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Assessment of Integrated Nutrients on Soil Health Parameters and Yield of Rice (*Oryza sativa* L.) var. Sarna

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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

A randomized block design having two factors with three levels of @ NPK 0, 50, and 100% ha^{-1}, three levels of @ FYM 0, 50 and 100% ha^{-1} and *Azospirillum* respectively. The best treatment was effect on physical and chemical property of soil and yield attributes in T_8 (NPK @100% + FYM @ 6 t ha^{-1} + *Azospirillum* @ 1 kg ha^{-1}) of rice. Post-harvest soil and pre harvest plant resulted significantly maximum values of percentage pore space (%) with depth 0-15 cm and 15-30 cm 49.89 % and 47.55 %, water holding capacity (%) with depth 0- 15 cm and 15-30 cm 44.66 % and 43.22 % , EC (dS m^{-1}) with depth 0-15 cm and 15-30 cm 0.26 dS m^{-1} and 0.22 dS m^{-1} , organic carbon (%) with

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depth 0-15 cm and 15-30 cm 0.67% and 0.63% , Av. Nitrogen (kg ha^{-1}) with depth 0-15 cm and 15-30 cm 295.09 kg ha^{-1} and 291.76 kg ha^{-1} , Av. Phosphorus (kg ha^{-1}) with depth 0-15 cm and 15-30 cm 31.45 kg ha^{-1} and 29.27 kg ha^{-1} , Av. Potassium (kg ha^{-1}) with depth 0-15 cm and 15-30 cm 213.89 kg ha^{-1} and 20.323 kg ha^{-1} , The maximum cost benefit ratio (C:B) 1:3.19, maximum gross return 1,85,612.00, maximum net profit 1,27,488.00 ha^{-1} and highest Grain yield as 44.86 q ha^{-1} , straw yield 63.88 q ha^{-1} with T_8 (NPK @100% + FYM 6 t ha^{-1} + *Azospirillum* @ 1 kg ha^{-1}).

Keywords: Soil parameters; integrated nutrient management; yield var. saran; etc.

1. INTRODUCTION

Soil plays a crucial role in determining the sustainable productivity of agro-ecosystems by supplying essential nutrients to growing plants. The uptake of macronutrients by plants is influenced by various factors, including interactions between major nutrients, as noted by [1]. However, soil degradation is becoming increasingly prevalent due to both natural processes and human activities, adversely impacting productivity [2-5]. With the continuous growth of the human population, there is a greater demand on soil to provide essential nutrients for food and fiber production. Unfortunately, the soil's inherent ability to supply these nutrients has diminished, largely due to increased plant productivity associated with rising food demand [6].

“Rice is the staple food crop of half the world’s population, cultivated over an area of 162.1 M ha globally with an annual production of 746.6 M t and productivity of 4661 kg ha^{-1}” [7]. “In Asia, the rice production is a key element for economic and social stability as more than two billion people depend on rice for their dietary requirements” [8]. Rice is largely cultivated in Asian countries with China occupying the first place followed by India, Indonesia, Bangladesh and Vietnam [9]. In India, rice occupies an area of 43.7 M ha with an average production of 118.9 M t and with productivity of 2423 kg ha^{-1}. Rice grain is consumed as popped or puffed rice, flakes, fermented products *etc*. while its byproducts viz; straw and husk are used as animal feed and raw material in paper industry, fuel, making ropes, mats *etc*. Rice bran rich in proteins and vitamins is used as animal feed and for extraction of rice bran oil. In Telangana, the area of rice is 3.19 M ha with production of 11.12 M t and productivity of 3483 kg ha^{-1}. Among the four rice ecosystems, irrigated rice under lowland dominates in both area and production. In terms of global rice productivity, irrigated lowland rice comprises of 55 and 75% of area and production, respectively [10].

