microbial population (15 %) and soluble N fractions (40 %) through leaching [7] are mostly responsible to minimize the yield of wheat crop. Lack of inputs management [8] in addition to tillage practices [9] are the important factors to minimize the yield of wheat crop to overcome the increasing need of the growing population.

Tillage practices like deep, conventional or minimum has considerable positive effects on the soil fertility, and crop yield. Obtaining maximum yield of the wheat crop required balanced and adequate nutrients. The deficiencies regarding micronutrients in the soils were observed from the last few years [6]. The excessive application of lime leads to the Zn deficiency [10]. Adaptation of high yielding cultivars, liming of acid soils and NPK fertilizers increase the crop yield [11]. A number of experiments and trails were conducted and obtained encouraging results of Zn application on the net yield of wheat [12] and therefore approved for field crops.

Information regarding the Zn application under a range of tillage practice for the wheat production and improved soil fertility is not widely available in the agro-climatic condition of Peshawar. After observing the above mentioned limitation and aspects, the experiment was planned to detect the best level of Zn and better tillage practice to improve production and soil physical and chemical properties in agro-climatic conditions of Peshawar.

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MATERIALS AND METHODS

Field experiment on "Improving zinc efficiency through tillage practices for wheat productivity" was carried out at Newly Developmental Research Farm at The University of Agriculture Peshawar in 2012-13, with the mentioned factors and levels. Factor A = Tillage practices (Main plot). Rotavator (Minimum plough), Filed cultivator (Farmer practice) and Chisel plough (Deep plough). Factor B contain Zinc levels was applied to Sub plot at 0, 2.5, 5.0, 7.5, 10.0 kg ha^{-1}.

Table 1.Physico-chemical properties of soil before wheat sowing

Soil physical and chemical	Units	Soil depths (cm)		
		0-15	15-30	30-45
Sand	%	24.33	26.12	27.54
Silt	%	67.21	65.21	62.14
Clay	%	8.42	8.67	10.32
Organic matter	%	0.86	0.81	0.67
Lime Content	%	9.04	9.02	9.01
pH	-	8.3	8.2	8.3
EC	d Sm^{-1}	0.56	0.55	0.55
Total N	g kg^{-1}	0.45	0.43	0.41
Mineral N	mg kg^{-1}	6.98	7.01	6.87
Potassium	mg kg^{-1}	91.24	105.24	84.24
Phosphorous	mg kg^{-1}	2.99	2.88	2.88
Zn	mg kg^{-1}	0.14	0.12	0.12

The field trail was carried out in RCBD with split plot arrangement and repeated three times. The sub plot size was 05 x 03 m^2 having 10 rows with a distance of 30 cm and length of 5 m. Tillage practices were carried out in the designated plots, whereas Zn ($ZnSO_4.7H_2O$) having 22 % Zn, were incorporated at the time of sowing. Recommended basal doses of N, P_2O_5 and K_2O at the rate of 120:60: 60 kg ha^{-1} respectively were used. Half of N (urea) and full doses of P (triple super phosphate) and K (sulphate of potash) were applied at the time of sowing, whereas other half of N were applied after first irrigation. All other cultural and agronomic practices including irrigation, weeding, hoeing etc. were done homogeneously for all the three replications. Data were taken for the below mentioned constraint

Soil sampling procedure: Three soil samples were taken from each subplot from a depth of 0-15, 15-30 and 30-45 cm after harvesting the wheat crop for determination of soil physical and chemical properties, however before sowing three bulk samples was collected in three different depths and was analyzed accordingly (Table 1).

LABORATORY ANALYSIS

Bulk density: Soil core-42 was used to sample for bulk density after wheat crop harvesting. In this case, three soil samples at random in each subplot were taken. The core samplers (100 cm^3) was injected in the soil up to certain depth as to fill the cylinder completely, precautions was followed to avoid the compression. Soil was removed from the sides of the cylinder. The obtained soil from core samplers was dried at 105ºC to a constant weight. Bulk density was calculated as;

$$\rho b = Ms/Vt$$

Where ρb=Bulk density (gcm^{-3})

Ms= Oven dry mass of the soil (g)

Vt= Volume of the core (cm^2)

Zinc content: ABDTPA extraction method was used to determine the Zn content in the soil [13]. In this procedure, ten gram soil sample and 20 ml AB-DTPA extract was added in conical flask and kept in shaker for fifteen minutes. After shaking, the solution was filtered through Whatmann 42 filter paper. The Zn content was determined through atomic absorption spectrophotometer.

