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Shreshthi Maurya
Research Scholar, Department of Soil Science and Agricultural Chemistry, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj, Uttar Pradesh, India

Narendra Swaroop
Associate Professor, Department of Soil Science and Agricultural Chemistry, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj, Uttar Pradesh, India

Tarence Thomas
Professor, Department of Soil Science and Agricultural Chemistry, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj, Uttar Pradesh, India

Arun Alfred David
Associate Professor, Department of Soil Science and Agricultural Chemistry, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj, Uttar Pradesh, India

Taniya Mistri
Ph.D. Scholar, Department of Soil Science and Agricultural Chemistry, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj, Uttar Pradesh, India

Divakar Swami
Department of Soil Science and Agricultural Chemistry, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj, Uttar Pradesh, India

Corresponding Author:
Shreshthi Maurya
Research Scholar, Department of Soil Science and Agricultural Chemistry, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj, Uttar Pradesh, India

Effect of different level of NPK and sulphur on soil physico-chemical properties and yield of Mustard (*Brassica juncea* L.) *var.* Shikar

Shreshthi Maurya, Narendra Swaroop, Tarence Thomas, Arun Alfred David, Taniya Mistri and Divakar Swami

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Abstract
The investigation on "Effect of different level of NPK and sulphur on soil physico-chemcial properties and yield of mustard (*Brassica juncea* L.) *var.* Shikar" comprise of a field experiment which was carried out at the Soil Science Research Farm, Sam Higginbottom University of Agriculture Technology, Prayagraj during rabi season 2023-2024. It is situated at $25^{0}40^{'}92^{''}$ N latitude, $81^{0}84^{'}93^{''}$E longitude and at the altitude of 98 meter above the sea level. The maximum temperature of the location reaches up to 46-48 °C and seldom falls as low as 4-5 °C. The relative humidity ranged between 20 to 94 percent. The average rainfall in this area is around 1100 mm annually. The experiment was conducted in randomized block design with different level of NPK and Sulphur. The treatments were replicated three times and were allocated at random in each replication. On the basis of findings it is concluded that the treatment combination @ 100% NPK + @ 100% Sulphur i.e, Treatment T_9 shows best result on growth and yield of mustard (*Brassica juncea* L.) *var.* Shikar in comparison to other treatment combination. Since the findings are based on the research done in one of season further experiments with more than one season will help in better to study the effect of different levels of NPK and sulphur on growth and yield by mustard (*Brassica juncea* L.) *var.* Shikar. The minimum bulk density (Mg m^{-3}), particle density (Mg m^{-3}), pH and EC (dSm^{-1}) was noted in @ 100% NPK + @ 100% Sulphur which was significantly superior over T_1 Control. Whereas The maximum pore space (%), organic carbon, available nitrogen (kg ha^{-1}), available phosphorus (kg ha^{-1}) and available potassium (kg ha^{-1}) and sulphur (ppm) was noted in @ 100% NPK + @ 100% Sulphur which was significantly superior over T_1 Control.

Keywords: NPK, sulphur physico-chemical properties, yield and mustard

Introduction
In early 1990's S deficiencies in Indian soils were estimated to occur in about 130 districts and recently about 45% districts of our country showed more than 40% Sulphur deficiency (Tandon, 1991) [11]. Mustard has highest requirement of Sulphur with optimum level ranging from 20 to 60 kg S/ ha depending on the soil Sulphur status and yield potential (Sarmah & Debnath, 1999). Indian mustard (*Brassica juncea* L. Czernj & Cosson) belongs to the family Brassicaceae and commonly called as rai or Indian mustard. It contain good amount of oil usually 30–38% Thomas (2004). The mustard oil contains low amount of saturated fatty acids among vegetable oils Rahangdale *et al.,* (2022) [7]. Indian mustard (*Brassica juncea* L.) commonly known as raya, rai or lahi is an important oilseed crop among the Brassica group of oilseed in India. It's the second most important edible oilseed crop in India after groundnut and accounts for nearly 30% of the total oilseeds produced in the country. Rapeseed-mustard is an important group of edible oil seed crops and contributes around 26.1% of the total oil seed production and contributes about 85% of the total rapeseed– mustard produced in India Singh *et al.,* (2017) [9]. Mustard (Brassica juncea) is predominantly cultivated in the states of Rajasthan. Uttar Pradesh, Madhya Pradesh. Haryana, Gujarat, Punjab and Bihar (AICRP, 2020-2021). Rajasthan is the state having the largest area of 2550.92 hectare and highest production of 1466 kg/ha as compared to Uttar Pradesh having an area of 694.66 hectare and production of 1290 kg/ha, respectively (Government of India Ministry of Agriculture and Farmers Welfare Department of Agriculture,