2. MATERIALS AND METHODS

The experiment was conducted at research farm of soil science and agricultural chemistry NAI, SHUATS, Prayagraj, U.P, India. It is situated at $25^{0}24'23''$ N latitude, $81^{0}50'38''$ E longitude and at an altitude of 98 meter above the sea level. During the summer *Kharif*, the maximum temperature of the location reaches up to $46^{0}C$ – $48^{0}C$ and seldom falls as low as $4^{0}C$ – $5^{0}C$ during winter season. The relative humidity ranged between 20 to 90 percent. The average rainfall in this area is around 1100mm annually.

The soil of experimental area falls in order Inceptisol and the experimental field is alluvial in nature. The design applied for statistical analysis was carried out with 3^3 randomized block design having three levels of NPK, three levels of FYM and one level of *Azospirillum*. The details of the treatment combinations are given below Table 1 and observation were recorded bulk density, particle density, water holding capacity %, pH, organic matter, nitrogen, phosphorus, potassium, plant height, number of leaves $plant^{-1}$, panicle length (cm), test weight, grain yield and stalk yield.

[Note: NPK 100% (30:10:40 Kg ha^{-1}), FYM 100% (10 t ha^{-1}) and Azospirillum 100% (1 Kg ha^{-1})]

Table 1. Soil physical parameters

Particulars	Methods employed	Reference Range
Bulk density (Mg m^{-3})	Muthuval et al., [11]	1.45-1.8
Particle density (Mg m^{-3})	Muthuval et al., [11]	2.65-2.8
Pore space (%)	Muthuval et al., [11]	Less than 50%
Water holding capacity (%)	(Muthuval et al., [11]	Less than 50%

3. RESULTS AND DISCUSSION

As depicted in Tables 2 and 3 the water holding capacity (%) in soil increased significantly with the increase in levels of NPK fertilizers and FYM. the maximum water holding capacity (%) of soil at were found in treatment T_8 (NPK @ 100% + FYM 6 t ha^{-1} + *Azospirillum* @ 1 kg ha^{-1}) with depth 0-15 cm and 15-30 cm which was 44.66 % and 43.22 % respectively, while the minimum values of the result were found in treatment T_1 (Absolute Control) with depth 0-15 cm and 15-30 cm which was 40.67 % and 338.50 % respectively. Water holding capacity of soil was found significant different. It was also observed the pore space of soil was gradually increased with an increase in dose of NPK and FYM. The effect of NPK and FYM on water holding capacity of soil was also found significantly, Pore space (%) in soil increased significantly with the increase in levels of NPK fertilizers and FYM. The maximum pore space (%) of soil at were found in treatment T_8 (NPK @ 100% + FYM 6 t ha^{-1} + *Azospirillum* @ 1 kg ha^{-1}) with depth 0-15 cm and 15-30 cm which was 49.89% and 47.55% respectively, while the minimum values of the result were found in treatment T_1 (Absolute Control) with depth 0-15 cm and 15-30 cm which was 45.17% and 42.83% respectively. Cereals have potential to improve soil nutrient status through biological nitrogen fixation and biomass absorption into the soil as organic manure. Similar findings were recorded by Kumawat et al., [16], Neha [17], Yaduwanshi et al., [18], Rishikesh et al., [19], Tejaswini [20], Sahare et al.,[21].

As depicted in Tables 2 and 3 the maximum pH (1:2.5) w/v of soil at were found in treatment T_1 (Absolute Control) with depth 0-15 cm and 15-30 cm which was 6.95 and 6.99 respectively while the minimum values of the result were found in treatment T_8 (NPK @ 100% + FYM 6 t ha^{-1} + *Azospirillum* @ 1 kg ha^{-1}) with depth 0-15 cm and 15-30 cm which was 6.89 and 6.91 respectively. Similar findings were recorded, maximum Electrical Conductivity (dS m^{-1}) of soil at were found in treatment T_8 (NPK @ 100% + FYM 6 t ha^{-1} + *Azospirillum* @ 1 kg ha^{-1}) with depth 0-15 cm and 15-30 cm which was 0.26 dS m^{-1} and 0.22 dS m^{-1} respectively while the minimum values of the result were found in treatment T_1 (Absolute Control) with depth 0-15 cm and 15-30 cm which was 0.15 dS m^{-1} and 0.14 dS m^{-1} respectively. The organic carbon (%) in soil increased significantly with the increase in levels of NPK fertilizers and FYM. The maximum values of the result were found in treatment T_8 (NPK @ 100% + FYM 6 t ha^{-1} + *Azospirillum* @ 1 kg ha^{-1}) with depth 0-15 cm and 15-30 cm which was 0.67% and 0.63% respectively. while the minimum organic carbon (%) of soil at were found in treatment T_1 (Absolute Control) with depth 0-15 cm and 15-30 cm which was 0.58% and 0.55% respectively.

