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Study the Effect of Integrated Nutrient Management with Bio-inoculants on Yield Attributes and Yields of Rice (*Oryza sativa* L.)

Abhishek Singh Yadav [a*], Sanjeev Sharma [a++], Anurag Dhankar [a], Mahendru Kumar Gautam [a], Veerendra Singh [a], Shubham Pandey [a], Krishna Kumar Patel [a] and Kapil Kumar Yadav [a]

[a] Department of Soil Science & Agriculture Chemistry, College of Agriculture, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur- 208002, India.

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

The experiments were conducted during the kharif season of 2021-22 and 2022-23 at the S.I.F, Chandra Shekhar Azad University of Agriculture & Technology, Kanpur. The experiment consists of 18 treatment combinations in randomized block design with three replications of different combinations of inorganic fertilizer, organic and bio-inoculants in rice. Based on results emanated

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[++] Assistant Professor;
**Corresponding author: E-mail: Singhyadava555@gmail.com;*

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from the investigation it can be concluded that among the productivity parameters viz: The statistically maximum grain yield (q ha^{-1}), straw yield (q ha^{-1}) and biological yield (q ha^{-1}) were found (47.38, 47.56 q ha^{-1}), (66.82, 67.22q ha^{-1}) and (114.20, 114.78 q ha^{-1}) in 2021-22 and 2022-23 respectively in the treatments recorded in the treatment T_{17} - 100% NPK+ 5 ton ha^{-1} FYM + Azolla (300 kg ha^{-1}) + S (30 kg ha^{-1}) + Zinc (5 kg ha^{-1}) during both years of experimentation and the plant growth traits viz: panicle length (28.93cm), panicle weight (g) (5.86g) number of grain panicle^{-1} (127) grains weight panicle^{-1} (4.11) and test weight (g) (24.97g) were recorded statistically maximum with the treatment T_{17} -100% NPK+ 5 ton ha^{-1} FYM + Azolla (300 kg ha^{-1}) + S (30 kg ha^{-1}) + Zinc (5 kg ha^{-1}) during the experimentation.

Keywords: Rice; Integrated nutrient management; organic manure; inorganic fertilizer; bio-inoculants; yield attributes.

1. INTRODUCTION

Rice (*Oryza sativa* L.) is the second most significant staple food for over half of the global population, supplying essential carbohydrates, proteins, and vitamins, and serving as a vital source of nutrients due to its daily consumption [1]. Nutrient supply is the most limiting factor next to the water for crop production. Maintaining rice production has become increasingly challenging, especially in regions where rice yields are declining despite adherence to recommended nutrient management practices. Integrating organic nutrient sources with inorganic fertilizers may play a crucial role in enhancing and sustaining rice productivity [2]. As the available land area continues to decrease over time, the intensified use of land, combined with insufficient and imbalanced application of chemical fertilizers and minimal or no use of organic manure, has led to a significant decline in soil fertility. This deterioration has resulted in stagnating or even declining crop productivity [3]. The integrated use of inorganic fertilizers, bio-fertilizers, and farmyard manure appears to be a viable solution to the current issue of unsustainable agriculture. Farmyard manure is a readily available, cost-effective, and time-tested nutrient source for crops, traditionally utilized by farmers. In addition to providing essential macro and micronutrients, it enhances the physical, chemical, and biological properties of the soil. The use of farmyard manure also boosts the effectiveness of bio-inoculants, supplies essential nutrients, improves soil health, and supports sustained yield improvement [4]. Biofertilizers and organic sources are cost-effective, environmentally friendly, and provide a sustained supply of both macro and micronutrients to crops over an extended period. Farmyard manure functions as a soil conditioner, enhancing the physical, chemical, and biological properties of the soil, thereby creating favourable conditions for the growth of microbial populations. This leads to vigorous root development, improved nutrient uptake, and ultimately better yield and grain quality [5]. Nitrogen is the most essential nutrient, and different organic and inorganic nitrogen sources have a significant impact and play a vital role in determining the quality of rice grains [6,7]. In light of the aforementioned factors, an investigation was carried out in the of eastern Uttar Pradesh. The study evaluated the response of rice varieties to integrated nutrient management to determine if equivalent productivity could be achieved compared to the exclusive use of inorganic sources. The objective of this study was to assess the effects of integrated nutrient management on the yield potential and quality of rice varieties in growing areas.