Organic matter: Organic matter in soil was determined through the procedure presented by [14]. In this procedure 10 ml of 1N $K_2Cr_2O_7$ solution and 20 ml of concentrated H_2SO_4 was treated with one gram of soil sample. Distilled water was used up to 200 ml after cooling and then filtered. Titration was made against 0.5 N $FeSO_4.7H_2O$ solutions in addition of 5-6 drops Ortho-phenopthroline indicator, end point was recorded when the color changed from greenish to dark brown. Reading of blank sample was also taken before rest of the samples. Organic matter was calculated as;

$$Organic\ matter\ (\%) = \frac{(meqK_2Cr_2O_7 - meq\ FeSO_4)\ x\ meq\ of\ C}{weight\ of\ drysample\ x\,(0.75)}\ x100$$

Where 0.75 in the above formulae is assumed that only 75% organic matter was oxidized in this procedure and Meq of Carbon is 0.003.

Determination of total N content: Soil total N for each treatment was recorded calorimetrically, through Kjeldahl procedure [15]. 0.2g of sampled soil along 1.1 g digestion mixture was digested with the help of 3-4mL of concentrated H_2SO_4 till the sample color turned to light greenish or colorless. Volume of 100 ml was made in volumetric flask after cooling through distilled water. Distilled 20 ml of digested with 40% NaOH solution along five ml of boric acid mixed indicator and then titrted against 0.005M HCl. Blank saple was also run before all the other samples, percent total soil N was calculated as;

$$Total\, N\% = \frac{mL\, of\, HCl\, used\, (sample - blank)\, x\, N\, of\, HCL\, x\, gram\, eq.wt\, of\, N\, x\, volume\, made}{weight\, of\, the\, sample} x100$$

Determination of P and K content: P and K was determined in the extract prepared for the micronutrients (AB-DTPA extract) [13]. P was determined with standard by suing spectrophotometer. Soil and plant samples were examined for Potassium through flame photometer which was first calibrated with standards.
Statistical Analysis: Recorded data of all the parameters was subjected to analysis of variance techniques which are appropriate in two factors randomized complete block design having split plot arrangement, significant variations were evaluated in the treatments through least significant difference test [16] and were also correlated with the critical values.

RESULTS AND DISCUSSION

Bulk density

The Mean values (Table 2) showed that ploughing soil with chisel plough had significantly higher bulk density (1.38 g cm^{-3}) than field cultivator (1.34 g cm^{-3}) and Rotavator ploughing (1.31 g cm^{-3}). Increasing the soil depth from 0-15 cm to 30-45 cm, the soil bulk density was significantly increased from 1.31 g cm^{-3} to 1.37 g cm^{-3}. Reduced tillage practices have shown significantly lower soil bulk density than plots ploughed deeply, which could be associated with improved aggregate stability [17], or improved microorganism activity [18]. Similarly, the samplings from 0-15 cm soil depth have lower bulk density. The probable reasons might be the improved microbial activity [19] in the upper soil surface, or due to higher porosity of the soil. No significant differences were observed for soil bulk density in response to zinc application. Our results support the finding of [20], who were of the opinion that zinc effects are restricted to plant attributes.

Soil zinc content

Perusal of the data regarding soil zinc content (Table 2) showed that higher soil zinc content (0.51 mg kg^{-1}) was observed in plots where rotavator was used as compared to both field cultivator (0.38 mg kg^{-1}) and chisel plough (0.37 mg kg^{-1}). Soil zinc content was not different in. 0-15 cm soil depth (0.44 mg kg^{-1}) and 15-30 cm soil depth (0.42 mg kg^{-1}), however both were significantly higher in zinc content (0.39 mg kg^{-1}) recorded at soil depth of 30-45 cm.

The minimum disturbance of the upper soil layer due to Rotavator might have resulted in greater soil zinc content. Soil zinc contents in 0-15 or 30-45 cm soil depth were significantly higher than zinc content recorded at the soil depth of 30-45 cm. The greater availability of soil organic matter, which contains the zinc content in the upper layer, might be a possible reason for improved zinc content in 0-15 or 15-30 cm layer as compared to 30-45 cm, [21]. The interactive response of tillage vs. soil depth (Fig. 1) indicated that increasing the soil depth from 0-15 to 15-30 cm, showed no variations in the soil zinc content in either tillage system, however with further increase in the soil depth by 30-45cm the soil zinc content was increased in rotavator and decreased with both field cultivator and chisel ploughs. Tillage practices x zinc interaction (Fig. 2) showed that with increasing soil zinc content from control to 10.0 kg ha^{-1}, soil zinc content linearly increased in all tillage practices. However, at higher level of zinc application, the increment in soil zinc was higher in rotavator than either field cultivator or chisel plough. Similarly, soil depth x zinc interaction (Fig. 3) demonstrated a linear increase in soil zinc content in all tillage practices with increasing the soil zinc application.

