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Soil Physico-chemical Properties as Influenced by Combined use of NPK and Zinc at Varying Levels under Blackgram (*Vigna mungo* L.) Cultivation 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.

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ABSTRACT

In the modern era, Indian farmers are constantly confronted with the enormous challenge of increasing blackgram production due to low inherent nutrient status, indiscriminate use of chemical fertilizers and rapid depletion of soil fertility. Therefore, the recommended dose of fertilizer application is essential for increasing the nutrient reputation of the soil, with the intention of enhancing the blackgram production in our country. In view of limited information, a field experiment was undertaken at the Research Farm, Department of Soil Science and Agricultural Chemistry, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj (U.P), during late *kharif* season of 2021, to investigate the "Effect of Different Levels of NPK and Zinc on Physico-Chemical properties of Soil, Growth and Yield of Blackgram (*Vigna mungo* L.) *var.* RBU-38". The experiment was laid out in randomized block design (RBD) with 9 treatments randomly

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allocated into three replications. The treatment consisted of three levels of NPK (0:0:0, 10:20:10 and 20:40:20 kg ha^{-1}) and three levels of zinc (0, 2.5 and 5 kg ha^{-1}). Statistical interpretation of experimental results indicated that application of blended NPK @ 20:40:20 kg ha^{-1} in conjunction with Zn @ 5 kg ha^{-1} [T9] performed better in maintaining soil properties by way of registering optimum values of bulk density (1.298 Mg m^{-3}), particle density (2.454 Mg m^{-3}), pore space (47.11%), water holding capacity (40.17%) with neutral in soil pH (7.375), non-saline nature of EC (0.281 dS m^{-1}) and low in organic carbon (0.437%). In case of soil nutrient status, the highest availability of nitrogen (287.08 kg ha^{-1}), potassium (201.53 kg ha^{-1}) and zinc (0.685 ppm) at post-harvest soil of blackgram were also recorded in T9 [N20P40K20 + Zn @ 5 kg ha^{-1}] as compared to other treatments, while maximum phosphorus (25.10 kg ha^{-1}) availability was noted under T7 [N20P40K20 + Zn @ 0 kg ha^{-1}] due to the antagonistic relationship between phosphorus and zinc.

Keywords: Chemical fertilizer; soil properties; nutrient status; blackgram; inceptisol.

1. INTRODUCTION

The term “pulse” comes from the Latin word “*puls*”, which means pottage, or boiled seed used to make porridge or thick soup. Pulses are a wonder gift of nature to the living universe and they hold a reputable place in Indian agriculture by means of the distinctive feature of the fact that they represent a chief and most efficient source of protein in the typical Indian diet [1]. In addition to being a superior source of protein, pulses are also a significant source of fiber, vitamins, minerals and essential amino acids. As the United Nations General Assembly (UNGA) has recognized the importance of pulses, it designated 2016 as the “International Year of Pulses” in order to promote awareness about the beneficial effects of pulses on nutrition, food security and the livelihoods of millions smallholder farmers.

Among the pulses, blackgram [*Vigna mungo* L.], widely recognized as “urdbean”, is one of the most highly prized protein-rich pulse crops grown in almost all parts of India during both the *kharif* and *zaid* seasons. It is a self-pollinated, short-lived leguminous crop of the *Leguminosae* family, containing protein (24%), fat (1.4%), carbohydrate (59.6%), calcium (154 mg), phosphorus (385 mg), iron (9.1 mg), beta-carotene (38 mg), riboflavin (0.37 mg), niacin (2 mg) and thiamine (0.4 mg) per 100 g seeds [2]. Blackgram is a tropical crop and it requires hot and humid climate. The ideal temperature for its cultivation ranges between 25^{o}C to 35^{o}C but it can tolerate temperatures up to 42^{o}C. In modern times, India is the world’s largest producer of blackgram, accounting for more than 70% of the global output, followed by Myanmar and Pakistan. In India during 2019-20, blackgram occupied an area of 4.6 million hectares, having a total production of 2.45 million tones with a productivity of 533 kg ha^{-1} (Directorate of Economics and Statistics, *4th advance estimates 2020-21) [3].