2020-2021) which is considered low. Nitrogen is the most important nutrient, which determines the growth of the mustard crop and increases the amount of protein and the yield. Phosphorus and potash are known to be efficiently utilized in the presence of nitrogen. It promotes flowering, setting of siliqua and in increase the size of siliqua and yield. Potassium is one of the seventeen elements which are essential for growth and development of plants. It's for improving the yield and quality of different crops because of its effect on photosynthesis, water use efficiency and plant tolerance to diseases, drought and cold as well for making the balance between protein and carbohydrates. Sulphur plays the key role is most important among the secondary nutrient in the production of oilseed crops. It plays significant role in the development of seed. An oilseed crop requires sulphur comparatively higher than other nutrient and it is now being recognized as the fourth major element of the plant.

Materials and Methods

The investigation on "Effect of different level of NPK and sulphur on soilphysico-chemcial properties and yield of mustard (*Brassica juncea* L.) *Var.* Shikar" comprise of a field experiment which was carried out at the Soil Science Research Farm, Sam Higginbottom University of Agriculture Technology, Prayagraj during zaid season 2023. The experiment was conducted at research Farm of Soil Science at Sam Higginbottom University of Agriculture Technology and Sciences, Prayagraj, the area is situated on the south of Prayagraj on the right side of the river Yamuna on the South of Rewa Road at a distance of about 6 km from Prayagraj city. It is situated at $25^{0}40'92''$ N latitude, $81^{0}84'93''$E longitude and at the altitude of 98 meter above the sea level. The maximum temperature of the location reaches up to 46-48 °C and seldom falls as low as 4-5 °C. The relative humidity ranged between 20 to 94 percent. The average rainfall in this area is around 1100 mm annually. The experiment was conducted in randomized block design with different level of NPK and Sulphur. The treatments were replicated three times and were allocated at random in each replication. The total number of plots was 27. Mustard (*Brassica juncea* L.) "Cv. Shikar" were sown in rabi season plots of size 2 x 2 m with row spacing 40 cm and plant to plant distance 30 cm. The soil samples were randomly collected from twenty seven different sites in the experiment plot prior to tillage operation from a depth of 0-15 cm and 15-30 cm. The treatment consisted of nine combination of NPK and sulphur *viz*., T_1 @ 0% NPK + @ 0% Sulphur, T_2 0% NPK + @ 50% Sulphur, T_3 @ 0% NPK + @ 100% Sulphur, T_4 @ 50% NPK + @ 0% Sulphur, T_5 @ 50% NPK + @ 50% Sulphur, T_6 @ 50% NPK + @ 100% Sulphur, T_7 100% NPK + @ 0% Sulphur, T_8 @ 100% NPK + @ 50% Sulphur and T_9 @ 100% NPK + @ 100% Sulphur.