2. MATERIALS AND METHODS

2.1 Experimental Details

The present field experiment was laid out at Student Instructional Farm, Nawabganj, C. S. Azad University of Agriculture & Technology, Kanpur (25.26˚ and 26.58˚ north latitude and 79.31° and 80.34° east longitude. It is situated at an elevation of 124 meters above the mean sea level in the alluvial belt of Gangetic plains of central Uttar Pradesh.) during the cropping period (2021-2022 and 2022-23) respectively. The soil of the experimental site is presented in Table 1 and prior to experimental crops, composite soil samples were drawn randomly (0-15 cm) depth from 10 places, dried and passed through 2.0 mm sieve and subjected to chemical analyses. the treatments details were laid down in Table 2 the treatments were laid out in a Randomized Block Design and replicated thrice with the variety PB-1509 of rice. The recommended dose of fertilizers (RDF) applied was 100 kg N ha^{-1}, 50 kg P_2O_5 ha^{-1}, and 40 kg K_2O ha^{-1}. Farmyard manure (FYM) containing

Table 1. Physico-chemical characteristics of the experimental field

Ph (1:2.5)	7.9
EC (dSm^{-1})	0.3
Organic carbon (g kg^{-1})	4.5
Available N (kg ha^{-1})	210
Available P (kg ha^{-1})	12.8
Available K (kg ha^{-1})	198
Available DTPA Zn (kg ha^{-1})	0.55

Table 2. Details of treatments

Symbol	Treatment combination
T_1	Control
T_2	100% NPK
T_3	50% NPK + 5 ton ha^{-1} FYM
T_4	75% NPK + 5 ton ha^{-1} FYM
T_5	100% NPK + 5 ton ha^{-1} FYM
T_6	50%NPK + 5 ton ha^{-1} FYM + Azolla (300 kg ha^{-1})
T_7	75% NPK + 5 ton ha^{-1} FYM + Azolla (300 kg ha^{-1})
T_8	100% NPK + 5 ton ha^{-1} FYM + Azolla (300 kg ha^{-1})
T_9	50% NPK + 5 ton ha^{-1} FYM + Azolla (300 kg ha^{-1}) + Sulfur (30 kg ha^{-1})
T_{10}	75 % NPK + 5 ton ha^{-1} FYM + Azolla (300 kg ha^{-1}) + Sulfur (30 kg ha^{-1})
T_{11}	100 % NPK + 5 ton ha^{-1} FYM + Azolla (300 kg ha^{-1}) + Sulfur (30 kg ha^{-1})
T_{12}	50% NPK+ 5 ton ha^{-1} FYM + Azolla (300 kg ha^{-1}) + Zinc (5 kg ha^{-1})
T_{13}	75% NPK+ 5 ton ha^{-1} FYM + Azolla (300 kg ha^{-1}) + Zinc (5 kg ha^{-1})
T_{14}	100% NPK+ 5 ton ha^{-1} FYM + Azolla (300 kg ha^{-1}) + Zinc (5 kg ha^{-1})
T_{15}	50% NPK+ 5 ton ha^{-1} FYM + Azolla (300 kg ha^{-1}) + Sulfur (30 kg ha^{-1}) + Zinc (5 kg ha^{-1})
T_{16}	75% NPK+ 5 ton ha^{-1} FYM + Azolla (300 kg ha^{-1}) + Sulfur (30 kg ha^{-1}) + Zinc (5 kg ha^{-1})
T_{17}	100% NPK+ 5 ton ha^{-1} FYM + Azolla (300 kg ha^{-1}) + Sulfur (30 kg ha^{-1}) + Zinc (5 kg ha^{-1})
T_{18}	5 ton ha^{-1} FYM + Azolla (300 kg ha^{-1}) + Sulfur (30 kg ha^{-1}) + Zinc (5 kg ha^{-1})