In addition to being a valuable natural resource for agriculture, food and nutritional security, environmental safety and social stability, soil also contributes to the preservation of the environment. In a variety of land use contexts, the quality of the soil is a significant predictor of good crop yield. Blackgram can be grown in a variety of soils, from sandy loam to heavy clay with the exception of alkaline and saline soils. However, it does well on heavier soils such as black cotton soils, which retain higher moisture for a longer period of time [4].

Chemical fertilizers, additionally referred to as mineral fertilizers, play an important role in meeting the nutrient requirements of the crop. However, immoderate use of chemical fertilizers has a negative impact on soil properties. One of the significant barriers to pulse production is a lack of effective management methods, which has resulted in constant micronutrient depletion due to intensive cultivation [5]. Therefore, adequate supply of macro and micronutrients, proper management and care may play a significant role in boosting blackgram production. Among all the plant nutrients, nitrogen (N), phosphorus (P), potassium (K) and zinc (Zn) are the four most important plant nutrients that play a vital role in boosting blackgram production.

Nitrogen (N), one of the foremost essential nutrient elements, plays a crucial role in the synthesis of chlorophyll, amino acids and different organic compounds that contribute to the building blocks of proteins as well as enhance plant’s growth. Insufficient nitrogen may extensively reduce yields and deteriorate the standard of produce. Plants that are deficient in nitrogen have stunted growth and develop a yellow-green colour on their older leaves. blackgram is capable of fixing atmospheric nitrogen, it responds to a small quantity of nitrogenous fertilizers applied as a starter dose. The application of 15-20 kg N ha^{-1} has been found to be most effective in terms of improving response. Increased nitrogen may reduce nodule number and growth, lowering nitrogen fixation capacity [6].

Phosphorus (P) is an important nutrient element among the three primary macronutrients that plants must require for their best growth and development. In plants, phosphorous is necessary for photosynthesis, sugar metabolism, energy storage and transfer, cell division, genetic information transfer, root growth, nodulation and nitrogen fixation [7]. It acts as an "energy currency" within plants, fostering the expansion of roots as well as seed formation. Deficient plants may have thin, erect and spindly stems and older leaves turn a reddish-purple colour and growth is stunted. large quantities of phosphorus are abundant in seeds and fruit and it is thought to be necessary for seed formation. It boosts rhizobial activity and promotes the formation of root nodules. As a result, it aids in the fixation of more nitrogen from the atmosphere into root nodules [8].

Potassium (K) has been referred to as "quality element" and "master cation" that are indispensable for the plant's growth and development. It is needed to increase crop yield and improving quality because of its result on photosynthesis, water use efficiency, plant tolerance to diseases, drought and cold as well as for maintaining protein-carbohydrate balance [9]. Once there is an absence of potassium in plants, several metabolic processes are affected just like the rate of photosynthesis, translocation and enzymes system [10].

Zinc (Zn) is an important micronutrient that plays an outstanding role in the synthesis of chlorophyll, protein and also regulates water absorption. It is also involved in photosynthesis channelization during the reproductive stage due to its involvement in electron transfer [11]. It is a vital element needed for the biosynthesis of hormones, viz., Indole Acetic Acid (IAA) and is necessary to activate many enzymes like Tryptophan synthetase and dehydrogenases. Zinc deficiency impairs the formation of ribonucleic acid (RNA) and proteins [12]. Among micronutrients, zinc deficiency is widespread throughout India and it has been reported specifically in Punjab, the Tarai area of U.P, some parts of Haryana, Western U.P and Delhi [13].

Therefore, in light of the foregoing facts, the current study was conducted during the late *kharif* season of 2021, to investigate the impact of various levels of NPK and Zinc on soil properties, growth and yield of blackgram under different establishment techniques.

2. MATERIALS AND METHODS

2.1 Location of the Experimental Site

The field experiment was pursued at the Research Farm of the Department of Soil Science and Agricultural Chemistry, which is located at 25^{o} 24' 30" N latitude, 81^{o} 51'10" E longitude and an altitude of 98 m above the mean sea level. It is situated 5 km away on the right bank of Yamuna river, representing the Agro-Ecological Sub Region [North Alluvium Plain Zone (0-1% slope)] and Agro-Climatic Zone (Upper Gangetic Plain Region).

