Response of NPK, Zinc and Boron fertilization on physico-chemical properties of soil under *summer* Green gram (*Vigna radiate* L.) cultivation in an Inceptisol of Prayagraj, (Uttar Pradesh)

Abstract

The study pertaining to the present topic under field investigation is entitled "Response of N, P, K, Zinc and Boron fertilization on Soil Health, Growth and Yield Attributes of *Summer* Green gram (*Vigna radiata L.*) in an Inceptisol of Prayagraj, Uttar Pradesh" for two consecutive years, beginning from the *summer* seasons of the years 2021 and 2022 at Research Farm, Department of Soil Science and Agricultural Chemistry. Before conducting research operations, an excavated soil sample from the experimental site revealed that the land topography ranged from nearly level to 1-3% slope, the soil is of sandy loam texture with near neutral in reaction (7.62), the electrical conductivity was non-saline (0.23 dS m^{-1}) in nature, the low organic carbon content (0.29%), the low to medium available N (146.62 kg ha^{-1}), available P (13.78 kg ha^{-1}) and available K (207.15kg ha^{-1}). The best results were seen with treatment (T_{11}), which was made up of RDF (20:40:20 NPK kg ha^{-1}) + Zinc@6 kg ha^{-1}+ Boron@3 kg ha^{-1}. This treatment used NPK and different micronutrient (Zinc and Boron) levels at the same time. regard to physical soil parameters, the cumulative mean value for bulk density (1.27 Mg m^{-3}), percent pore space (47.74%), particle density (2.67 Mg m^{-3}) and percent maximum water holding capacity (43.68%) were increased and chemical soil parameters with a cumulative mean of slightly saline soil pH (7.81), average electrical conductivity (0.37 dS m^{-1}), medium available N (275.93 kg ha^{-1}), medium available P in T_2 (21.07 kg ha^{-1}) due to the antagonistic effect of zinc on Phosphorous, medium available K (230.38 kg ha^{-1}), high available Zn (0.623 mg kg-1), and high available B (0.616 mg kg^{-1}) were labeled in comparison to other NPK and micronutrients levels treatments.

Key words: Soil health, Green gram, Zinc, Boron and soil properties.

Introduction

Next to cereals, Pulses play a vital role in agriculture as these provide proteins, minerals, vitamins, rich vegetables and fodder. As the legume crops have self-nitrogen fixing capacity, their contribution has an added advantage in the present day of fertilizer crisis in the country.

Pulses form the second largest source of dietary protein. Pulses are annual leguminous crops yielding between one and 12 grains or seeds of variable size, shape and colour within a pod, used for both food and feed. The term "pulses" is limited to crops harvested solely for dry grain, thereby excluding crops harvested green for food, which are classified as vegetable crops, as well as those crops used mainly for oil extraction and leguminous crops that are used exclusively for sowing purposes (Kumar *et al*., 2008).

The most limiting factor that has affected the production of crops and productivity of Indo Gangetic plain is fertilizer through imbalanced and indiscriminate use on one hand and withdrawal of organic matter from the schedule of inputs on the other. Therefore integrated nutrient management (INM) has been an increasing necessity especially for the sub-tropical Indian soils. Using mixture of organic manure with that of the fertilizers is believed to increase productivity of the crop plants. Thus, to achieve higher efficiency, the awareness needs to be spread on use of organic manure in the farms. Even though there has been a marked increase in the production due to use of NPK fertilizers; however, this has led to a number of issues, such as causing micronutrient deficiency in plants, like that of the Zn. Micronutrient deficiency in Indian soils has emerged as one of the major constraints to crop productivity. While zinc, iron, boron and manganese deficient areas are vast, copper and molybdenum deficiency has also been observed in many districts of the country. Zinc is involved in auxin formation, activation of dehydragenase enzymes and stabilization of ribosomal fractions. Iron (Fe) is an essential nutrient for plant growth and development and it is involved in chlorophyll and thylakoid synthesis and chloroplast development (Gidaganti *et. al.* 2019).

Lack of zinc causes deficiency in formation of RNA and protein. Therefore, the plant with lack of zinc is poor in amount of protein. Hence, the present study was undertaken to examine the integrated impact of spacing, sources of nutrient and method of zinc application on yield attributes, productivity and economics of green gram (Krishnaprabu, 2019).