0.51% N was used to supply 25% (6 t ha^{-1}) and 50% (12 t ha^{-1}) of the recommended nitrogen dose (RDN), applied three days before transplanting. The recommended nitrogen dose was provided through inorganic fertilizer and farmyard manure (FYM). Half of the nitrogen, along with the total amounts of phosphorus and potassium, was applied at the time of transplanting. The remaining half of the nitrogen was top-dressed in two equal splits during the active tillering and panicle initiation stages. all treatments were applied to their designated plots according to the scheduled plan. The fertilizer sources used were urea (46% N), diammonium phosphate (18% N, 46% P_2O_5), and muriate of potash (60% K_2O). Analysis of variance (ANOVA) was conducted following the procedures outlined for the Randomized Block Design (Gomez & Gomez, 1984), using the SPSS software package (version 23.0; IBM Corp.; Armonk, NY, USA). All graphs were generated in Excel, and mean values were reported with the standard error of the means.

3. RESULTS AND DISCUSSION

3.1 Plant Growth Traits

The data in Table 3 demonstrate that, among the yield attribute parameters, panicle length (cm), the number of grains per panicle, grain weight (g) per panicle, and test weight (g) significantly increased as a result of the application of NPK, zinc, sulfur, FYM, and Azolla. A significant increase in these parameters was observed due to the application of nitrogen, zinc, sulfur, FYM, and Azolla. Additionally, growth parameters showed a consistent increase over time. panicle length varied from (19.66 to 28.00cm) in 2021-22 and (20.33 to 28.93cm) in 2022-23, and panicle weight (g) varied from (2.13 to 5.16g) in 2021-22 and (2.16 to 5.86g) in 2022-23, number of grains/$panicle^{-1}$ varied from (56 to 124) in 2021-22 and (59 to 127) in 2022-23, grains weight/ panicle varied from (1.10 to 3.15) in 2021-22 and (1.15 to 4.11)in 2022-23 and test weight (g) varies from (20.15 to 24.63) in 2021-22 and (20.24 to 24.97) in 2022-23. Maximum panicle length (28.93cm), the maximum Panicle weight

(g) (5.86g) and the maximum number of grains/panicle^{-1} (127) and maximum Grains weight/ panicle (4.11) additionally maximum Test weight (g) (24.97g) was associated with the treatment T_{17} -100% NPK+ 5 ton ha^{-1} FYM + Azolla (300 kg ha^{-1}) + S (30 kg ha^{-1}) + Zinc (5 kg ha^{-1}) during the second year (2022-23) of experimentation. The minimum Panicle length (19.66 cm), the minimum panicle weight (g) (2.13 g), the minimum number of grains/panicle^{-1} (56) and the minimum grains weight/ panicle (1.10) additionally minimum test weight (g) (20.15 g) was associated with the treatment T_1 [control] during the first year (2021-22) of experimentation, its also reported by Razavipour et al. [8]. An increase in nitrogen dose within a certain range resulted in improvements in LAI, plant height, the number of tillers, net photosynthetic rate, transpiration rate, and grain yield. Furthermore, nitrogen treatment significantly enhanced the grain length and width of head rice, while ear length was not significantly affected. Zinc application significantly increased the number of tillers, panicles, plant height, 1000-grain weight, percentage of filled grains, and grain yield in rice. Among the various zinc application methods, soil application of $ZnSO_4.H_2O$ resulted in the highest increase in total nitrogen percentage, total potassium percentage, and available zinc content in both grain and straw. However, the total phosphorus percentage decreased significantly. Zinc content in the soil after harvesting was also significantly influenced by zinc application. Organic materials, such as FYM, and their continuous use have a strong impact on soil productivity and nitrogen dynamics within the soil–plant system. The application of Azolla compost, based on soil weight, resulted in the highest grain yield. This increase in grain yield may be attributed to the efficient absorption of nitrogen and other nutrients facilitated by Azolla, which enhanced the production and translocation of assimilates from source to sink. Overall, Azolla compost can be considered a beneficial management practice in rice production, especially under water-deficit conditions. The consequences of the current investigation are additionally in concurrence with the investigation of Zhang, et al. [9] and Ghoneim, [10].