2.2 Climatic Condition of the Study Area

In terms of climate, Prayagraj district is situated in the subtropical belt of Uttar Pradesh's South-East region and enjoys an extremely hot summer and a fairly cold winter. During the summer months (April-May), the temperature reaches between 45^{o}C and 48^{o}C, while in the winter months, especially December and January, the temperature may drop down to as low as 4^{o}C-5^{o}C. Hot scorching winds are common during the summer season, whereas there may be occasional frost during the winter season. The average rainfall of this area is around 850 to 1100 mm and relative humidity ranges between 20-94%.

2.3 Initial Soil Characteristics of the Site

The soil at the experimental site was well-drained alluvial soil (order: Inceptisol), sandy loam in texture, neutral in reaction with moderate fertility. Before conducting research work, the detailed physico-chemical properties of soil of the experimental plots have been presented in Table 1.

Table 1. Details of physico-chemical properties at different depth of soil before experimentation

Particulars	Values	
	0-15 cm depth	**15-30 cm depth**
Physical Properties		
Sand (%)	60.20	58.65
Silt (%)	25.00	25.20
Clay (%)	14.80	16.15
Soil Texture	Sandy loam	Sandy loam
Soil Colour	Yellowish brown	Light Yellowish Brown
Bulk Density (Mg m^{-3})	1.329	1.342
Particle Density (Mg m^{-3})	2.463	2.475
Pore Space (%)	46.04	45.77
Water Holding Capacity (%)	37.95	36.72
Chemical Properties		
Soil pH (1:2.5, soil-water suspension)	7.582	7.653
Electrical Conductivity (dS m^{-1})	0.238	0.252
Organic Carbon (%)	0.376	0.352
Available Nitrogen (kg ha^{-1})	255.65	249.38
Available Phosphorus (kg ha^{-1})	18.25	16.72
Available Potassium (kg ha^{-1})	172.86	166.35
Available Zinc (ppm)	0.462	0.428

2.4 Experimental Design and Treatment Details

The current study was arranged in a randomised block design (RBD) with 9 treatment combinations that was replicated three times, with each replication being randomly assigned, dividing the research site into twenty-seven plots. Detailed descriptions of the treatments are presented in Table 2.

2.5 Crop Management Practices

A well-known urdbean variety, RBU-38 was chosen for the experimental purpose because of its high yielding nature, moderately long lifespan and resistant to cercospora leaf blight (CLS). On August 12, 2021, seeds were sown at the rate of 15 kg ha^{-1} with a spacing of 30×10 cm at 5 cm depth of soil in an individual experimental plot of 2m×2m. The recommended doses of NPK @ 20:40:20 kg ha^{-1} and Zn @ 5 kg ha^{-1} were applied as per treatment wise allotments through neem coated urea (46% N), single superphosphate (16% P2O5), muriate of potash (60% K2O) and zinc sulphate heptahydrate (21% Zn), respectively, at the time of land preparation prior to seed sowing. After sowing of crop in each plot, only one irrigation was provided at 10 days after sowing. Two hand weeding was practiced at 20 and 40 days after sowing, respectively for proper stand establishment of the crop. In order to protect the crop from various diseases and insect-pests, fungicides and insecticides were sprayed. Finally, crop was harvested and threshed at 70 days after sowing.

Table 2. Treatment Details of the Field Experiment

Treatment	Treatment Combination	Symbol
T1	[Absolute Control]	L1+Z1
T2	[N0P0K0 + Zn @ 2.5 kg ha^{-1}]	L1+Z2
T3	[N0P0K0 + Zn @ 5 kg ha^{-1}]	L1+Z3
T4	[N10P20K10 + Zn @ 0 kg ha^{-1}]	L2+Z1
T5	[N10P20K10 + Zn @ 2.5 kg ha^{-1}]	L2+Z2
T6	[N10P20K10 + Zn @ 5 kg ha^{-1}]	L2+Z3
T7	[N20P40K20 + Zn @ 0 kg ha^{-1}]	L3+Z1
T8	[N20P40K20 + Zn @ 2.5 kg ha^{-1}]	L3+Z2
T9	[N20P40K20 + Zn @ 5 kg ha^{-1}]	L3+Z3