Boron is important for sugar translocation, nitrogen utilization and protein synthesis. plays important role in synthesis of essential amino acids like cystine, methionine & certain vitamins like biotine, thymine, Vitamin B1 as well as the formation of ferodoxin & iron containing plants.

Hence, objectives of the study are simply justified. Keeping these considerations in view, an investigation was carried out during *summer* season of 2021 and 2022.

Material and Methods

Experimental site and location

The experimental 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. Representing the Agro-Ecological Sub Region [North Alluvial plain zone **(**0-1 % slope**)**] and Agro-Climatic Zone (Upper Gangetic Plain Region).

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.

Experimental details

The present research investigation was setup in a randomized block design (RBD) having eleven treatment combinations which is replicated thrice, randomly allocated in each replication, dividing the research site into thirty-three plots. The Green gram variety PDM-139 (Samrat) was grown during the two experimental years 2021 and 2022. In this study, inorganic fertilizers like Nitrogen, Phosphorous, Potassium, Zinc and Boron were applied.

Table 1. Treatment details

Treatment	***Summer* variety- PDM-139 (Samrat)**
T_1	Absolute control
T_2	Only RDF

T_3	RDF + Zn@2 + B @1 kg ha^{-1}
T_4	RDF + Zn@2 + B @2 kg ha^{-1}
T_5	RDF + Zn@2 + B @3 kg ha^{-1}
T_6	RDF + Zn@4 + B @1 kg ha^{-1}
T_7	RDF + Zn@4 + B @2 kg ha^{-1}
T_8	RDF + Zn@4 + B @3 kg ha^{-1}
T_9	RDF + Zn@6 + B @1 kg ha^{-1}
T_{10}	RDF + Zn@6 + B @2 kg ha^{-1}
T_{11}	RDF + Zn@6 + B @3 kg ha^{-1}

Fertilizer application

Recommended dose of NPK (100%) was applied to the green gram crop were N (20 kg ha^{-1}), P2O5 (40 kg ha^{-1}) and K2O (20 kg ha^{-1}). The 100 percent application of N, P and K was applied as basal dose at the time of sowing. In addition to these applications, Zinc was applied as basal @ 2, 4 and 6 kg ha^{-1} with Boron 1, 2 and 3 kg ha^{-1} only to the treatment with Zn and B. The sources of NPK fertilizers was nitrogen through urea (46% N), phosphorus through single superphosphate (16% P_2O_5), potash through Muriate of potash (60% K_2O) and zinc through zinc sulphate (21% Zn) and Boron through borax (11.3% B) was applied prior to sowing in concerning treatments just before the seed sowing.

Sowing of Green gram crop was carried out on 26th and 25th of March month during 2021 and 2022, respectively by manually. Seed variety PDM-139 (Samrat) was sown at the rate of 25 kg ha^{-1} and 5 cm depth, at a row to row spacing of 30 cm and plant to pant spacing 10 cm.

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 OC by Walkley and Black method (Walkley and Black 1934), water holding capacity (WHC) using Keen Raczkowski box (Piper 1966), pH, available K (Jackon 1973) and available P (Bray and Kurtz 1945) before sowing the experimental crop and after the harvest of crop. The soil samples were extracted for available B (Wear 1965); the extract was treated with activated

Table : Methods employed for the analysis of soil samples.

S.No	Particulars	Author (s)	Methodology	Unit
I.	**Physical properties**			
1.	Soil texture	Bouyoucous, 1927	Hydrometer method	Percentage