3.2 Productivity Parameters

The data presented in Table 3 and Fig. 1 indicate that, among the yield attributes parameters: straw yield (q ha^{-1}) and biological yield (q ha-1) significantly increase due to the application of NPK, zinc, sulphur, FYM, azolla. Grain yield varied from 22.16 to 47,38 qha^{-1} in 2021-22 and 22.56 to 47.56 q ha^{-1} in 2022-23, straw yield varied from 36.12 to 66.82 q ha^{-1}in 2021-2022 and 36.24 to 67.22 q ha^{-1}in 2022-23 and biological yield varied from 58.28 to 114.20q ha^{-1}in 2021-22 and 58.80 to 114.78 ha^{-1} in 2022-23. The maximum grain yield (47.38 q ha^{-1}) in 2021-22 and (47.56q ha^{-1}) in 2022-23, straw yield (66.82q ha^{-1}) in 2021-22 and (67.22 ha^{-1}) in 2022-23 and biological yield (114.20q ha^{-1}) in 2021-2022 and (114.78q ha^{-1}) in 2022-23 were recorded in the treatment T_{17} - 100% NPK+ 5 ton ha^{-1} FYM + Azolla (300 kg ha^{-1}) + S (30 kg ha^{-1}) + Zinc (5 kg ha^{-1}) during the second year (2022-23) of experimentation. The minimum grain yield (22.16 q ha^{-1}) in 2021-22 and (22.56 q ha-^{1}) in 2022-23, straw yield (36.12qha^{-1}) in 2021-22 and (36.24 q ha^{-1}) in 2022-23 and biological yield (58.28q ha^{-1}) in 2021-22 and (58.80 q ha^{-1}) in 2022-23 was recorded in the treatment T_1 [control]. during the first year (2021-22) of experimentation also reported by Marzouk, et al. [11] The increase in seed and stover yields under adequate nutrient supply can largely be attributed to the combined effects of a higher number of spikelets per ear, grains per ear, and 100-grain weight (in grams). This improvement is a result of enhanced translocation of photosynthates from the source to the sink, leading to an overall increase in yield. The rise in productivity with sufficient nutrient supply is primarily due to the enhancement of yield attributes, which ultimately results in a greater grain yield. Additionally, the application of farmyard manure (FYM) significantly increased the grain, straw, and biological yields of Rice compared to the controls. The application of Azolla significantly increased both grain and straw yields of rice compared to conditions without Azolla. Furthermore, inoculating Azolla led to a further significant increase in both grain and straw yields. This enhancement is likely due to the bio-inoculant's ability to fix atmospheric nitrogen, thereby improving the supply of other nutrients to the plants and ultimately boosting both grain and straw yields of rice. These results also confirm the findings of Razavipour, et al. [8]. The integrated nutrient application did not significantly affect the harvest index. The harvest index ranged from 37.42% to 41.49% in 2021-22 and from 36.76% to 41.44% in 2022-23.

Table 3. Effect of organic manure, inorganic fertilizer and bio-inoculants on grain yield, straw yield, total biological yield and harvest index of rice during 2021-22 and 2022-23