2.6 Laboratory Analysis of Post-harvest Soil

The post-harvest soil samples were taken from an individual plot using soil augur at two consecutive depths, 0-15 and 15-30 cm, respectively and collected samples were oven dried at 105 ^oC temperature, grinded and sieved to pass a mesh of aperture 2-mm for generalised soil properties using the standard procedures. These samples were analysed for physical properties viz., bulk density, particle density, porosity and water holding capacity by graduated measuring cylinder method [14] as well as chemical properties viz., soil pH by digital pH meter [15], electrical conductivity by digital conductivity meter [16] and organic carbon by wet oxidation method [17]. In case of nutrients, available nitrogen was estimated by alkaline permanganate method [18], available phosphorus by Olsen's extraction method [19], available potassium by neutral normal ammonium acetate extraction method [20] and available zinc was extracted with DTPA and determined using AAS as described by Lindsay and Norvell [21].

2.7 Statistical Analysis

The collected experimental data was statistically analysed using the Fisher's methods of analysis of variance (ANOVA) as outlined by Gomez and Gomez [22]. When the F-test was found to be significant at 5% level, the critical difference (CD) was calculated.

3. RESULTS AND DISCUSSION

3.1 Effect of NPK and Zinc on Physical Properties of Soil after Harvest of Blackgram

Data pertaining to soil physical properties namely, bulk density, particle density, pore space and water holding capacity as influenced by NPK and zinc fertilizers are given in Table 3 and graphically illustrated in Fig. 1.

3.1.1 Bulk density (Mg m-3)

From the data, it was discernable that the bulk density of soil was non-significantly decreased with the addition of organic matter due to increasing levels of NPK and zinc fertilizers. It was also observed that higher bulk density in sub-surface soil could be ascribed to decreased organic matter and secondary accumulation of illuviated clay in pore space. The highest bulk density of soil (1.332 Mg m^{-3} and 1.345 Mg m^{-3} at 0-15 and 15-30 cm depth, respectively) was recorded in T1 [Absolute Control] and lowest bulk density of soil (1.298 Mg m^{-3} and 1.311 Mg m^{-3} at 0-15 and 15-30 cm depth, respectively) was recorded with T9 [N20P40K20 + Zn @ 5 kg ha^{-1}]. The results are was conformity with Kumar et al. [23].

3.1.2 Particle density (Mg m-3)

Scanning of data reveals that particle density of soil was non-significantly decreased by treatments at two consecutive depths of soil because the presence of organic matter lowered the particle density. In case of sub-surface layer, particle density was slightly increased due to presence of less amount of organic matter. The maximum particle density (2.465 Mg m^{-3} and 2.474 Mg m^{-3} at 0-15 and 15-30 cm depth, respectively) was recorded in T1 [Absolute Control], while minimum particle density of soil (2.454 Mg m-3 and 2.461 Mg m-3 at 0-15 and 15-30 cm depth, respectively) was recorded in T9 [N20P40K20 + Zn @ 5 kg ha-1]. The result was in close association with the findings of Kumar et al. [23] and Chethan et al. [24].

3.1.3 Pore space (%)

It was also evident from the data that combined use of NPK and zinc fertilizers did not show any significant effect on pore space in soil. Pore space was increased with increasing levels of fertilizers, which might be due to supplying more amount of organic matter and slightly decreased with an increment of soil depth due to low amount of organic matter present at lower depth of soil. The maximum pore space (47.11% and 46.74% at 0-15 and 15-30 cm depth, respectively) was registered in T9 [N20P40K20 + Zn @ 5 kg ha^{-1}], while minimum pore space (45.97% and 45.63% at 0-15 and 15-30 cm depth, respectively) was registered in T1 [Absolute Control]. Similar result also noted by Chethan et al. [24].