Organic matter

The data regarding organic matter (Table 2) revealed that greater organic matter was recorded for rotavator (0.95 %) compared to chisel plough (0.84 %), however was not significantly different than field cultivator (0.91 %). The lower organic matter (0.85 %) was measured when the soil was sampled from 30-45cm depth compared to either the depth of 15-30 cm (0.91 %) or 0-15cm (0.93 %). Rotavator had resulted in greater soil organic matter than chisel ploughed plots. This higher organic matter content in minimum tilled plots might be associated with more particulate organic carbon [22], or C sequestration [23] due to improved microbial activity [19].

Table 2. Soil bulk density, Zinc content and Organic Matter in response to Zinc levels under various tillage practices

Tillage practices (TP)	Bulk density (g cm^{-3})	Zinc (mg kg^{-1})	Organic matter (%)
Rotavator	1.31c	0.51a	0.95a
Field cultivator	1.34b	0.38b	0.91ab
Chisel plough	1.38a	0.37b	0.84b
LSD0.05	0.02	0.05	0.07
Soil depth (D, cm)			
0-15	1.31c	0.44a	0.93a
15-30	1.35b	0.42a	0.91a
30-45	1.37a	0.39b	0.85b
LSD0.05	0.02	0.03	0.05
Zinc (Zn, kg ha^{-1})			
0	1.34	0.13e	0.85
2.5	1.34	0.26	0.88
5.0	1.34	0.36c	0.91
7.5	1.34	0.56b	0.92
10	1.35	0.78a	0.92
LSD0.05	NS	0.04	NS
Interactions			
TP x D	NS	**	NS
TP x Zn	NS	**	NS
D x Zn	NS	**	NS
TP x D x Zn	NS	NS	NS

Means followed by different letter (s) are significantly different from each other in each category at $P \leq 0.05$ using LSD test

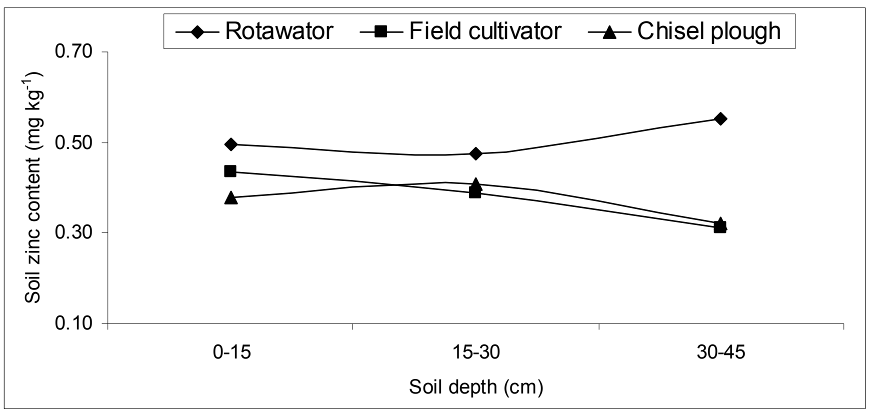

Fig 1. The effect of soil depth and tillage practices interaction on the soil zinc content (mg kg^{-1})

Soil total nitrogen

The results (Table 3) indicated that greater soil total nitrogen (0.45g kg^{-1}) was recorded in plots where rotavator was practiced compared to the lower soil total nitrogen measured in plots where field cultivator (0.42 g kg^{-1}) or chisel plough (0.41 g kg^{-1}) were used. Rotavator had higher soil total nitrogen compared to field cultivator or chisel plough. The increased soil total nitrogen in reduced tillage might be due to the higher soil organic matter [24], soil porosity [25] or greater residue return from the current crops.