Treatments		Yield Studies							
		Pooled				Pooled			
		Grain yield (q ha^{-1})	Straw yield (q ha^{-1})	Biological yield (q ha^{-1})	Harvest Index (%)	Grain yield (q ha^{-1})	Straw yield (q ha^{-1})	Biological yield (q ha^{-1})	Harvest Index (%)
T_1	Control	22.16	36.12	58.28	37.42	22.56	36.24	58.80	36.76
T_2	100% NPK	23.82	38.47	62.29	37.88	24.12	38.00	62.12	38.37
T_3	50% NPK + 5 ton ha^{-1} FYM	25.42	42.51	67.93	38.02	24.50	42.15	66.65	38.43
T_4	75% NPK + 5 ton ha^{-1} FYM	27.80	43.98	71.78	38.24	28.80	44.00	72.80	38.64
T_5	100% NPK + 5 ton ha^{-1} FYM	30.12	47.09	77.21	38.59	31.12	47.00	78.12	38.83
T_6	50%NPK + 5 ton ha^{-1} FYM + Azolla (300 kg ha^{-1})	32.44	50.17	82.61	38.73	32.42	50.00	82.42	39.04
T_7	75% NPK + 5 ton ha^{-1} FYM + Azolla (300 kg ha^{-1})	40.18	61.90	101.68	39.52	40.81	62.30	103.01	39.84
T_8	100% NPK + 5 t ha^{-1} FYM + Azolla (300 kg ha^{-1})	44.52	64.22	108.74	40.94	44.47	64.68	109.15	40.74
T_9	50% NPK + 5 t ha^{-1} FYM + Azolla (300 kg ha^{-1}) + S (30 kg ha^{-1})	35.19	57.71	92.90	38.90	35.90	57.00	92.90	39.34
T_{10}	75 % NPK + 5 t ha^{-1} FYM + Azolla (300 kg ha^{-1}) + S(30 kg ha^{-1})	42.79	62.78	105.57	40.53	42.88	62.98	105.86	40.41
T_{11}	100 % NPK + 5 t ha^{-1} FYM + Azolla (300 kg ha^{-1}) + S (30 kg ha^{-1})	45.92	65.00	110.92	41.28	45.27	65.00	110.27	40.83
T_{12}	50% NPK+ 5 ton ha^{-1} FYM + Azolla (300 kg ha^{-1}) + Zn (5 kg ha^{-1})	38.30	60.16	98.46	39.01	38.08	61.00	99.08	39.56
T_{13}	75% NPK+ 5 ton ha^{-1} FYM + Azolla (300 kg ha^{-1}) + Zn (5 kg ha^{-1})	43.28	63.00	106.28	40.61	43.00	63.42	106.42	40.51
T_{14}	100% NPK+ 5 ton ha^{-1} FYM + Azolla (300 kg ha^{-1}) + Zn (5 kg ha^{-1})	43.25	65.78	112.03	41.40	46.00	66.65	112.65	41.05
T_{15}	50% NPK+ 5 t ha^{-1} FYM + Azolla (300 kg ha^{-1}) + S (30 kg ha^{-1}) + Zinc (5 kg ha^{-1})	38.90	61.50	100.80	39.27	39.90	62.20	102.20	39.62
T_{16}	75% NPK+ 5 t ha^{-1} FYM + Azolla (300 kg ha^{-1}) + S (30 kg ha^{-1}) + Zinc (5 kg ha^{-1})	43.68	63.89	107.57	40.72	43.68	64.00	107.68	40.56
T_{17}	100% NPK+ 5 ton ha^{-1} FYM + Azolla (300 kg ha^{-1}) + S (30 kg ha^{-1}) + Zinc (5 kg ha^{-1})	47.38	66.82	114.20	41.49	47.56	67.22	114.78	41.44
T_{18}	5 t ha^{-1} FYM + Azolla (300 kg ha^{-1}) + S (30 kg ha^{-1}) + Zn (5 kg ha^{-1})	22.38	36.82	59.20	37.80	22.88	37.28	60.16	38.03
CD		4.99	6.69	11.49	1.37	4.98	6.70	11.51	1.29
SEm (±)		1.73	2.38	3.98	0.47	1.72	2.32	3.98	0.44

Table 4. Effect of Organic manure, Inorganic fertilizer and Bio-inoculants on panicle length, panicle weight, number of grains panicle^{-1}, grains weight/panicle and test weight of rice during 2021-22 and 2022-23