3.1.4 Water holding capacity (%)

A perusal of analyzed data indicated that there was a significant increase in water holding capacity of soil with the increasing levels of NPK and zinc fertilizers due to more additions of organic matter in the soil. The water holding capacity of soil was gradually decreased with an increasing depth of soil due to presence of low amount of organic matter in sub-surface soil layer. The highest water holding capacity (40.17% and 39.08% at 0-15 and 15- 30 cm depth of soil, respectively) was noted under T9 [N20P40K20 + Zn @ 5 kg ha^{-1}] and lowest water holding capacity (37.84% and 36.95% at 0-15 and 15-30 cm depth, respectively) was noted under T1 [Absolute Control]. This result also corroborated with findings of Ravindra et al. [25].

3.2 Effect of NPK and Zinc on Chemical Properties of Soil after Harvest of Blackgram

The statistically analyzed data with respect to soil chemical properties namely, pH, electrical conductivity, organic carbon, available nitrogen, phosphorus, potassium and zinc as affected by different levels of NPK and zinc fertilizer, are presented in Tables 4 & 5 and graphically represented in Figs. 2 & 3.

3.2.1 Soil pH (1:2.5, soil-water suspension)

A review of data shows that blended NPK and zinc fertilizers had no significant effect on soil pH. It aws evident from the table that soil pH was decreased by the use of nitrogenous fertilizers was due to acid producing nature of nitrogenous fertilizer, which upon nitrification release H^+ ions that are potential sources of acidity. It has been also mentioned that the soil pH was slightly increased with an increasing depth of soil might be due to leaching and accumulation of basic cations in sub-surface soil layer. The maximum soil pH (7.542 and 7.605 at 0-15 and 15-30 cm depth, respectively) was observed in T2 [N0P0K0 + Zn @ 2.5 kg ha^{-1}], while minimum soil pH (7.375 and 7.457 at 0-15 and 15-30 cm depth, respectively) was recorded in T9 [N20P40K20 + Zn @ 5 kg ha^{-1}]. Similar result also reported by David et al. [26].

3.2.2 Electrical conductivity (dS m-1)

The response of the electrical conductivity of soil was found to be non-significant to different levels of NPK and zinc fertilizer at different depths. The electrical conductivity of soil was gradually increased with an increasing level of chemical fertilizer. The low EC values of surface soil as compared to sub-surface layer might be due to leaching of salts from surface to sub-surface layer. The maximum EC of soil (0.281 dS m^{-1} and 0.298 dS m^{-1} at 0-15 and 15-30 cm depth, respectively) was obtained from the plot receiving of NPK @ 20:40:20 kg ha^{-1} along with Zn @ 5 kg ha^{-1} [T9], whereas minimum EC of soil (0.235 dS m^{-1} and 0.251 dS m^{-1} at 0-15 and 15-30 cm depth, respectively) was obtained from T1 [Absolute Control]. The result was good agreement with findings of Verma et al. [27].

3.2.3 Organic carbon (%)

It could be noticed that the soil organic carbon (%) was significantly influenced by different treatments regarding NPK and zinc fertilizer. It was also found that the organic carbon of soil was gradually increased with an increasing dose of NPK and zinc, which might be due to higher production of root and plant biomass and these biomasses ultimately decomposed and supplied organic matter to the soil, while organic carbon content in soil decreased with an increasing depth of soil. With respect to 0-15 cm and 15-30 cm soil depths, the highest value of soil organic carbon (0.437% and 0.407%) was noted under T9 [N20P40K20 + Zn @ 5 kg ha^{-1}] and lowest value of soil organic carbon (0.365% and 0.340%) was recorded in T1 [Absolute Control]. Similar trend also observed by Kumar et al. [23].

3.2.4 Available nitrogen (kg ha-1)

It was clear from the table that the available nitrogen content in soil was significantly increased with an increasing dose of NPK and zinc fertilizer due to their synergistic effect and decreased with an increasing depth of soil, which might be due low organic matter content of the soil at lower depth. With respect to available nitrogen, the maximum value (287.08 kg ha^{-1} and 278.37 kg ha^{-1} at 0-15 and 15-30 cm depth, respectively) was obtained from the plot receiving of N20P40K20 with Zn @ 5 kg ha^{-1} [T9], whereas minimum value (258.76 kg ha^{-1} and 251.12 kg ha^{-1} at 0-15 and 15-30 cm depth, respectively) was observed in case of absolute control [T1], which was quite obvious because of the absence of any external source of nutrients to the plot. The result was in concurrence with the findings of Kumar et al. [23].