Table 2. Soil chemical parameters

Parameters	Scientist	Reference range/permissible limits		
		Low	Medium	High
Soil pH	Jackson [12]	< 6.5	6.5-7.5	>7.5
Soil EC (dS m^{-1})	Wilcox [13]	< 0.8	0.8-2.0	> 2.0
Organic carbon (%)	Walkley and Black [14]	< 0.50	0.50-0.75	>0.75
Av. Nitrogen (Kg ha^{-1})	Subbaiah and Asija [15]	< 280	280-560	>560
Av. Phosphorus (Kg ha^{-1})	Brays and Kurtz (1945)	< 10	10-25	>25
Av. Potassium (Kg ha^{-1})	Toth and Prince (1945)	< 118	118-280	>280

Table 3. Treatment combination of rice var. saran

Treatment	Description
T_1	Absolute Control
T_2	[NPK @ 0% + FYM 6 t ha^{-1} + *Azospirillum* @ 1 kg ha^{-1}]
T_3	[NPK @ 0% + FYM 12 t ha^{-1} + *Azospirillum* @ 1 kg ha^{-1}]
T_4	[NPK @ 50% + FYM 0 t ha^{-1} + *Azospirillum* @ 1 kg ha^{-1}]
T_5	[NPK @ 50% + FYM 6 t ha^{-1} + *Azospirillum* @ 1 kg ha^{-1}]
T_6	[NPK @ 50% + FYM 12 t ha^{-1} + *Azospirillum* @ 1 kg ha^{-1}]
T_7	[NPK @ 100% + FYM 0 t ha^{-1} + *Azospirillum* @ 1 kg ha^{-1}]
T_8	[NPK @ 100% + FYM 6 t ha^{-1} + *Azospirillum* @ 1 kg ha^{-1}]
T_9	[NPK @ 100% + FYM 12 t ha^{-1} + *Azospirillum* @ 1 kg ha^{-1}]

Table 4. Effect of different level of NPK FYM and *Azospirillum* on physico-chemical properties of rice var. sarna (0 cm-15 cm)

Treatment	Bulk Density ($Mg\ m^{-3}$)	Particle Density ($Mg\ m^{-3}$)	Water holding capacity (%)	Pore Space (%)	EC ($dS\ m^{-1}$)	pH (1:2.5)	OC (%)	Nitrogen ($Kg\ ha^{-1}$)	P_2O_5 ($Kg\ ha^{-1}$)	K_2O ($Kg\ ha^{-1}$)
T_1	1.35	2.45	40.67	45.17	0.15	6.95	0.58	279.15	25.32	201.21
T_2	1.32	2.48	42.73	47.23	0.19	6.92	0.61	282.76	27.76	203.63
T_3	1.29	2.51	44.29	48.79	0.23	6.89	0.64	286.43	30.11	206.45
T_4	1.34	2.46	41.37	45.87	0.16	6.94	0.59	284.87	25.87	204.87
T_5	1.31	2.49	43.19	47.69	0.20	6.91	0.62	287.32	28.65	207.43
T_6	1.28	2.52	44.52	49.02	0.24	6.88	0.65	291.48	30.76	210.65
T_7	1.33	2.47	41.85	46.35	0.18	6.93	0.60	289.79	26.15	208.89
T_8	1.27	2.53	44.66	49.89	0.26	6.89	0.67	295.09	31.45	213.89
T_9	1.30	2.50	43.71	48.21	0.22	6.90	0.63	292.15	29.23	211.71
F- test	**NS**	**NS**	**S**	**S**	**S**	**NS**	**S**	S	**S**	**S**
S.Em. (±)	-	-	0.70	0.82	0.020	-	0.011	4.059	0.521	2.676
C.D. @ 5%	-	-	2.09	2.46	0.059	-	0.033	12.170	1.562	8.021

[Note: S- Significant, NS- Non significant.]