Treatments		Yield attributes									
		Pooled					Pooled				
		Panicle length (cm)	Panicle weight (g)	Number of grains panicle^{-1}	Grains weight/ panicle	Test weight (g)	Panicle length (cm)	Panicle weight (g)	Number of grains panicle^{-1}	Grains weight/ panicle	Test weight (g)
T$_1$	Control	19.66	2.13	56	1.10	20.15	20.33	2.16	59	1.15	20.24
T$_2$	100% NPK	22.80	3.30	85	2.20	21.46	22.92	3.60	86	2.28	21.82
T$_3$	50% NPK + 5 ton ha^{-1} FYM	23.10	3.40	87	2.22	21.62	23.31	3.68	87	2.36	2198
T$_4$	75% NPK + 5 ton ha^{-1} FYM	23.50	3.50	89	2.22	21.91	23.62	3.70	90	2.41	22.32
T$_5$	100% NPK + 5 ton ha^{-1} FYM	24.00	3.61	92	2.31	22.12	24.52	3.81	92	2.52	22.46
T$_6$	50%NPK + 5 ton ha^{-1} FYM + Azolla (300 kg ha^{-1})	24.80	3.70	93	2.31	22.26	24.92	3.90	93	2.68	22.58
T$_7$	75% NPK + 5 ton ha^{-1} FYM + Azolla (300 kg ha^{-1})	25.50	4.11	103	2.58	23.18	25.50	4.40	105	2.91	23.38
T$_8$	100% NPK + 5 t ha^{-1} FYM + Azolla (300 kg ha^{-1})	26.00	4.52	118	2.79	23.88	26.12	4.98	118	3.58	23.72
T$_9$	50% NPK + 5 t ha^{-1} FYM + Azolla (300 kg ha^{-1}) + S (30 kg ha^{-1})	24.80	3.80	95	2.32	22.52	25.00	4.12	96	2.75	22.92
T$_{10}$	75 % NPK + 5 t ha^{-1} FYM + Azolla (300 kg ha^{-1}) + S(30 kg ha^{-1})	25.50	4.15	109	2.59	23.20	25.72	4.68	108	2.98	23.49
T$_{11}$	100 % NPK + 5 t ha^{-1} FYM + Azolla (300 kg ha^{-1}) + S (30 kg ha^{-1})	26.50	4.72	120	2.83	23.97	26.50	5.20	119	3.74	23.94
T$_{12}$	50% NPK+ 5 ton ha^{-1} FYM + Azolla (300 kg ha^{-1}) + Zn (5 kg ha^{-1})	25.00	3.90	100	2.41	22.74	25.21	4.12	100	2.82	23.12
T$_{13}$	75% NPK+ 5 ton ha^{-1} FYM + Azolla (300 kg ha^{-1}) + Zn (5 kg ha^{-1})	25.60	4.20	111	2.74	23.45	25.96	4.72	112	3.12	23.51
T$_{14}$	100% NPK+ 5 ton ha^{-1} FYM + Azolla (300 kg ha^{-1}) + Zn (5 kg ha^{-1})	27.00	4.73	121	2.98	24.12	28.00	5.72	121	3.98	23.97
T$_{15}$	50% NPK+ 5 t ha^{-1} FYM + Azolla (300 kg ha^{-1}) + S (30 kg ha^{-1}) + Zinc (5 kg ha^{-1})	25.00	4.01	102	2.45	22.94	25.50	4.28	103	2.90	23.21
sT$_{16}$	75% NPK+ 5 t ha^{-1} FYM + Azolla (300 kg ha^{-1}) + S (30 kg ha^{-1}) + Zinc (5 kg ha^{-1})	25.80	4.23	115	2.76	23.74	26.00	4.92	116	3.31	23.62
T$_{17}$	100% NPK+ 5 ton ha^{-1} FYM + Azolla (300 kg ha^{-1}) + S (30 kg ha^{-1}) + Zinc (5 kg ha^{-1})	28.00	5.16	124	3.15	24.63	28.93	5.86	127	4.11	24.97
T$_{18}$	5 t ha^{-1} FYM + Azolla (300 kg ha^{-1}) + S (30 kg ha^{-1}) + Zn (5 kg ha^{-1})	22.00	3.28	83	1.95	21.00	22.00	3.58	84	1.96	21.20
CD		NS	0.68	17.36	0.34	3.26	NS	0.66	18	0.45	3.33
SEm (±)		1.44	0.23	5.84	0.11	1.10	1.43	0.22	5.9	0.15	1.12
CV		10.13	5.65	5.61	4.62	4.65	9.90	5.03	5.67	5.11	4.72

Table 5. Effect of organic manure, inorganic fertilizer and bio-inoculants on physical properties in soil after harvest of rice during 2021-22 and 2022-23