3.2.5 Available phosphorus (kg ha-1)

The data related to available phosphorus content in soil was significantly increased with an increasing level of NPK but decreased with an increasing level of zinc due to their negative interaction. The available phosphorus was decreased with an increasing depth of soil, which might be due to low amount of soil organic matter and unfavorable soil pH. The maximum available phosphorus (25.10 kg ha^{-1} and 23.02 kg ha^{-1} at 0-15 and 15-30 cm depth, respectively) was recorded in T7 [N20P40K20 + Zn @ 0 kg ha^{-1}] and minimum value (17.89 kg ha^{-1} and 16.49 kg ha^{-1} at 0-15 and 15-30 cm depth, respectively) was noted under T3 [N0P0K0 + Zn @ 5 kg ha^{-1}]. The finding was in confirmation with results of Ravindra et al. [25].

3.2.6 Available potassium (kg ha-1)

From the analyzed data, it was evident that there was a significant increase in available potassium with an increasing dose of NPK and zinc at two consecutive depths of soil, 0-15 and 15-30 cm, respectively due higher abundance of organic matter but decreased as the depth of soil increases due to presence low amount soil organic matter as compared to surface soil. The highest value of available potassium (201.53 kg ha^{-1} and 194.26 kg ha^{-1} at 0-15 and 15-30 cm depth, respectively) was registered in T9 [N20P40K20 + Zn @ 5 kg ha^{-1}], while the lowest value of available potassium content in soil (178.43 kg ha^{-1} and 172.65 kg ha^{-1} at 0-15 and 15-30 cm depth, respectively) was obtained from T1 [Absolute Control]. The result of the current research is was also in line with the findings of Sahu et al. [28]. and Ravindra et al. [25].

3.2.7 Available zinc (ppm)

Interestingly, it was clear from the data that there was significant decrease in zinc content in soil as the rate of phosphorus application increased due to their antagonistic relationship. As a result of this relationship, insoluble zinc phosphate is formed, which reduced the zinc availability in soil. The results further indicated that available zinc content in soil was decreased with an increasing depth, which might be due to high soil pH. It was known that higher availability of zinc content in soil (0.685 ppm and 0.622 ppm at 0-15 and 15-30 cm depth, respectively) was recorded in T9 [N20P40K20 + Zn @ 5 kg ha^{-1}], while minimum value of available zinc (0.487 ppm and 0.432 ppm at 0-15 and 15-30 cm depth, respectively) was noted under T1 [Absolute Control]. Similar finding also reported by Balai et al. [29].