Table 5. Effect of different level of NPK FYM and *Azospirillum* on physico-chemical properties of rice var. sarna (15 cm-30 cm)

Treatment	Bulk Density (Mg m^{-3})	Particle Density (Mg m^{-3})	Water holding capacity (%)	Pore Space (%)	EC (dS m^{-1})	pH (1:2.5)	OC (%)	Nitrogen (Kg ha^{-1})	P_2O_5 (Kg ha^{-1})	K_2O (Kg ha^{-1})
T_1	1.33	2.43	38.50	42.83	0.14	6.99	0.55	275.34	23.23	195.87
T_2	1.30	2.47	40.56	44.89	0.17	6.96	0.58	277.76	25.45	198.34
T_3	1.27	2.50	42.12	46.45	0.20	6.93	0.61	281.32	27.65	201.68
T_4	1.32	2.44	39.20	43.53	0.15	6.98	0.56	279.15	23.89	196.43
T_5	1.29	2.47	41.02	45.35	0.18	6.95	0.59	283.67	25.78	199.11
T_6	1.26	2.50	42.35	46.68	0.21	6.92	0.62	287.45	28.31	202.32
T_7	1.31	2.46	39.68	44.01	0.16	6.97	0.57	285.87	24.43	197.56
T_8	1.25	2.52	43.22	47.55	0.22	6.91	0.63	291.76	29.27	203.23
T_9	1.28	2.49	41.54	45.87	0.19	6.94	0.60	288.09	26.65	200.79
F- test	**NS**	**NS**	**S**	**S**	**S**	**NS**	**S**	**S**	**S**	**S**
S. Em. (±)	-	-	0.54	0.66	0.006	-	0.009	3.609	0.477	2.971
C.D. @ 5	-	-	1.62	1.98	0.017	-	0.027	10.820	1.431	8.906