	(Sand,Silt and clay%)			
2.	Bulk density	Muthuaval *et al*., 1992	Copper core cylinder method	Mg m^{-3}
3.	Particle density	Muthuaval *et al*., 1992	Measuring cylinder method	Mg m^{-3}
4.	Soil porosity	-	-	Percentage
5.	Maximum water holding Capacity	Muthuaval *et al*., 1992	Measuring cylinder followed by water displacement method	Percentage
II	**Chemical properties**			
1.	Soil pH (1:2.5)	Jackson, 1973	pH meter	-
2.	Electrical conductivity (1:2.5)	Wilcox, 1950	EC bridge (digital conductivity meter–304.)	dS m^{-1}
3.	Organic carbon	Walkley and Black, 1947	Walkley and Black Wet oxidation method	Percentage
4.	Available nitrogen	Subbiah and Asija,1956	Modified alkaline permanganate oxidation method	Kg ha^{-1}
5.	Available phosphorus	Olsen *et al*.1954.	Olsen's extraction followed by Spectrophotometric method	Kg ha^{-1}
6.	Available potassium	Toth and Prince,1949	Neutral normal ammonium acetate extraction fallowed by Flame photometric method	Kg ha^{-1}
7.	Available Zn & B	Lindsay and Novell, 1978	DTPA extraction followed by Atomic Absorption Spectrophotometer	Mg kg^{-1}

Charcoal and estimated calorimetrically using azomethine-H method (Wolf 1971). Available Zn was extracted with DTPA-TEA (pH 7.3) (Lindsay and Norvell, 1978) and estimated with the help of atomic absorption spectrophotometer (AAS, Model: ELCO-SL194).

Statistical analysis

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

Results and Discussion

Effect of nutrient management in physical properties of soil after harvest of Green gram

The data showed that the bulk density of soil were 1.24 and 1.27 Mg m^{-3} and 1.25 and 1.27 Mg m^{-3}, particle density 2.65 and 2.66 Mg m^{-3} and 2.66 and 2.67 Mg m^{-3}, pore space 46.79 and 47.74 % and 46.99 and 47.56 %, water retention capacity 43.59 % and 43.37 % and 43.63 % and 43.68 % of soil were found optimum in treatment T_{11} RDF (20:40:20 NPK kg ha^{-1}) + Zinc@6 kg ha^{-1}+ Boron @3 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 2). This corroborates with the findings of Kumari *et al*., 2017, Kudi *et al*., 2018 and Karthik *et al*., 2021.

Effect of nutrient management in chemical properties of soil after harvest of Green gram

The data showed that the treatment T_{11} with RDF (20:40:20 NPK kg ha^{-1}) + Zinc@6 kg ha^{-1}+ Boron @3 kg ha^{-1}) significantly influenced the soil pH 7.79 and 7.74 and 7.81 and 7.78, electrical conductivity 0.35 and 0.33 and 0.37 and 0.35, organic carbon 0.48 and 0.45 % and

0.49 and 0.44 % 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 2021 and 2022, accordingly (Table 3).

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 (272.07, 274.50 kg ha^{-1} and 273.60, 275.93 kg ha^{-1}), available K (226.42, 225.81 kg ha^{-1} and 230.38, 228.54 kg ha^{-1}), available Zn (0.570, 0.557 mg kg^{-1} and 0.623 and 0.607 mg kg^{-1}) and available B (0.587, 0.573 mg kg^{-1} and 0.616, 0.604 mg kg^{-1}) was recorded under the treatment T_{11} RDF (20:40:20 NPK kg ha^{-1}) + Zinc@6 kg ha^{-1}+ Boron @3 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 (20.70, 20.48 kg ha^{-1} and 21.07, 20.86 kg ha^{-1}) over all other remaining treatment combinations at 0-15 cm and at 15-30 cm soil depth during the years 2021 and 2022, 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 green gram.

Conclusion

Based on the results, it is concluded that the application of NPK with micronutrient levels (Zinc and Boron) in treatment (T_{11}) RDF (20:40:20 NPK kg ha^{-1})+ Zinc@6 kg ha^{-1}+ Boron @3 kg ha^{-1}, was found foremost 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 levels of Zinc and Boron. Thus, it can be concluded that NPK and different levels of micronutrients (Zinc and Boron) improved 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_{11} recorded the finest treatment which increased the accessibility of nutrients and altered physico-chemical properties of soil.

Zinc and Boron nutrition with NPK significantly improves the soil health in green gram crop. The soil method of application of Zinc and Boron with NPK show favourable results. It is preferable nutrient (NPK with micronutrient) management option for improving the fertility of the soil. Hence, it can be recommended that to ameliorate sustainability of soil fertility in the inceptisol, the combined application of NPK, Zinc and Boron is the best option.