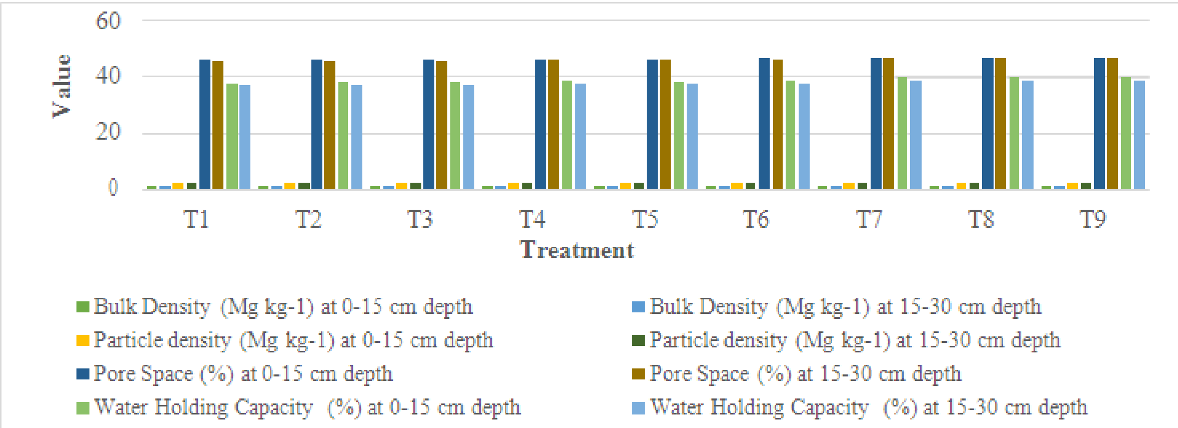

Fig. 1. Effect of NPK and Zinc on physical properties of soil after crop harvest

Table 3. Effect of NPK and Zinc on Physical Properties of Soil after Crop Harvest.

Treatment	Bulk Density (Mg m-3)		Particle Density (Mg m-3)		Pore Space (%)		Water Holding Capacity (%)	
	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	1.332	1.345	2.465	2.474	45.97	45.63	37.84	36.95
T2	1.325	1.339	2.462	2.472	46.16	45.84	38.25	37.32
T3	1.328	1.341	2.464	2.473	46.08	45.76	37.97	37.10
T4	1.317	1.330	2.460	2.469	46.46	46.12	38.68	37.68
T5	1.320	1.332	2.461	2.471	46.33	46.08	38.47	37.51
T6	1.315	1.327	2.458	2.467	46.51	46.20	38.92	37.82

Treatment	Bulk Density		Particle Density		Pore Space		Water Holding Capacity	
	(Mg m-3)		(Mg m-3)		(%)		(%)	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
T7	1.302	1.315	2.456	2.464	46.98	46.61	39.75	38.79
T8	1.301	1.313	2.455	2.462	47.01	46.67	39.88	38.91
T9	1.298	1.311	2.454	2.461	47.11	46.74	40.17	39.08
F-test	NS	NS	NS	NS	NS	NS	S	S
S.Em. (±)	-	-	-	-	-	-	0.358	0.429
C.D @ 5%	-	-	-	-	-	-	1.074	1.287

Table 4. Effect of NPK and Zinc on chemical properties of soil after crop harvest

Treatment	pH		Electrical Conductivity		Organic Carbon	
			(dS m-1)		(%)	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
T1	7.538	7.602	0.235	0.251	0.365	0.340
T2	7.542	7.605	0.237	0.253	0.373	0.347
T3	7.535	7.597	0.241	0.255	0.368	0.342
T4	7.473	7.543	0.253	0.271	0.396	0.365
T5	7.458	7.556	0.249	0.268	0.392	0.362
T6	7.461	7.552	0.258	0.273	0.405	0.370
T7	7.385	7.468	0.272	0.294	0.426	0.398
T8	7.379	7.463	0.275	0.295	0.429	0.404
T9	7.375	7.457	0.281	0.298	0.437	0.407
F-test	NS	NS	NS	NS	S	S
S.Em. (±)	-	-	-	-	0.006	0.005
C.D @ 5%	-	-	-	-	0.019	0.017

Table 5. Effect of NPK and Zinc on available nutrient status of soil after crop harvest

Treatment	Available Nitrogen		Available Phosphorus		Available Potassium		Available Zinc	
	(kg ha-1)		(kg ha-1)		(kg ha-1)		(ppm)	
	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	258.76	251.12	18.31	16.89	178.43	172.65	0.487	0.432
T2	259.85	251.95	18.15	16.72	179.32	173.31	0.534	0.478
T3	261.38	253.14	17.89	16.49	181.90	174.98	0.592	0.536
T4	267.65	258.70	21.16	19.53	186.64	181.46	0.518	0.453
T5	269.24	261.76	20.98	19.34	187.93	183.33	0.576	0.505
T6	272.39	262.91	20.72	18.98	189.58	184.57	0.621	0.570
T7	281.81	273.48	25.10	23.02	196.76	191.20	0.556	0.483
T8	283.53	275.53	24.89	22.81	198.69	192.84	0.613	0.548
T9	287.08	278.37	24.62	22.57	201.53	194.26	0.685	0.622
F-test	S	S	S	S	S	S	S	S
S.Em. (±)	4.892	4.502	0.554	0.516	4.366	4.249	0.017	0.015
C.D @ 5%	14.667	13.498	1.663	1.547	13.090	12.740	0.053	0.047