Table 1: Mechanical analysis of pre-soil samples

Particulars	Results	Method employed
Sand (%)	62.71	Bouyoucous Hydrometer method (1952)
Silt (%)	23.10	
Clay (%)	14.19	
Textural class	**Sandy loam**	
Soil Colour		MunshellColour Chart (1971)
Dry Soil	Pale brown Colour	
Wet Soil	Olive brown Colour	
Bulk density (Mg m^{-3})	1.35	The Gravimetrical Method (Muthuval *et al*.,1992)
Particle density (Mg m^{-3})	2.48	
Pore Space (%)	48.64	

Table: Chemical analysis of pre sowing soil samples

Parameters	Method employed	Results
Soil pH (1:2)	Digital pH meter (Jackson, 1958)	7.61
Soil EC(dSm^{-1})	Digital EC meter (Wilcox, 1950)	0.28
Organic Carbon (%)	Wet oxidation method (Walkley and Black's, 1947)	0.31
Available Nitrogen (kg ha^{-1})	Alkaline permanganate method (Subbiah and Asija (1956)	264.33
Available Phosphorus (kg ha^{-1})	Olsen spectrophotometric method (Olsen *et al*. 1954)	12.25
Available Potassium (kg ha^{-1})	Flame photometric method (Toth and Price, 1949)	139.03

Results and Discussion

Observations regarding the response of integrated nutreints different levels of NPK (0.00, 50, and 100%) and sulpur (0.00, 50, and 100%) affect the soil bulk density (Mg m^{-3}) at 0-15cm and 15-30 cm soil depth are given in table 1& 2. The statistically analysed data presented in table and graphically depicted. The result of the data depleted that the maximum bulk density (Mg m^{-3}) (1.38 and 1.35) at 0-15 and 15-30 cm soil depth after harvest was found in @ 100% NPK + @ 100% Sulphur and minimum bulk density (Mg m^{-3}) was found in T_1 (control) which was (1.35 and 1.31) respectively. Table depicted that the mean value of bulk density (Mg m^{-3}) was found significant on different levels of NPK and sulphur. It was also observed that bulk density (Mg m^{-3}) were gradually increase with an increase in dose of NPK and sulphur. Tadesse *et al.*, (2013) [10] also reported the same findings. The result of the data depleted that the minimum Particle Density (Mg m^{-3}) (2.46 and 2.48) at 0-15 and 15-30 cm soil depth after harvest was found in @ 100% NPK + @ 100% Sulphur and maximum Particle Density (Mg m^{-3}) was found in T_1 (control) which was (2.48 and 2.49) respectively. Table 1 depicted that the mean value of Particle Density (Mg m^{-3}) was found significant on different levels of NPK and sulphur. It was also observed that Particle Density (Mg m^{-3}) were gradually increase with an increase in dose of NPK and sulphur. Tadesse *et al.*, (2013) [10] also reported the same findings. The result of the data depleted that the minimum pore space (%) (50.01 and 40.97) at 0-15 and 15-30 cm soil depth after harvest was found in @ 100% NPK + @ 100% Sulphur and maximum pore space (%)was found in T_1 (control) which was (48.64 and 45.41) respectively. Table 1 depicted that the mean value of pore space (%) was found significant on different levels of NPK and sulphur. It was also observed that pore space