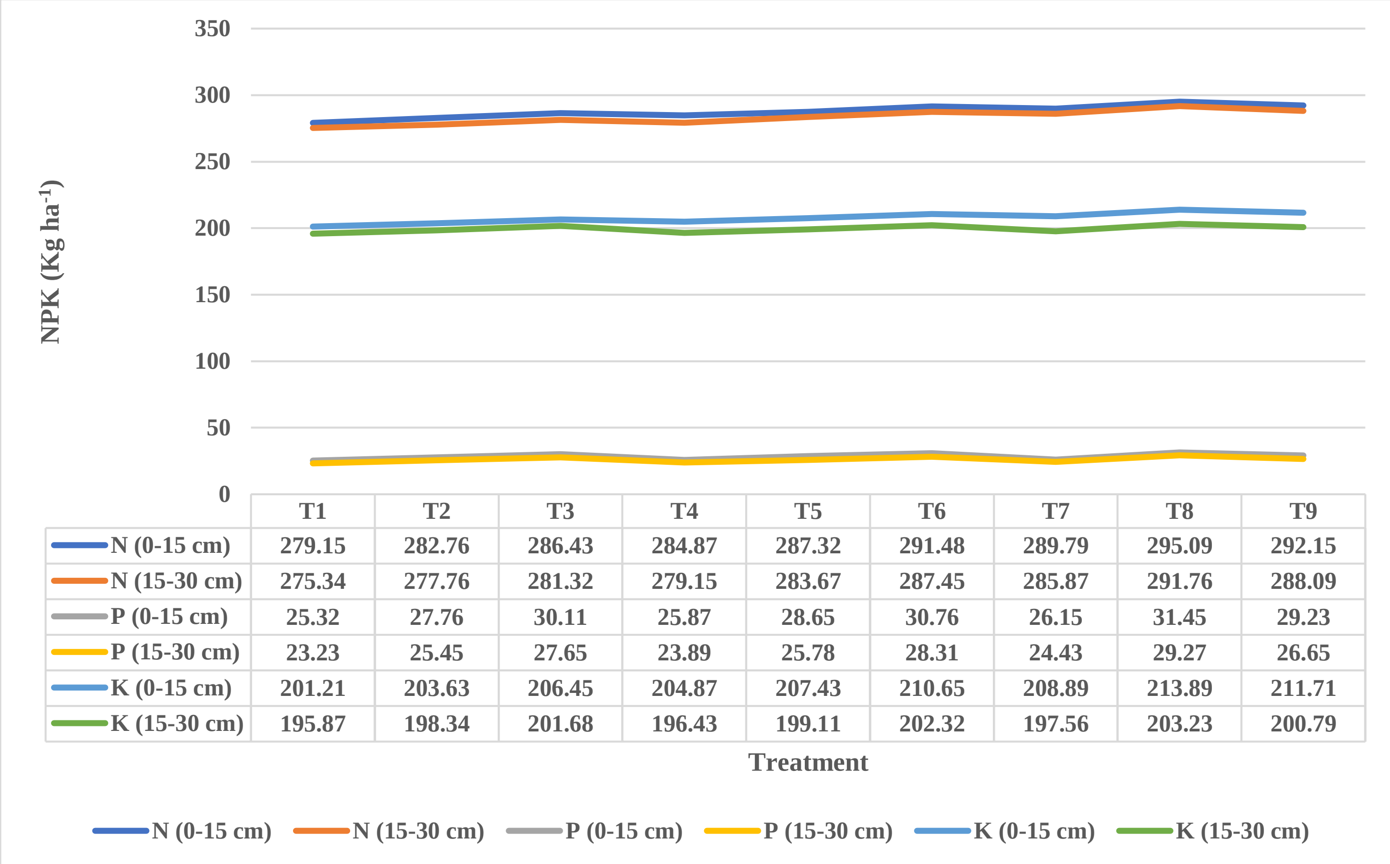
[Note: S- Significant, NS- Non significant.]

Table 6. Effect of different level of NPK FYM and *Azospirillum* on Growth and yield parameter of Rice

Treatment	Plant height (cm)	Number of Leaves plant^{-1}	Length of Panicle (cm)	Grain yield (q ha^{-1})	Straw yield (q ha^{-1})	Test weight (g)
T_1	85.50	8.66	18.35	32.25	51.67	19.35
T_2	86.70	8.98	18.87	34.12	53.14	21.21
T_3	88.42	9.58	19.76	37.54	55.49	23.15
T_4	87.82	9.20	16.90	36.09	54.31	20.07
T_5	89.24	9.67	20.17	38.51	56.84	21.97
T_6	90.38	10.08	21.23	41.71	59.67	23.87
T_7	89.72	9.84	20.57	40.07	57.25	20.87
T_8	91.50	10.68	22.13	44.86	63.88	24.33
T_9	91.22	10.26	21.59	42.28	60.85	22.37
F- test	**S**	**S**	**S**	**S**	**S**	**S**
S. Em. (±)	1.08	0.16	0.94	0.474	0.816	0.22
C.D. (P= 0.05)	3.25	0.48	2.81	1.422	2.446	0.67