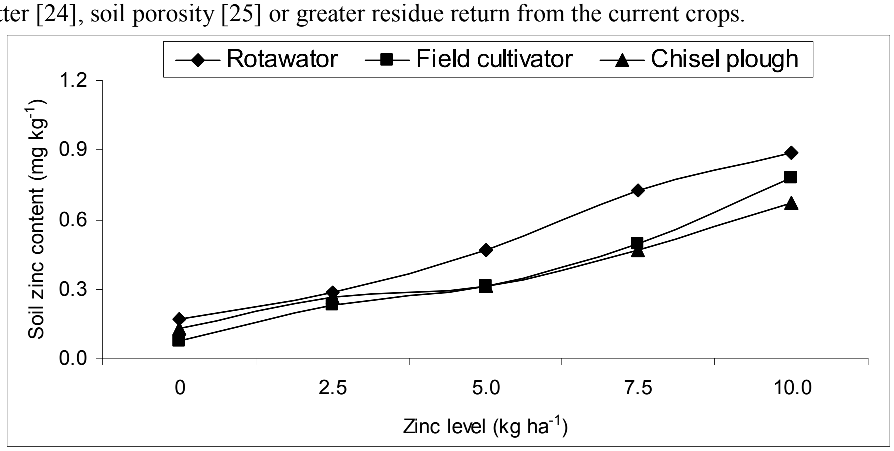

Fig 2. The effect of tillage practices and zinc levels interaction on the soil zinc content (mg kg^{-1})

Table 3: Soil total Nitrogen, Phosphorous and Potash in response Zinc levels under various tillage practices

Tillage practices (TP)	Soil total N (g kg^{-1})	Phosphorous (mg kg^{-1})	Potash (mg kg^{-1})
Rotavator	0.45a	3.34a	93.22a
Field cultivator	0.42b	3.29a	89.85a
Chisel plough	0.41b	2.80b	82.58b
LSD0.05	0.02	0.44	5.26
Soil depth (D, cm)			
0-15	0.44	3.39a	91.06a
15-30	0.43	3.09b	88.58a
30-45	0.42	2.96b	86.02b
LSD0.05	NS	0.24	2.49
Zinc (Zn, kg ha^{-1})			
0	0.44	2.98	87.33
1.0	0.43	2.97	87.95
5.0	0.43	3.18	88.88
2.0	0.42	3.28	88.81
2.0	0.42	3.32	89.79
LSD0.05	NS	NS	NS
Interactions			
TP x D	NS	**	NS
TP x Zn	NS	NS	NS
D x Zn	NS	NS	NS
TP x D x Zn	NS	NS	NS

Mean followed by different letter (s) are significantly different from each other in each category at $p \leq 0.05$ using LSD test

Soil phosphorous

Soil phosphorous (Table 3) was higher for rotavator (3.34 mg kg^{-1}), followed by field cultivator (3.29 mg kg^{-1}), and lower for chisel plough (2.80 mg kg^{-1}). Increasing the soil depth beyond 15-30 cm, the soil phosphorous reduced. Mean values showed that significantly higher soil phosphorous was recorded in 0-15 cm soil depth (3.39 mg kg^{-1}) compared to lower in soil depth of 30-45 cm (2.96 mg kg^{-1}). However, no difference in soil phosphorous was observed between 15-30 cm and d30-45 cm soil depth.Soil phosphorous was higher for rotavator than chisel plough. These higher phosphorous in reduced tillage system might be due to higher organic matter content [26], which could contribute more to available phosphorous. The top soil contained more organic matter, which might have increased the soil available phosphorous as compared to deep soil[27]. No significant differences for soil phosphorous were observed by zinc application, these results are supported by [28].The interaction between tillage x depth (Fig. 4) revealed that soil phosphorous was increased for chisel ploughed plots with increasing the sampling depth, whereas both for rotavator and field cultivator it was decreased.

4.1.8 Soil potash

Potash content (Table 3) was higher in plots where rotavator was used (93.22 mg kg^{-1}) compared to chisel ploughed plots (82.58 mg kg^{-1}), however was statistically not different from plots where field cultivator were used. No significant differences for soil potash was observed between 0-15 cm (91.06 mg kg^{-1})and 15-30 cm (88.58 mg kg^{-1}) soil depths, however, both were significantly higher in potash content than 30-45 cm soil depth (86.02 mg kg^{-1}).Soil potash content was higher in plots where rotavator was used compared to chisel ploughed plots. The higher organic matter content in the reduced tillage [29], or more stubble availability [30]might be a probable reason for higher potash content. No significant differences for potash were observed for sampling depth and zinc application. Similarly [31] reported no difference in soil potassium content in response to zinc application.

