Influence of Zinc and Boron on Physico-chemical Properties of Soil under Maize Crop in an Inceptisol of Prayagraj, Uttar Pradesh, India

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Original Research Article

ABSTRACT

The research was conducted during the *Rabi* 2020-2021 and 2021-2022. The experiment was laid out in Randomized Block Design with sixteen treatments and three replications with four levels of Zinc and Boron along with NPK as RDF. The non-significant findings were B.D, P.D, % pore space, water holding capacity, and pH were as, the present macro- micro nutrients in soil and also the morphological parameters have significant findings which comprises color is yellowish brown sandy loam textured neutral to alkaline soil that is non- saline in nature among all the treatment combination applied. The OC, NK observed significantly medium to high in treatment T_{16} RDF

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(120:60:40 NPK kg ha^{-1}) + Zinc@20 kg ha^{-1}+ Boron @5 kg ha^{-1}), micro-nutrients such as Zinc, Boron were knowingly medium to high in T_{16} RDF (120:60:40 NPK kg ha^{-1}) + Zinc@20 kg ha^{-1}+ Boron @5 kg ha^{-1}). The maximum mean value for bulk density (1.33 Mg m^{-3}), particle density (2.589 Mg m^{-3}) percent pore space (47.98%), and percent maximum water holding capacity (45.87%) were found. The chemical soil parameters with a cumulative mean of slightly saline soil pH (7.93), average Electrical conductivity (0.41 dS m^{-1}), maximum percent OC (0.42), high Available N (288.52 kg ha^{-1}), high Available P in T_2 (16.85 kg ha^{-1}) due to the antagonistic effect of zinc on Phosphorous, high Available K (207.98 kg ha^{-1}), high Available Zn (1.144 mg kg^{-1}), and high Available B (1.243 mg kg^{-1}) were categorized in evaluation to other NPK and micronutrients levels treatments.

1. INTRODUCTION

Maize (*Zea mays* L.) is a member of family Gramineae and it is one of the most important cereal crops. It is also important about its nutritional value for humans, poultry and livestock. Throughout the world, Maize is one of the prominent cereal crops and total yield of Maize is more as compared to other cereal crops [1].

Origin of Maize is Latin America. It is extremely cultivated in USA, Rumania, Argentina, Brazil, Russia, Mexico, South Africa and Italy (Anonymous 2016). Total production of Maize is 38.105 million tones and some major growing countries are USA (13601mt), China (8841mt), Brazil (3208mt), Mexico (925mt) and India (827mt). In India, Maize ranks 5$_{th}$ in total area and 6$_{th}$ in production and productivity [2].

"In India, Andhra Pradesh was reported to be the largest producer of Maize among the producing state contributing 21 per cent (%) of total production, followed by Karnataka 16%, Rajasthan 10%, Bihar and Maharashtra 9% each as well as Uttar Pradesh and Madhya Pradesh each contribute 6%" [3]. "Majorly poor management of fertilizer has key role to play in obtaining low yield productivity, so in order to achieve optimum crop production management of nutrients through judicious application of organic sources, bio-fertilizers and micro-nutrients are required. Furthermore, the fertilizer management is one of the most important factors that influence the growth and yield of Maize crop". [4].

"It is the third most important staple food crop both in terms of area and production after wheat and rice in Egypt. Total area under cultivation of Maize in Egypt is 888329 hectare which is about 25.17 % of the total cultivated agricultural land while average yield is 7.80 t ha^{-1}. It is about 21.90 % of the total cereals production" [1]. "The rapidly increasing demand of Maize is driven by the increased demand for direct human consumption in the hills as a staple food crop" (Ghimire et al., 2007). "As food, it can be consumed directly as green cob, roasted cob and popped grain. Its grain can be used for human consumption in various ways such as corn meal, fried grain and flour. Its grain has high nutritive value containing 66.2% starch, 11.1% protein, 7.12% oil and 1.5% minerals. Moreover, it contains 90 mg carotene, 1.8 mg niacin, 0.8 mg thiamin and 0.1 mg riboflavin per 100 g grains" [5].

"Zinc is an important part of the package or suggested practices for reclaiming sodic soils. Zn shortage is a critical nutritional limitation for good crop development, regardless of the fact that crops have shown a strong response to Zn application. The Available Zn content in Indian soils ranged from traces to 22 mg kg^{-1}, with 47 percent of Indian soils being Zn deficient" (Mishra et al., 2011).