Treatments		Economics							
		Pooled				Pooled			
		Total Cost	Gross Return	Net Return	B:C Ratio	Total Cost	Gross Return	Net Return	B:C Ratio
T_1	Control	36306	48818	12512	1.34	36681	50460	13779	1.38
T_2	100% NPK	42269	52440	10171	1.24	42644	53867	11223	1.26
T_3	50% NPK + 5 ton ha^{-1} FYM	46788	56108	9320	1.20	47163	55107	7944	1.17
T_4	75% NPK + 5 ton ha^{-1} FYM	48278	61110	12832	1.27	48653	64168	15515	1.32
T_5	100% NPK + 5 ton ha^{-1} FYM	49769	66154	16385	1.33	50144	69277	19133	1.38
T_6	50%NPK + 5 ton ha^{-1} FYM + Azolla (300 kg ha^{-1})	52261	77315	25054	1.48	52636	79152	26516	1.50
T_7	75% NPK + 5 ton ha^{-1} FYM + Azolla (300 kg ha^{-1})	53751	88157	34406	1.64	54126	90922	36796	1.68
T_8	100% NPK + 5 t ha^{-1} FYM + Azolla (300 kg ha^{-1})	55242	97243	42001	1.76	55617	98723	43106	1.78
T_9	50% NPK + 5 t ha^{-1} FYM + Azolla (300 kg ha^{-1}) + S (30 kg ha^{-1})	52801	77559	24758	1.47	53176	80224	27048	1.51
T_{10}	75 % NPK + 5 t ha^{-1} FYM + Azolla (300 kg ha^{-1}) + S(30 kg ha^{-1})	54291	93570	39279	1.72	54666	95261	40595	1.74
T_{11}	100 % NPK + 5 t ha^{-1} FYM + Azolla (300 kg ha^{-1}) + S (30 kg ha^{-1})	55782	100177	44395	1.80	56157	100406	44249	1.79
T_{12}	50% NPK+ 5 ton ha^{-1} FYM + Azolla (300 kg ha^{-1}) + Zinc (5 kg ha^{-1})	52636	84148	31512	1.60	53011	85155	32144	1.61
T_{13}	75% NPK+ 5 ton ha^{-1} FYM + Azolla (300 kg ha^{-1}) + Zinc (5 kg ha^{-1})	54126	94591	40465	1.75	54501	95556	41055	1.75
T_{14}	100% NPK+ 5 ton ha^{-1} FYM + Azolla (300 kg ha^{-1}) + Zn (5 kg ha^{-1})	55617	94808	39191	1.70	55992	102092	46100	1.82
T_{15}	50% NPK+ 5 t ha^{-1} FYM + Azolla (300 kg ha^{-1}) + Sulfur (30 kg ha^{-1}) + Zinc (5 kg ha^{-1})	53176	85506	32330	1.61	53551	89036	35485	1.66
T_{16}	75% NPK+ 5 t ha^{-1} FYM + Azolla (300 kg ha^{-1}) + Sulfur (30 kg ha^{-1}) + Zinc (5 kg ha^{-1})	54666	95496	40830	1.75	55041	97021	41980	1.76
T_{17}	100% NPK+ 5 ton ha^{-1} FYM + Azolla (300 kg ha^{-1}) + S (30 kg ha^{-1}) + Zinc (5 kg ha^{-1})	56157	103337	47180	1.84	56532	105368	48836	1.86
-T_{18}	5 t ha^{-1} FYM + Azolla (300 kg ha^{-1}) + S (30 kg ha^{-1}) + Zn (5 kg ha^{-1})	50194	51717	1523	1.03	50569	52607	2038	1.04
CD		**-**	**8585**	**8585**	**0.16**	**-**	**8961**	**8961**	**0.16**
SEm (±)		**-**	**2974**	**2974**	**0.06**	**-**	**3104**	**3104**	**0.05**
CV		**-**	**6.49**	**18.39**	**6.35**	**-**	**6.61**	**18.14**	**6.42**