(%) were gradually increase with an increase in dose of NPK and sulphur. The result of the data depleted that the maximum pH (7.61 and 7.51) at 0-15 and 15-30 cm soil depth after harvest was found in @ 100% NPK + @ 100% Sulphur and minimum pH was found in T_1 (control) which was (7.05 and 6.90) respectively. Table 1 depicted that the mean value of pH was found significant on different levels of NPK and sulphur. It was also observed that pH were gradually increase with an increase in dose of NPK and sulphur. Results were same reported by Tadesse *et al.,* (2013) [10] and Hemalata *et al.,* (2013) [3]. The result of the data depleted that the minimum EC dSm^{-1}(0.19 and 0.18) at 0-15 and 15-30 cm soil depth after harvest was found in @ 100% NPK + @ 100% Sulphur and maximum EC $dSm^{-1}$was found in T_1 (control) which was (0.28 and 0.30) respectively. Table 4.5 depicted that the mean value of EC dSm^{-1} was found significant on different levels of NPK and sulphur. It was also observed that EC dSm^{-1} were gradually increase with an increase in dose of NPK and sulphur. Results were same reported by Tadesse *et al.,* (2013) [10] and Hemalata *et al.,* (2013) [3] and Singh *et al.,* (2017). The result of the data depleted that the maximum organic carbon (0.50 and 0.48) at 0-15 and 15-30 cm soil depth after harvest was found in @ 100% NPK + @ 100% Sulphur and minimum organic carbon was found in T_1 (control) which was (0.31 and 0.30) respectively. Table 1 depicted that the mean value of organic carbon was found significant on different levels of NPK and sulphur. It was also observed that organic carbon were gradually increase with an increase in dose of NPK and sulphur. Similar findings were reported by Shankar *et al.,* (2002), Miles *et al.,* (2011), [6] Masood *et al.,* (2014) [4] and Brar *et al.,* (2015) and Singh *et al.,* (2017) [9]. The result of the data depleted that the minimum available nitrogen (kg ha^{-1}) (264.33 and 262.33) at 0-15 and 15-30 cm soil depth after harvest was found in @ 100% NPK + @ 100% Sulphur and maximum available nitrogen (kg ha^{-1}) was found in T_1 (control) which was (291.00 and 289.00) respectively. Table 2 depicted that the mean value of available nitrogen (kg ha^{-1}) was found significant on different levels of NPK and sulphur. It was also observed that available nitrogen (kg ha^{-1}) were gradually increase with an increase in dose of NPK and sulphur. Tadesse *et al.,* (2013) [10] and Hemalata *et al.,* (2013) [3] and Singh *et al.,* (2017) also reported the similar findings. The result of the data depleted that the minimum available phosphorus (kg ha^{-1}) (28.67 and 26.25) at 0-15 and 15-30 cm soil depth after harvest was found in @ 100% NPK + @ 100% Sulphur and maximum available phosphorus (kg ha^{-1}) was found in T_1 (control) which was (12.25 and 10.18) respectively. Table 2 depicted that the mean value of available phosphorus (kg ha^{-1}) was found significant on different levels of NPK and sulphur. It was also observed that available phosphorus (kg ha^{-1}) were gradually increase with an increase in dose of NPK and sulphur. Corroborative findings also were reported by Tadesse *et al.,* (2013) [10] and Hemalata *et al.,* (2013) [3] and Singh *et al.,* (2017) [9]. The result of the data depleted that the maximum available potassium (kg ha^{-1}) (182.06 and 180.02) at 0-15 and 15-30 cm soil depth after harvest was found in @ 100% NPK + @ 100% Sulphur and minimum available potassium (kg ha^{-1}) was found in T_1 (control) which was (139.03 and 136.67) respectively. Table 2 depicted that the mean value of available potassium (kg ha^{-1}) was found significant on different levels of NPK and sulphur. It was also observed that available potassium (kg ha^{-1}) were gradually increase with an increase in dose of NPK and sulphur. Rather and Sharma (2009) and Babar and Dongle (2011) [1] and Singh *et al.,* (2017) also reported in line with same findings. The result of the data depleted that the minimum available sulphur (ppm) (16.297 and 15.497) at 0-15 and 15-30 cm soil depth after harvest was found in @ 100% NPK + @ 100% Sulphur and maximum available sulphur (ppm) was found in T_1 (control) which was (11.407 and 10.220) respectively. Table 2 depicted that the mean value of available sulphur (ppm) was found significant on different levels of NPK and sulphur. It was also observed that available sulphur (ppm) were gradually increase with an increase in dose of NPK and sulphur. These are similar finding repoted by Singh *et al.,* (2017) [9].