"Boron is unique, not only in its chemical properties, in its roles in biology. Since Boron discovery can be as essential plant nutrient, the importance of B element as an agricultural chemical has grown very rapidly and its availability in soil and irrigation water is an important determinant of agricultural production" [6]. "Boron deficiency is the most common and widespread micronutrient deficiency problem, which impairs plant growth and reduces yield. Normal healthy plant growth requires a continuous supply of B, once it is taken up and used in the plant; it is not translocated from old to new tissue. That is why, deficiency symptoms start with the youngest growing tissues. Therefore, adequate B supply is necessary for

obtaining high yields and good quality y of crops" [7].

Hence, objectives of the study are simply justified. Keeping these considerations in view, an investigation was carried out during *rabi* season of 2020-21 and 2021-22.

2. MATERIALS AND METHODS

2.1 Experimental Site and Location

The investigational site of the research farm which falls under Geographical Co-ordinates of Prayagraj District which is located at 25^0 58' N latitude and 81^0 52' E longitude with an altitude of 98 meter above mean sea level and is situated 5 km away on the right bank of Yamuna-river. Representative the Agro-Ecological Sub Region [North Alluvial plain zone (0-1 % slope)] and Agro-Climatic Zone (Upper Gangetic Plain Region).

2.2 Climate Condition

The area of the region which is characterized by sub-tropical and has a semi-arid type of climate, which experience extremely hot and dry summer spells from April to June where temperature reaches maximum up to 46^0C and touches 48^0C followed by relative humidity during July to September ranged from 20 - 90 percent, fairly seldom falls of cold with frosty spells as low as 4^0C and dips up to 2^0C is noticed. Here a few showers of cyclonic rains are received are called as winter monsoon (North-East monsoon), which is seen during November to January and mild climate from February to March. The rainfall in this particular region starts from middle of July to end of September and commonly known as summer monsoon (South-West monsoon). This South-West monsoon brings major portion of the rainfall (75 percent) with mean annually around 900 to 1100 mm [8].

2.3 Experimental Details

The present research investigation was setup in a randomized block design (RBD) having sixteen treatment combinations which is replicated thrice, randomly allocated in each replication, dividing the research site into forty-eight plots. The Maize variety P3396 was grown during the two experimental years 2020-21 and 2021-22. In this study, inorganic fertilizers like Nitrogen, Phosphorous, Potassium, were applied as RDF and Zinc and Boron were applied in four different doses.

2.4 Fertilizer Application

Recommended dose of NPK (100%) was applied to the Maize were N (120 kg ha^{-1}), P_2O_5 (60 kg ha^{-1}) and K_2O (60 kg ha^{-1}). The 100 percent application of P and K was applied as basal dose at the time of sowing. In addition to these applications, Zinc was applied as basal @ 0,10,15 and 20 kg ha^{-1} with Boron 0, 2, 4, and 6 kg ha^{-1} only to the treatment with Zn and B. The sources of NPK fertilizers were Phosphorus through single superphosphate (16% P2O5), Potash through Muriate of Potash (60% K2O) and Zinc through Zinc sulphate (21% Zn) and

Table 1. Randomized Block Design (RBD) having sixteen treatment combinations

Treatment	Treatment combination	Symbols
T_1	(Control)	$Z_0 B_0$
T_2	RDF + Zn @ 0 kg ha^{-1}+ B@ 2 kg ha^{-1}	$Z_0 B_1$
T_3	RDF + Zn @ 0 kg ha^{-1}+ B@ 4 kg ha^{-1}	$Z_0 B_2$
T_4	RDF + Zn @ 0 kg ha^{-1}+ B@ 6 kg ha^{-1}	$Z_0 B_3$
T_5	RDF + Zn @ 10 kg ha^{-1}+ B@ 0 kg ha^{-1}	$Z_1 B_0$
T_6	RDF + Zn @ 10 kg ha^{-1}+ B@ 2 kg ha^{-1}	$Z_1 B_1$
T_7	RDF + Zn @ 10 kg ha^{-1}+ B@ 2 kg ha^{-1}	$Z_1 B_2$
T_8	RDF+ Zn @ 10 kg ha^{-1}+ B@ 6 kg ha^{-1}	$Z_1 B_3$
T_9	RDF+ Zn @ 15 kg ha^{-1}+ B@ 0 kg ha^{-1}	$Z_2 B_0$
T_{10}	RDF+ Zn @ 15 kg ha^{-1}+ B@ 2 kg ha^{-1}	$Z_2 B_1$
T_{11}	RDF+ Zn @ 15 kg ha^{-1}+ B@ 4 kg ha^{-1}	$Z_2 B_2$
T_{12}	RDF+ Zn@ 15 kg ha^{-1}+ B@ 6 kg ha^{-1}	$Z_2 B_3$
T_{13}	RDF+ Zn @ 20 kg ha^{-1}+ B@ 0 kg ha^{-1}	$Z_3 B_0$
T_{14}	RDF+ Zn @ 20 kg ha^{-1}+ B@ 2 kg ha^{-1}	$Z_3 B_1$
T_{15}	RDF+ Zn@ 20 kg ha^{-1}+ B@ 4 kg ha^{-1}	$Z_3 B_2$
T_{16}	RDF+ Zn @ 20 kg ha^{-1}+ B@ 6 kg ha^{-1}	$Z_3 B_3$