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Table 2. Soil physical properties after harvest of green gram 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	Absolute control	1.19	1.20	1.19	1.21	2.61	2.63	2.62	2.63	44.44	45.62	45.41	46.00	34.91	35.92	35.04	36.12
T_2	Only RDF	1.20	1.22	1.20	1.23	2.62	2.64	2.64	2.64	45.80	46.21	45.45	46.59	36.26	36.53	36.48	36.91
T_3	RDF + Zn@2 + B @1 kg ha^{-1}	1.22	1.23	1.22	1.23	2.63	2.64	2.64	2.65	46.38	46.59	46.21	46.41	36.72	36.76	37.30	36.92
T_4	RDF + Zn@2 + B @2 kg ha^{-1}	1.19	1.23	1.23	1.24	2.64	2.64	2.66	2.64	45.07	46.59	46.24	46.96	37.94	38.29	38.15	38.70
T_5	RDF + Zn@2 + B @3 kg ha^{-1}	1.20	1.24	1.23	1.24	2.63	2.65	2.64	2.65	45.62	46.79	46.59	46.79	38.83	39.15	38.94	39.57
T_6	RDF + Zn@4 + B @1 kg ha^{-1}	1.23	1.23	1.23	1.24	2.63	2.63	2.65	2.64	46.76	46.76	46.41	46.96	38.95	39.50	39.15	39.84
T_7	RDF + Zn@4 + B @2 kg ha^{-1}	1.23	1.24	1.23	1.24	2.64	2.62	2.64	2.65	46.59	47.32	46.59	46.79	39.01	39.61	39.12	39.79
T_8	RDF + Zn@4 + B @3 kg ha^{-1}	1.23	1.24	1.23	1.24	2.62	2.64	2.65	2.65	46.94	46.96	46.41	46.79	40.54	40.66	40.63	40.73
T_9	RDF + Zn@6 + B @1 kg ha^{-1}	1.24	1.25	1.24	1.25	2.63	2.64	2.65	2.65	47.14	47.34	46.79	47.16	40.82	40.99	40.93	41.17
T_{10}	RDF + Zn@6 + B @2 kg ha^{-1}	1.23	1.25	1.24	1.26	2.64	2.65	2.65	2.66	46.59	47.16	46.79	47.36	41.48	41.82	41.57	41.87
T_{11}	RDF + Zn@6 + B @3 kg ha^{-1}	1.24	1.27	1.25	1.27	2.65	2.66	2.66	2.67	46.79	47.74	46.99	47.56	43.59	43.37	43.63	43.68
SE m (±)		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CD (P=0.05)		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 3. Soil chemical properties and available nutrients after harvest of green gram as influence by different treatment combinations.

Treatments		pH				EC				OC (%)				Available Nitrogen (kg ha^{-1})			
		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	Absolute control	7.14	7.08	7.45	7.38	0.25	0.24	0.26	0.25	0.34	0.32	0.37	0.34	261.80	265.13	263.27	266.13
T_2	Only RDF	7.58	7.46	7.73	7.67	0.29	0.28	0.30	0.29	0.35	0.34	0.38	0.35	267.03	268.10	267.60	269.40
T_3	RDF + Zn@2 + B @1 kg ha^{-1}	7.61	7.56	7.64	7.59	0.27	0.27	0.28	0.29	0.39	0.37	0.40	0.39	266.97	268.27	267.50	269.83
T_4	RDF + Zn@2 + B @2 kg ha^{-1}	7.69	7.58	7.78	7.74	0.28	0.27	0.30	0.30	0.43	0.41	0.44	0.42	267.37	267.93	267.27	268.90
T_5	RDF + Zn@2 + B @3 kg ha^{-1}	7.69	7.69	7.75	7.71	0.29	0.28	0.31	0.32	0.43	0.42	0.45	0.41	266.10	268.27	268.00	269.33
T_6	RDF + Zn@4 + B @1 kg ha^{-1}	7.55	7.52	7.56	7.53	0.28	0.27	0.30	0.32	0.43	0.40	0.44	0.39	267.40	268.43	268.57	269.60
T_7	RDF + Zn@4 + B @2 kg ha^{-1}	7.55	7.54	7.67	7.64	0.28	0.27	0.30	0.30	0.43	0.42	0.44	0.41	268.80	269.80	269.80	270.60
T_8	RDF + Zn@4 + B @3 kg ha^{-1}	7.76	7.72	7.79	7.73	0.32	0.31	0.32	0.32	0.43	0.42	0.44	0.41	270.13	271.60	271.47	272.47
T_9	RDF + Zn@6 + B @1 kg ha^{-1}	7.57	7.55	7.61	7.58	0.32	0.30	0.34	0.34	0.44	0.43	0.45	0.42	271.63	272.80	272.70	273.57
T_{10}	RDF + Zn@6 + B @2 kg ha^{-1}	7.66	7.61	7.69	7.64	0.31	0.30	0.33	0.32	0.45	0.42	0.47	0.43	272.01	273.77	272.87	274.07
T_{11}	RDF + Zn@6 + B @3 kg ha^{-1}	7.79	7.74	7.81	7.78	0.35	0.33	0.37	0.35	0.48	0.45	0.49	0.44	272.07	274.50	273.60	275.93
SE m (±)		-	-	-	-	0.00	0.00	0.01	0.01	0.02	0.01	0.02	0.01	0.76	1.88	0.27	1.67
CD (P=0.05)		-	-	-	-	0.02	0.02	0.03	0.04	0.07	0.04	0.06	0.04	2.24	5.53	0.80	4.90