The statistically analysed data presented in table 3. The result of the data depleted that the maximum plant height of mustard (*Brassica juncea* L.) *var.* Shikar days after sowing at different days 30, 60, 90and 120 DAS was (32.27, 84.14, 163.45 and 186.39) found in @ 100% NPK + @ 100% Sulphur and minimum plant height was found in T_1(control) which was(18.80, 64.40, 134.49 and 152.20) respectively. The result of the data depleted that the maximum number of branches per plant of mustard (*Brassica juncea* L.) *var.* Shikar days after sowing at different days 30, 60, 90and 120 DAS was (2.37, 5.83, 8.74) found in @ 100% NPK + @ 100% Sulphur and minimum number of branches per plant was found in T_1 (control) which was (1.59, 3.74 and 5.20) respectively. The result of the data depleted that the minimum Days taken to appearance of first flowering (36.04) of mustard (*Brassica juncea* L.) *var.* Shikar found in @ 100% NPK + @ 100% Sulphur and maximum Days taken to appearance of first flowering was found in T_1 (control) which was (53.76) respectively. The result of the data depleted that the maximum test weight (gm) (5.10) of mustard (*Brassica juncea* L.) *var.* Shikar found in @ 100% NPK + @ 100% Sulphur and minimum test weight (gm) was found in T_1 (control) which was (4.33) respectively. The result of the data depleted that the maximum seed yield (t ha^{-1}) (2.41) of mustard (*Brassica juncea* L.) *var.* Shikar found in @ 100% NPK + @ 100% Sulphur and minimum seed yield (t ha^{-1}) was found in T_1. (control) which was (1.72) respectively. It was also observed that plant height (cm) were gradually increase with an increase in dose of NPK and sulphur. Similar results have also been recorded by Tripathi *et al.,* (2003) [12]. Application of Sulphur resulted in improvement in root growth, cell multiplication, elongation and cell expansion in the plant body which ultimately increased in growth character of mustard crop. Singh & Meena (2004) [8] Tripathi & Tripathi (2003) [12] and Dixit *et al.,* (2023) [2].

Table 1: Effect of different level of NPK and sulphuron physico-chemical properties of soil at 0-15 and 15-30 of mustard (*Brassica juncea* L.) *var.* Shikar

Treatments No.	Treatment combinations	Bulk Density		Particle Density		Pore space		pH		EC (dSm^{-1})		Organic carbon	
		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	@ 0% NPK + @ 0% Sulphur	1.35	1.31	2.48	2.49	48.64	45.41	7.61	7.51	0.28	0.30	0.31	0.30
T_2	@ 0% NPK + @ 50% Sulphur	1.36	1.31	2.48	2.49	48.66	44.83	7.57	7.50	0.26	0.28	0.32	0.32
T_3	@ 0% NPK + @ 100% Sulphur	1.36	1.32	2.47	2.48	48.96	44.03	7.47	7.45	0.25	0.26	0.34	0.32
T_4	@ 50% NPK + @ 0% Sulphur	1.36	1.33	2.47	2.47	49.28	43.99	7.43	7.43	0.23	0.27	0.34	0.34
T_5	@ 50% NPK + @ 50% Sulphur	1.36	1.33	2.47	2.47	49.44	43.67	7.36	7.38	0.25	0.26	0.37	0.36
T_6	@ 50% NPK + @ 100% Sulphur	1.37	1.33	2.47	2.47	49.61	42.92	7.22	7.26	0.24	0.23	0.41	0.40
T_7	@ 100% NPK + @ 0% Sulphur	1.37	1.34	2.46	2.46	49.69	42.71	7.14	7.07	0.22	0.21	0.45	0.42
T_8	@ 100% NPK + @ 50% Sulphur	1.37	1.35	2.46	2.47	49.82	42.51	7.09	7.01	0.21	0.19	0.48	0.47
T_9	@ 100% NPK + @ 100% Sulphur	1.38	1.35	2.46	2.48	50.01	40.97	7.05	6.90	0.19	0.18	0.50	0.48
	F-Test	S	S	S	NS	NS	NS	S	S	S	S	S	S
	C. D. at 5%	0.03	0.02	0.02	0.02	0.42	2.50	0.25	0.18	0.01	0.03	0.06	0.05
	S.Ed. (±)	0.01	0.01	0.01	0.01	0.20	1.18	0.12	0.09	0.01	0.02	0.03	0.02

Table 2: Effect of different level of NPK and sulphuron physico-chemical properties of soil at 0-15 and 15-30 of mustard (*Brassica juncea* L.) *var.* Shikar