Chart 1. Soil characteristics of pre soil sample

Soil characteristics	Soil depth(0-15cm)	Soil depth (15-30 cm)
BD (Mg m^{-3})	1.15	1.25
PD (Mg m^{-3})	2.15	2.48
Pore space (%)	44.19	56.42
Water Holding Capacity (%)	54.14	48.19
Soil texture	Sandy loam	Sandy loam
Soil pH	7.41	7.53
Electrical conductivity (dS m^{-1})	0.24	0.20
Organic carbon (%)	0.57	0.48
Available Nitrogen (kg ha^{-1})	250.19	180.19
Available Phosphorus (kg ha^{-1})	19.04	17.34
Available Potassium (kg ha^{-1})	184.21	164.04
Available Zn (mg kg^{-1})	0.45	0.44
Available B (mg kg^{-1})	0.55	0.53

Boron through borax (11.3% B) was applied previous to sowing in concerning treatments just before the seed sowing [8]. Nitrogen through urea (46% N), were applied in 3 different doses.

Sowing of Maize crop was carried out on 15th and 18th of October month during 2020 and 2021, respectively by manually. Seed variety P3396 was sown at the rate of 18-20 kg ha^{-1} and at a row to row spacing of 60 cm and plant to pant spacing 20 cm.

2.5 Soils Analysis

The soils from each plot were separately collected, air-dried, ground and passed through 2-mm size sieve for laboratory analysis. Soil samples were analyzed for Bulk density, Particle density, pore space and water holding capacity (WHC) were estimated using 100 ml measuring cylinder (Muthuval, 1992), pH, [9] EC, [10] OC by Walkley and Black [11] and Available Nitrogen [12] Available P [13] Available Potassium [14] before sowing the experimental crop and after the harvest of crop. The soil samples were extracted for available B, the extract was treated with activated charcoal and estimated calorimetrically using azomethine-H method [15]. Available Zn was extracted with DTPA-TEA (pH 7.3) [15] and estimated with the help of atomic absorption spectrophotometer (AAS, Model: ELCO-SL194).

2.6 Statistical Analysis

The statistical analysis of the data was carried out using STATISTICA (7.0) software.

3. RESULTS AND DISCUSSION

3.1 Effect of Nutrient Management in Physical Properties of Soil after Harvest of Maize

The data found that, bulk density of soil were found 1.29 and 1.33 Mg m^{-3} and 1.30 and 1.31 Mg m^{-3}, particle density 2.581 and 2.58 Mg m^{-3} and 2.579 and 2.589 Mg m^{-3}, pore space 47.97 and 47.67 % and 47,98 and 47.32 %, water retention capacity 46.19 % and 46.82 % and 46.27 % and 46.87 % of soil were got highest in treatment T_{16} RDF (120:60:40 NPK kg ha^{-1}) + Zinc@20 kg ha^{-1}+ Boron @5 kg ha^{-1}) over absolute control treatment at 0-15 cm depth and at 15-30 cm depth during the years 2021 and 2022 (Table 3). This corroborates with the findings of Panwar, et al., [16], and Yadav et al., 2020.