Table 7. Cost benefit ratio of rice var. Sarna

Treatment	Grain Yield (q ha^{-1})	Straw Yield (q ha^{-1})	Grain (₹) Q ha^{-1} yield	Straw (₹) Q ha^{1} yield	Total Gross return ha^{-1} (₹)	Total cost of cultivation ha^{-1} (₹)	Net profit ha^{-1} (₹)	Cost benefit ratio (C:B)
T1	32.25	51.67	80,625	59,420.5	1,40,045.5	49,980	90,066	1:2.80
T2	34.12	53.14	85,300	61,111.0	1,46,411.0	53,239	93,172	1:2.75
T3	37.54	55.49	93,850	63,813.5	1,57,663.5	56,239	1,01,425	1:2.80
T4	36.09	54.31	90,225	62,456.5	1,52,681.5	51,182	1,01,500	1:2.98
T5	38.51	56.84	96,275	65,366.0	1,61,641.0	54,182	1,07,459	1:2.98
T6	41.71	59.67	1,04,275	68,620.5	1,72,895.5	57,182	1,15,714	1:3.02
T7	40.07	57.25	1,00,175	65,837.5	1,66,012.5	52,124	1,13,889	1:3.18
T8	44.86	63.88	1,12,150	73,462.0	1,85,612.0	58,124	1,27,488	1:3.19
T9	42.28	60.18	1,05,700	69,207.0	1,74,907.0	55,124	1,19,783	1:3.17



	T1	T2	T3	T4	T5	T6	T7	T8	T9
N (0-15 cm)	279.15	282.76	286.43	284.87	287.32	291.48	289.79	295.09	292.15
N (15-30 cm)	275.34	277.76	281.32	279.15	283.67	287.45	285.87	291.76	288.09
P (0-15 cm)	25.32	27.76	30.11	25.87	28.65	30.76	26.15	31.45	29.23
P (15-30 cm)	23.23	25.45	27.65	23.89	25.78	28.31	24.43	29.27	26.65
K (0-15 cm)	201.21	203.63	206.45	204.87	207.43	210.65	208.89	213.89	211.71
K (15-30 cm)	195.87	198.34	201.68	196.43	199.11	202.32	197.56	203.23	200.79

Fig. 1. Response of NPK, FYM AND *Azospirillum* on NPK of Soil (0-15 cm and 15-30 cm)

The Av. Nitrogen (kg ha^{-1}) in soil increased significantly with the increase in levels of NPK fertilizers and FYM. The maximum Av. Nitrogen (kg ha^{-1}) of soil at were found in treatment T_8 (NPK @ 100% + FYM 6 t ha^{-1} + *Azospirillum* @ 1 kg ha^{-1}) with depth 0-15 cm and 15-30 cm which was 295.09 kg ha^{-1} and 291.76 kg ha^{-1} respectively, while the minimum values of the result were found in treatment T_1 (Absolute Control) with depth 0-15 cm and 15-30 cm which was 279.15 kg ha^{-1} and 275.34 kg ha^{-1} respectively. Similar findings were recorded. The Av. Phosphorus (kg ha^{-1}) in soil increased significantly with the increase in levels of NPK fertilizers and FYM. The maximum Av. Phosphorus (kg ha^{-1}) of soil at were found in treatment T_8 (NPK @ 100% + FYM 6 t ha^{-1} + *Azospirillum* @ 1 kg ha^{-1}) with depth 0-15 cm and 15-30 cm which was 31.45 kg ha^{-1} and 29.27 kg ha^{-1} respectively, while the minimum values of the result were found in treatment T_1 (Absolute Control) with depth 0-15 cm and 15-30 cm which was 25.32 kg ha^{-1} and 23.23 kg ha^{-1} respectively. Similar findings were recorded. The Av. Potassium (kg ha^{-1}) in soil increased significantly with the increase in levels of NPK fertilizers and FYM. The maximum Av. Potassium (kg ha^{-1}) of soil at were found in treatment T_8 (NPK @ 100% + FYM 6 t ha^{-1} + *Azospirillum* @ 1 kg ha^{-1}) with depth 0-15 cm and 15-30 cm which was 213.89 kg ha^{-1} and 203.23 kg ha^{-1} respectively while the minimum values of the result were found in treatment T_1 (Absolute Control) with depth 0-15 cm and 15-30 cm which was 201.21 kg ha^{-1} and 195.87.31 kg ha^{-1} respectively. Legumes have potential to improve soil nutrients status through biological nitrogen fixation and incorporation of biomass in to the soil as green manure. Similar findings were recorded by Kumawat et al., [16], Neha [17], Yaduwanshi et al., [18], Rishikesh et al., [19], Tejaswini [20], Sahare et al., [21].