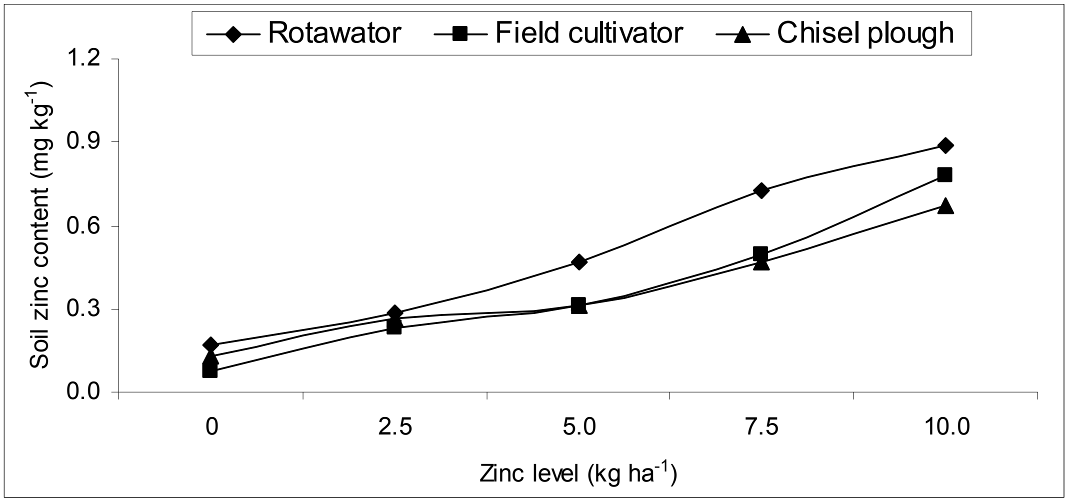

Fig 2. The effect of tillage practices and zinc levels interaction on the soil zinc content (mg kg^{-1})

5. CONCLUSION

It was concluded form the experiment that tillage had no effect on zinc use efficiency. However rotavator had improved most of the soil physico-chemical properties of the soil, grain and biological yield and zinc contents. Macro nutrients availability was higher in soil depth of 0-15 cm, with improved soil bulk density and organic matter. Zinc application effects were restricted to plants characteristics soil zinc contents and organic matter with no effects on soil other physico-chemical properties. Increasing the zinc contents had improved yield and yield components, zinc concentration. It is recommended that rotawator should be used for improved soil physico-chemical properties of the soil and improved wheat production. Higher rate of 7.5 kg Zn ha^{-1} is advisable only for improving the wheat productivity.

6. ACKNOWLEDGEMENT

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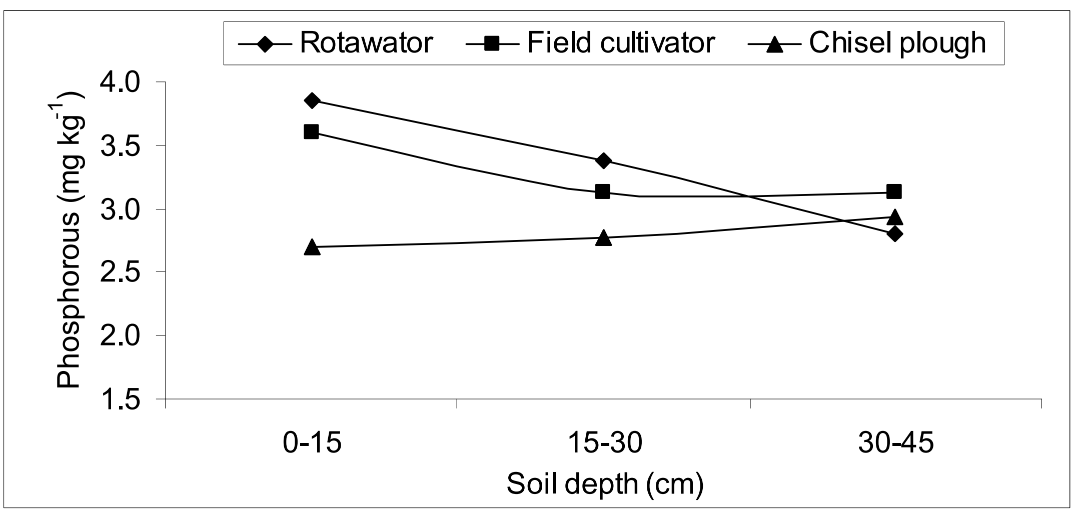

Fig 4. The effect of soil depth and tillage practices interaction on the soil phosphorous content (mg kg^{-1})

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