3.2 Effect of Nutrient Management in Chemical Properties of Soil after Harvest of Maize

The data showed that the treatment T_{16} with RDF (120:60:40 NPK kg ha^{-1}) + Zinc@20 kg ha^{-1}+ Boron @5 kg ha^{-1}) significantly influenced the soil pH 8.24 and 8.34 in the year 2020-21 and 8.22 and 8.34, in the year 2021-22 electrical conductivity 0.414 and 0.416 and 0.413 and 0.415, organic carbon 0.421 and 0.425 % and 0.422 and 0.426 % content in soil, however lowest values were observed in the treatments T_1 (absolute control) at 0-15 cm depth and at 15-30 cm depth during the years 2020-21 and 2021-22, accordingly (Table 3).

Table 2. Soil physical properties after harvest of Maize as influence by different treatment combinations

Treatments	Bulk density (Mg m^{-3})				Particle density (Mg m^{-3})				Pore space (%)				Water retention capacity (%)			
	2021		2022		2021		2022		2021		2022		2021		2022	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
T$_1$ (Control)	1.19	1.21	1.20	1.22	2.403	2.408	2.401	2.403	44.52	43.42	44.34	43.54	43.21	43.87	41.32	41.87
T$_2$ RDF + Zn @ 0 kg ha-1+ B@ 2 kg ha-1	1.20	1.23	1.21	1.24	2.433	2.438	2.432	2.433	45.14	44.34	45.66	44.22	44.14	44.76	43.24	43.66
T$_3$ RDF + Zn @ 0 kg ha-1+ B@ 4 kg ha-1	1.25	1.26	1.25	1.26	2.457	2.462	2.454	2.457	45.20	44.26	45.32	45.78	44.25	44.49	42.41	42.69
T$_4$ RDF + Zn @ 0 kg ha-1+ B@ 6 kg ha-1	1.23	1.25	1.23	1.24	2.417	2.422	2.411	2.417	47.14	46.11	47.67	46.87	44.60	44.95	43.33	43.70
T$_5$ RDF + Zn @ 10 kg ha-1+ B@ 0 kg ha-1	1.22	1.25	1.24	1.26	2.428	2.433	2.424	2.428	47.31	46.24	47.21	46.28	45.31	45.90	45.12	45.70
T$_6$ RDF + Zn @ 10 kg ha-1+ B@ 2 kg ha-1	1.26	1.27	1.26	1.27	2.465	2.47	2.461	2.465	46.42	45.23	46.12	45.29	44.62	44.86	44.63	44.86
T$_7$ RDF+ Zn @ 10 kg ha-1+ B@ 4 kg ha-1	1.25	1.26	1.27	1.28	2.505	2.51	2.507	2.505	46.78	45.89	46.32	46.83	45.14	45.59	45.18	45.84
T$_8$ RDF+ Zn @ 10 kg ha-1+ B@ 6 kg ha-1	1.26	1.28	1.25	1.26	2.484	2.489	2.482	2.484	46.81	46.42	46.65	45.25	45.32	44.65	44.77	44.93
T$_9$ RDF+ Zn @ 15 kg ha-1+ B@ 0 kg ha-1	1.24	1.26	1.24	1.27	2.511	2.516	2.517	2.511	47.21	46.65	47.34	46.69	45.50	45.88	44.33	44.80
T$_{10}$ RDF+ Zn @ 15 kg ha-1+ B@ 2 kg ha-1	1.27	1.28	1.26	1.29	2.521	2.526	2.521	2.521	47.14	46.78	47.54	45.75	44.10	44.60	43.10	43.84
T$_{11}$ RDF+ Zn @ 15 kg ha-1+ @ 4 kg ha-1	1.25	1.27	1.25	1.28	2.528	2.533	2.526	2.528	46.52	45.98	46.11	45.98	44.47	44.74	44.21	44.72
T$_{12}$ RDF+ Zn@ 15 kg ha-1+ B@ 6 kg ha-1	1.27	1.28	1.27	1.29	2.554	2.559	2.551	2.554	46.77	45.87	46.44	46.84	44.33	45.91	45.32	45.77
T$_{13}$ RDF+ Zn @ 20 kg ha-1+ B@ 0 kg ha-1	1.28	1.29	1.27	1.30	2.565	2.57	2.563	2.565	47.34	47.22	47.53	47.23	44.58	45.94	44.64	44.85
T$_{14}$ RDF+ Zn @ 20 kg ha-1+ B@ 2 kg ha-1	1.27	1.30	1.28	1.29	2.543	2.548	2.541	2.543	47.72	47.64	47.78	46.68	46.18	46.60	45.19	46.13
T$_{15}$ RDF+ Zn@ 20 kg ha-1+ B@ 4 kg ha-1	1.28	1.32	1.30	1.31	2.575	2.58	2.573	2.575	46.92	46.78	46.65	46.79	45.04	45.75	46.29	45.81
T$_{16}$ RDF+ Zn @ 20 kg ha-1+ B@ 6 kg ha-1	1.29	1.33	1.30	1.31	2.581	2.589	2.579	2.581	47.97	47.67	47.98	47.32	46.19	46.80	46.27	46.87
SE m (±)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CD (P=0.05)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 3. Soil chemical properties after harvest of Maize as influence by different treatment combinations