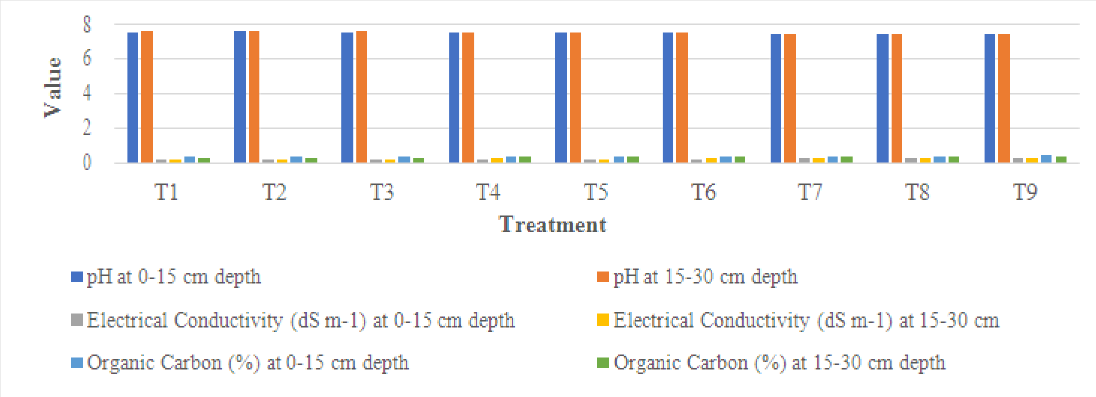

Fig. 2. Effect of NPK and Zinc on chemical properties of soil after crop harvest

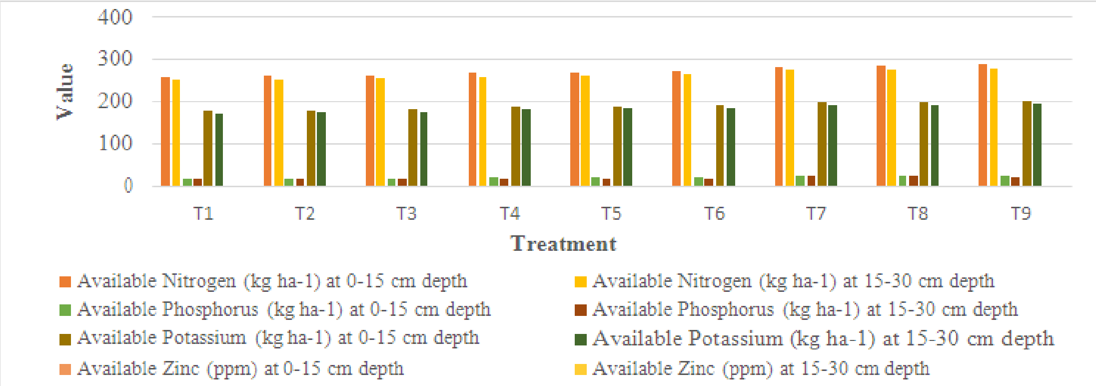

Fig. 3. Effect of NPK and Zinc on available nutrient status of soil after crop harvest

4. CONCLUSIONS

From the statistically analysed of experimental results, we found that physical-chemical parameters namely, bulk density, particle density and pH were slightly decreased, while pore space, water holding capacity, electrical conductivity and organic carbon were marginally increased as compared to initial values of soil before experimentation. The findings further, revealed that nutrient availability in soil namely, nitrogen, phosphorus, potassium and zinc were found in a moderate range. Finally, it seems quite logical to conclude that judicious application of NPK @ 20:40:20 kg ha^{-1} along with zinc @ 5 kg ha^{-1} [T9] was found to be one of the most effective options to enhancing the nutrient status as well as maintains physico- chemical characteristics of soil. Therefore, the findings regarding this experimental topic will help farmers achieve profitable production as well as improve soil health through the highest availability of nutrients in soil.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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