Treatments No.	Treatment combinations	Nitrogen (kg ha^{-1})		Phosphorus (kg ha^{-1})		Potassium (kg ha^{-1})		Available sulphur (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
T_1	@ 0% NPK + @ 0% Sulphur	264.33	262.33	12.25	10.18	139.03	136.67	11.407	10.220
T_2	@ 0% NPK + @ 50% Sulphur	264.67	263.67	13.10	11.48	145.99	142.66	14.207	12.317
T_3	@ 0% NPK + @ 100% Sulphur	267.33	266.00	14.82	13.10	149.03	148.13	15.293	12.910
T_4	@ 50% NPK + @ 0% Sulphur	269.67	266.67	16.10	14.38	153.93	149.08	13.503	12.603
T_5	@ 50% NPK + @ 50% Sulphur	271.33	267.00	16.92	14.56	159.89	153.96	14.163	13.237
T_6	@ 50% NPK + @ 100% Sulphur	275.67	274.67	20.46	19.03	166.68	163.15	14.393	13.457
T_7	@ 100% NPK + @ 0% Sulphur	279.33	276.33	21.87	19.81	170.74	168.55	15.420	14.213
T_8	@ 100% NPK + @ 50% Sulphur	285.67	285.33	26.03	24.93	179.37	178.16	16.100	15.342
T_9	@ 100% NPK + @ 100% Sulphur	291.00	289.00	28.67	26.25	182.06	180.02	16.297	15.497
	F-Test	S	S	S	S	S	S	S	S
	C. D. at 5%	3.07	5.25	1.55	1.30	1.08	0.99	0.270	0.538
	S.Ed. (±)	1.45	2.48	0.73	0.61	0.51	0.46	0.127	0.254

Table 3: Effect of different level of NPK and sulphuron growth and yield of mustard (*Brassica juncea* L.) *var.* Shikar

Treatments No.	Treatment combinations	Plant height (cm)	Number of branches	Days taken to appearance of first flowering	Test weight (gm)	Seed yield (t ha^{-1})
T_1	@ 0% NPK + @ 0% Sulphur	152.20	5.20	53.76	4.33	1.72
T_2	@ 0% NPK + @ 50% Sulphur	162.92	7.07	51.25	4.45	1.77
T_3	@ 0% NPK + @ 100% Sulphur	166.18	7.12	48.73	4.54	1.88
T_4	@ 50% NPK + @ 0% Sulphur	171.02	7.66	46.73	4.62	1.97
T_5	@ 50% NPK + @ 50% Sulphur	172.71	7.82	44.10	4.71	2.03
T_6	@ 50% NPK + @ 100% Sulphur	176.17	8.15	42.38	4.83	2.06
T_7	@ 100% NPK + @ 0% Sulphur	181.94	8.60	40.70	4.93	2.18
T_8	@ 100% NPK + @ 50% Sulphur	182.67	8.64	38.30	5.05	2.31
T_9	@ 100% NPK + @ 100% Sulphur	186.39	8.74	36.04	5.10	2.41
	F-Test	S	S	S	S	S
	C. D. at 5%	3.778	0.185	2.248	0.051	0.071
	S.Ed. (±)	1.782	0.087	1.060	0.024	0.033

Conclusion

On the basis of findings it is concluded that the treatment combination @ 100% NPK + @ 100% Sulphur i.e., Treatment T_9 shows best result on growth and yield of mustard (*Brassica juncea* L.) *var.* Shikar in comparison to other treatment combination. Since the findings are based on the research done in one of season further experiments with more than one season will help in better to study the effect of different levels of NPK and sulphur on growth and yield by mustard (*Brassica juncea* L.) *var.* Shikar. The minimum bulk density (Mg m^{-3}), particle density (Mg m^{-3}), pH and EC dSm^{-1}was noted in @ 100% NPK + @ 100% Sulphur which was significantly superior over T_1 Control. Whereas the maximum pore space (%), organic carbon, available nitrogen (kg ha^{-1}), available phosphorus (kg ha^{-1}) and

available potassium (kg ha^{-1}) and sulphur (ppm) was noted in @ 100% NPK + @ 100% Sulphur which was significantly superior over T_1 Control.

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