Treatments		pH				EC				OC (%)				Available Nitrogen (kg ha^{-1})			
		2021		2022		2021		2022		2021		2021		2022		2021	
		0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
T_1	(Control)	7.42	7.53	7.43	7.48	0.343	0.345	0.342	0.343	0.368	0.370	0.367	0.368	259.21	261.32	258.94	260.70
T_2	RDF + Zn @ 0 kg ha-1+ B@ 2 kg ha-1	7.65	7.74	7.62	7.67	0.350	0.353	0.356	0.354	0.389	0.392	0.389	0.392	264.24	266.52	265.58	268.54
T_3	RDF + Zn @ 0 kg ha-1+ B@ 4 kg ha-1	7.66	7.76	7.63	7.72	0.362	0.364	0.365	0.366	0.392	0.395	0.393	0.396	262.53	265.59	263.74	265.39
T_4	RDF + Zn @ 0 kg ha-1+ B@ 6 kg ha-1	7.52	7.67	7.53	7.58	0.348	0.350	0.347	0.352	0.395	0.397	0.396	0.396	265.64	267.79	264.38	267.59
T_5	RDF + Zn @ 10 kg ha-1+ B@ 0 kg ha-1	7.47	7.62	7.44	7.53	0.349	0.351	0.344	0.349	0.387	0.390	0.385	0.392	268.76	272.04	268.52	273.53
T_6	RDF + Zn @ 10 kg ha-1+ B@ 2 kg ha-1	7.76	7.81	7.73	7.79	0.368	0.372	0.368	0.373	0.388	0.389	0.386	0.388	266.58	270.79	267.48	272.90
T_7	RDF+ Zn @ 10 kg ha-1+ B@ 4 kg ha-1	7.85	7.93	7.84	7.91	0.375	0.377	0.375	0.376	0.395	0.398	0.395	0.398	267.46	272.40	266.53	270.32
T_8	RDF+ Zn @ 10 kg ha-1+ B@ 6 kg ha-1	7.74	7.85	7.76	7.84	0.371	0.374	0.376	0.378	0.398	0.403	0.396	0.402	268.43	271.53	265.48	271.26
T_9	RDF+ Zn @ 15 kg ha-1+ B@ 0 kg ha-1	7.53	7.78	7.53	7.68	0.377	0.379	0.375	0.376	0.399	0.405	0.394	0.405	270.46	273.59	272.64	274.47
T_{10}	RDF+ Zn @ 15 kg ha-1+ B@ 2 kg ha-1	7.48	7.67	7.45	7.56	0.383	0.385	0.386	0.388	0.404	0.408	.0.405	0.407	267.83	271.52	268.80	271.49
T_{11}	RDF+ Zn @ 15 kg ha-1+ B@ 4 kg ha-1	8.21	8.23	8.21	8.29	0.385	0.388	0.385	0.387	0.399	0.406	0.397	0.406	271.72	274.18	272.69	275.33
T_{12}	RDF+ Zn@ 15 kg ha-1+ B@ 6 kg ha-1	7.23	7.44	7.25	7.31	0.392	0.395	0.394	0.398	0.406	0.409	0.405	0.407	273.82	275.32	272.59	276.56
T_{13}	RDF+ Zn @ 20 kg ha-1+ B@ 0 kg ha-1	8.13	8.32	8.16	8.32	0.396	0.399	0.395	0.397	0.410	0.413	0.411	0.415	77.45	279.61	275.63	280.27
T_{14}	RDF+ Zn @ 20 kg ha-1+ B@ 2 kg ha-1	7.64	7.87	7.63	7.82	0.388	0.392	0.387	0.391	0.415	0.416	0.414	0.417	276.63	280 .02	277.40	281 .42
T_{15}	RDF+ Zn@ 20 kg ha-1+ B@ 4 kg ha-1	7.89	8.04	7.85	8.07	0.410	0.413	0.411	0.414	0.417	0.418	0.416	0.419	281.43	283.24	282.75	284.49
T_{16}	RDF+ Zn @ 20 kg ha-1+ B@ 6 kg ha-1	8.24	8.34	8.22	8.34	0.414	0.416	0.413	0.415	0.421	0.425	0.422	0.426	283.27	287.12	284.59	288.52
SE m (±)		-	-	-	-	0.02	0.04	0.02	0.03	0.02	0.08	0.06	0.04	13.48	11.46	8.13	10.29
CD (P=0.05)		-	-	-	-	0.01	0.03	0.01	0.02	0.01	0.04	0.03	0.02	1.60	5.61	3.98	5.04