According to Table 4 plant height was exhibited maximum in T_8 (NPK @ 100% + FYM 6 t ha^{-1} + *Azospirillum* @ 1 kg ha^{-1}), 91.50 cm at crop harvesting (90 DAS) and found to be lowest in T_1 – [Absolute control] 29.70 cm at crop harvesting (90 DAS) [22-25]. As depicted in Table 4 number of leaves plant^{-1} was exhibited maximum in T_8 (NPK @ 100% + FYM 6 t ha^{-1} + *Azospirillum* @ 1 kg ha^{-1}), 15.2, 39.4 and 44.2 at 30, 60 and 90 DAS respectively and found to be lowest in T_1 – [Absolute control] 8.2, 31.2 and 36.4 at 30, 60 and 90 DAS respectively. Among all applied treatments, length of panicle was exhibited maximum in T_8 (NPK @ 100% + FYM 6 t ha^{-1} + *Azospirillum* @ 1 kg ha^{-1}), 15.2, 39.4 and 44.2 at 30, 60 and 90 DAS respectively and found to be lowest in T_1 – [Absolute control] 8.2, 31.2 and 36.4 at 30, 60 and 90 DAS respectively [26-28]. Among all applied treatments, Seed yield (kg ha^{-1}) was exhibited maximum in T_8 (NPK @ 100% + FYM 6 t ha^{-1} + *Azospirillum* @ 1 kg ha^{-1}), 5331.11 and found to be lowest in T_1 – [Absolute control], 1580.00. Stalk yield was exhibited maximum in T_8 (NPK @ 100% + FYM 6 t ha^{-1} + *Azospirillum* @ 1 kg ha^{-1}), 6983.13 Kg ha^{-1} and found to be lowest in T_1 – [Absolute control] 1983.33 Kg ha^{-1}, Similar results were also reported by Kumawat et al., (2023), Neha [17], Yaduwanshi et al., [18], Rishikesh et al., [19], Tejaswini [20], Sahare et al., [21].

4. CONCLUSION

It revealed from the trial that percentage pore space (%) was found to be significant, water holding capacity(%) electrical conductivity (dS m^{-1}), organic carbon (%), Av, Nitrogen (kg ha^{-1}), Phosphorus (kg ha^{-1}) and Potassium (kg ha^{-1}) in T_8 [NPK @ 100% + FYM 6 t ha^{-1} + *Azospirillum* @ 1 kg ha^{-1}] was found most effective in improving physico-chemical properties of soil followed by T_6-[NPK @ 50% + FYM 12 t ha^{-1} + *Azospirillum* @ 1 kg ha^{-1}]. Similarly, the maximum plant height (cm), number of leaves, panicle length (cm), grain yield (q ha^{-1}), straw yield (q ha^{-1}) and test weight (g) were found in treatment T_8-[NPK @ 100% + FYM 6 t ha^{-1} + *Azospirillum* @ 1 kg ha^{-1}] followed by T_9-[NPK @ 100% + FYM 12 t ha^{-1} + *Azospirillum* @ 1 kg ha^{-1}]. It is also recorded that treatment T_8-[NPK @ 100% + FYM 6 t ha^{-1} + *Azospirillum* @ 1 kg ha^{-1}] gave maximum gross return of ₹ 1,85,612.00 ha^{-1}, net return of ₹ 1,27,488.00 ha^{-1} with cost benefit ratio 1:3.19 followed by T_9 that gave gross return of ₹ 1,74,907, net return of ₹ 1,19,783 with cost benefit ratio 1:3.17. The treatment combination T_8-[NPK @ 100% + FYM 6 t ha^{-1} + *Azospirillum* @ 1 kg ha^{-1}] can be taken for better income of the farmers of Prayagraj region, (U.P.), to increase income and sustainable agriculture.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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