Table 4. Soil available nutrients after harvest of green gram 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		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	Absolute control	16.87	16.24	17.40	16.76	150.05	149.84	166.59	165.86	0.158	0.146	0.189	0.176	0.213	0.207	0.230	0.223
T_2	Only RDF	20.70	20.48	21.07	20.86	162.10	161.88	176.88	175.99	0.257	0.243	0.277	0.270	0.293	0.287	0.317	0.310
T_3	RDF + Zn@2 + B @1 kg ha^{-1}	18.90	18.56	19.07	18.73	172.38	168.87	184.17	183.56	0.303	0.297	0.317	0.313	0.363	0.357	0.390	0.383
T_4	RDF + Zn@2 + B @2 kg ha^{-1}	19.28	19.11	19.33	19.24	177.30	177.05	188.81	188.31	0.333	0.327	0.347	0.337	0.370	0.363	0.413	0.407
T_5	RDF + Zn@2 + B @3 kg ha^{-1}	18.63	18.31	18.69	18.60	185.09	184.41	191.07	190.14	0.390	0.380	0.420	0.413	0.423	0.417	0.437	0.423
T_6	RDF + Zn@4 + B @1 kg ha^{-1}	19.70	19.53	19.77	19.72	192.21	191.50	196.20	194.93	0.433	0.417	0.457	0.447	0.453	0.447	0.480	0.470
T_7	RDF + Zn@4 + B @2 kg ha^{-1}	18.93	18.51	19.01	18.61	202.44	201.59	205.96	204.98	0.450	0.440	0.477	0.457	0.470	0.460	0.500	0.487
T_8	RDF + Zn@4 + B @3 kg ha^{-1}	18.10	17.89	18.14	18.03	212.94	212.13	216.30	214.58	0.473	0.460	0.497	0.487	0.507	0.497	0.557	0.537
T_9	RDF + Zn@6 + B @1 kg ha^{-1}	19.37	18.95	19.45	19.29	216.61	216.04	219.76	218.03	0.487	0.473	0.517	0.507	0.500	0.490	0.570	0.560
T_{10}	RDF + Zn@6 + B @2 kg ha^{-1}	19.17	18.59	19.19	18.76	221.34	220.52	224.19	223.42	0.523	0.513	0.557	0.547	0.530	0.521	0.597	0.585
T_{11}	RDF + Zn@6 + B @3 kg ha^{-1}	18.90	18.44	19.05	18.55	226.42	225.81	230.38	228.54	0.570	0.557	0.623	0.607	0.587	0.573	0.616	0.604
SE m (±)		0.26	0.36	0.35	0.47	0.66	0.85	0.91	0.93	0.02	0.02	0.01	0.01	0.02	0.02	0.02	0.02
CD (P=0.05)		0.76	1.08	1.03	1.39	1.96	2.51	2.69	2.74	0.06	0.07	0.03	0.03	0.05	0.05	0.06	0.06