Table 4. Soil chemical properties after harvest of Maize as influence by different treatment combinations

Treatments	Available Phosphorus (kg ha⁻¹)				Available Potassium (kg ha⁻¹)				Available Zinc (mg kg⁻¹)				Available Boron (mg kg⁻¹)			
	2021		2022		2021		2022		2021		2021		2022		2021	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
T₁ (Control)	13.64	13.23	12.87	12.41	196.64	196.23	195.64	196.44	0.453	0.445	0.465	0.433	0-15	15-30	0-15	15-30
T₂ RDF + Zn @ 0 kg ha-1+ B@ 2 kg ha-1	16.75	16.31	16.85	16.32	197.86	197.12	196.86	195.75	0.625	0.416	0.634	0.421	0.556	0.544	0.565	0.532
T₃ RDF + Zn @ 0 kg ha-1+ B@ 4 kg ha-1	15.89	15.11	15.96	15.10	197.68	198.21	197.18	196..37	0.586	0.524	0.566	0.541	0.723	0.511	0.734	0.523
T₄ RDF + Zn @ 0 kg ha-1+ B@ 6 kg ha-1	13.75	13.23	13.96	14.31	199.75	199.24	198.15	198.86	0.667	0.637	0.657	0.642	0.687	0.623	0.666	0.642
T₅ RDF + Zn @ 10 kg ha-1+ B@ 0 kg ha-1	14.74	14.12	14.80	13.13	201.74	201.12	202.24	201.15	0.656	0.634	0.665	0.651	0.767	0.734	0.757	0.743
T₆ RDF + Zn @ 10 kg ha-1+ B@ 2 kg ha-1	13.63	13.21	14.87	13.12	203.63	201.21	202.23	201.31	0.655	0.635	0.666	0.641	0.754	0.731	0.765	0.752
T₇ RDF+ Zn @ 10 kg ha-1+ B@ 4 kg ha-1	14.84	13.11	13.82	14.33	203.84	202.11	203.22	202.13	0.757	0.716	0.745	0.724	0.757	0.732	0.766	0.742
T₈ RDF+ Zn @ 10 kg ha-1+ B@ 6 kg ha-1	14.80	14.35	13.52	14.24	204.80	204.35	204.65	204.41	0.735	0.734	0.743	0.714	0.854	0.812	0.845	0.823
T₉ RDF+ Zn @ 15 kg ha-1+ B@ 0 kg ha-1	15.64	14.27	14.59	15.27	205.64	203.27	205.68	203.21	0.857	0.726	0.766	0.732	0.933	0.932	0.924	0.913
T₁₀ RDF+ Zn @ 15 kg ha-1+ B@ 2 kg ha-1	13.86	13.31	13.70	14.41	203.86	202.31	203.57	202.41	0.754	0.734	0.764	0.711	0.857	0.823	0.862	0.832
T₁₁ RDF+ Zn @ 15 kg ha-1+ B@ 4 kg ha-1	14.79	14.29	14.79	13.27	204.79	203.29	204.86	203.21	0.827	0.807	0.815	0.801	0.854	0.832	0.863	0.843
T₁₂ RDF+ Zn@ 15 kg ha-1+ B@ 6 kg ha-1	15.86	15.10	14.86	15.31	205.86	202.10	205.79	202.19	0.834	0.714	0.823	0.702	0.921	0.904	0.914	0.909
T₁₃ RDF+ Zn @ 20 kg ha-1+ B@ 0 kg ha-1	14.89	15.16	15.76	14.22	204.89	203.16	204.78	203.20	0.837	0.804	0.843	0.821	0.837	0.811	0.822	0.808
T₁₄ RDF+ Zn @ 20 kg ha-1+ B@ 2 kg ha-1	14.95	14.13	14.70	14.31	204.95	204.13	204.55	204.31	0.834	0.812	0.845	0.815	0.932	0.909	0.943	0.903
T₁₅ RDF+ Zn@ 20 kg ha-1+ B@ 4 kg ha-1	13.68	12.21	12.68	13.21	205.89	205.11	205.65	205.42	1.127	1.117	1.115	1.109	0.934	0.916	0.942	0.912
T₁₆ RDF+ Zn @ 20 kg ha-1+ B@ 6 kg ha-1	14.86	14.52	14.68	13.21	206.75	206.31	20768	207.98	1.144	1.108	1.134	1.112	1.224	1.219	1.213	1.212
SE m (±)	0.62	0.55	0.57	0.62	10.45	8.92	9.76	7.83	0.04	0.03	0.03	0.4	0.04	0.04	0.05	0.04
CD (P=0.05)	0.30	0.27	0.38	0.32	5.11	4.37	4.78	3.83	0.02	0.01	0.02	0.02	0.02	0.02	0.03	0.02