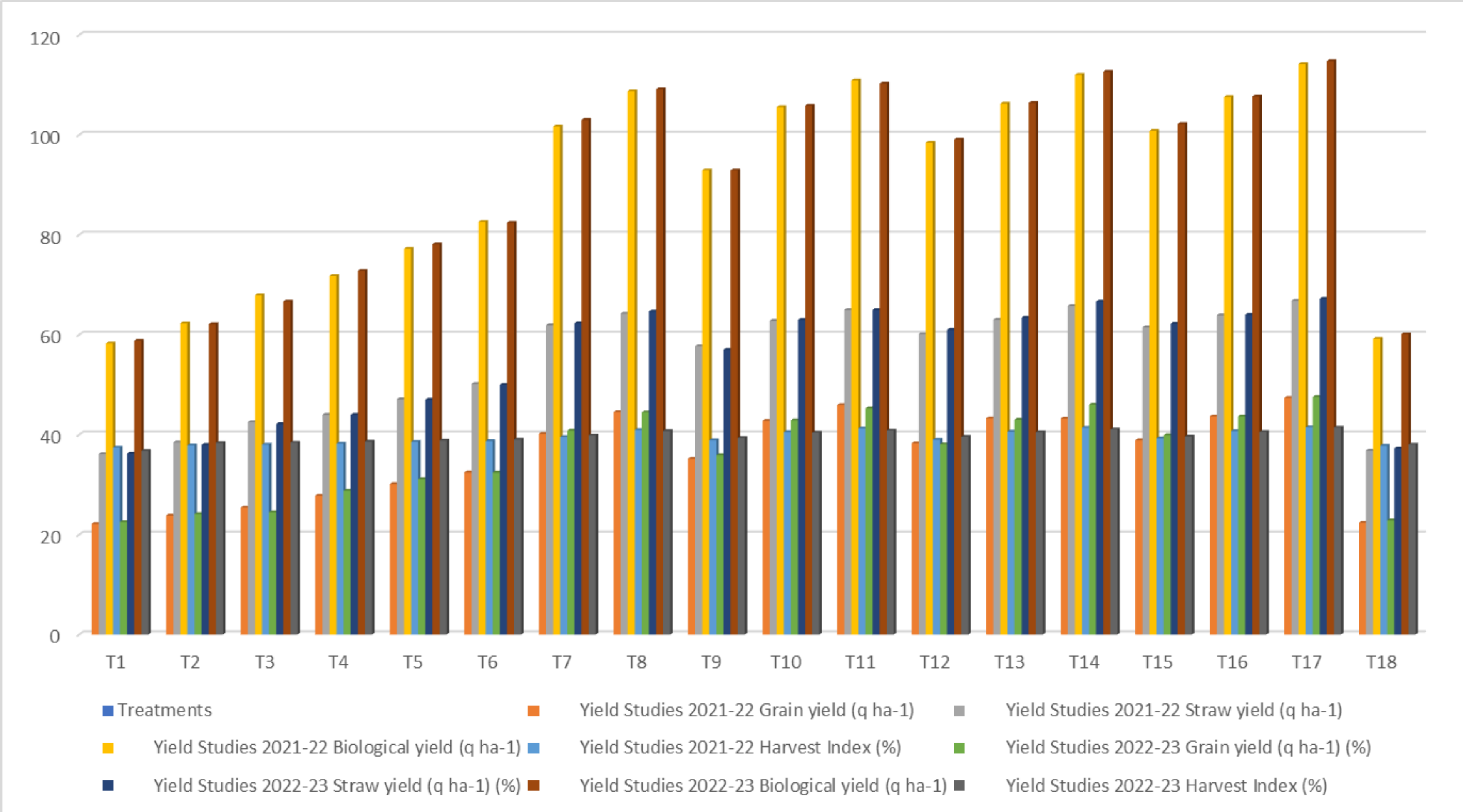

Fig. 1. Effect of organic manure, inorganic fertilizer and bio-inoculants on grain yield, straw yield, total biological yield and harvest index of rice during 2021-22 and 2022-23

4. CONCLUSION

Globally use of organic fertilizer is crucial in enhancing soil health, improving nutrient availability, and supporting sustainable agriculture worldwide. The current study revealed the advantages of nitrogen, Zinc, Sulphur, FYM, and Azolla with recommended doses of nitrogen phosphorous and potassium for achieving higher growth parameters and productivity by rice. Use nitrogen, Zinc, Sulphur, FYM, and Azolla yield attributes and rice yield. In conclusion, it can be concluded that the treatment T_{17} (100% NPK+ 5 ton ha^{-1} FYM + Azolla (300 kg ha^{-1}) + S (30 kg ha^{-1}) + Zinc (5 kg ha^{-1}) is the best option for grain yield and economy of rice crop.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

The author(s) hereby declare that no generative AI technologies, including but not limited to Large Language Models such as ChatGPT, Copilot, or similar, were used in the conceptualization, drafting, or editing of this work. All content has been produced solely through human effort and intellectual input.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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