There was significant build-up of available N, available K, available Zn and available B with the applied treatments (Table 4). Maximum build-up of available N (283.27, 287.12 kg ha^{-1} and 284.59, 288.52 kg ha^{-1}), available K (206.75, 206.31 kg ha^{-1} and 207.68, 205.67 kg ha^{-1}), available Zn (1.144, 1.108 mg kg^{-1} and 1.134, 1.112 and mg kg^{-1}) and available B (1.243, 1.221 mg kg^{-1} and 1.235, 1.224 mg kg^{-1}) was recorded under the treatment T_{16} RDF (120:60:40 NPK kg ha^{-1}) + Zinc@20 kg ha^{-1}+ Boron @5 kg ha^{-1}) which was at par with the treatments T_9 with (RDF 20:40:20 NPK kg ha^{-1} + Zinc@6 kg ha^{-1} and Boron @1 kg ha^{-1}) and T_{10} with (RDF 20:40:20 NPK kg ha^{-1} + Zinc@6 kg ha^{-1} and Boron @2 kg ha^{-1}). Thus, the results indicate that both B and Zn significantly affected N, K, Zn and B availability in the soil. However, build-up of available P was drastically reduced with the application of Zn and B. optimum results were found in treatment T_2 with RDF *i.e.* NP and K only (16.75, 16.31 kg ha^{-1} and 16.85, 16.32 kg ha^{-1}) over all other remaining treatment combinations at 0-15 cm and at 15-30 cm soil depth during the years 2020-21 and 2021-22, accordingly. This may be due to negative interaction of Zn and B on availability of soil. Kumari et al., 2017, Kudi et al., 2018 and Karthik et al., 2021 also reported similar trends of results with Maize.

4. CONCLUSION

Based on the results, it is concluded that the application of NPK with micronutrient levels (Zinc and Boron) in treatment (T_{16}) T_{16} with RDF (120:60:40 NPK kg ha^{-1}) + Zinc@20 kg ha^{-1}+ Boron @5 kg ha^{-1}), was found primary in improving physical and chemical properties of soil, namely bulk density, particle density, % pore space, water holding capacity, EC, pH, organic carbon, available NPK and micronutrients *(*Zinc and Boron) than other treatment, combined with NPK and different doses of Zinc and Boron. Thus, it can be concluded that NPK and different levels of micronutrients (Zinc and Boron) enhanced soil available nutrients *i.e.* soil available Nitrogen, Phosphorus, Potassium, Zinc, Boron and electrical conductivity. However, pH of soil increased and also the treatments T_{16} recorded the premium treatment which increased the availability of nutrients and changed physico-chemical properties of soil.

Zinc and Boron nutrition with NPK knowingly recovers the soil health in Maize crop. The soil method of application of Zinc and Boron with NPK show advantageous results. It is better nutrient (NPK with micronutrient) organization option for enhancing the fertility of the soil. Hence, it can be suggested that to upgrade sustainability of soil fertility in the inceptisol, the combined application of NPK, Zinc and Boron is the finest option.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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