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RESEARCH ARTICLE

PERFORMANCE EVALUATION OF SPRING RICE (ORYZA SATIVA L.) UNDER DIFFERENT BIOFERTILIZER TREATMENTS IN FIELD CONDITIONS

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ABSTRACT

The field study was carried out during the rabi seasons during the 2025 to study the performance of spring rice under different biofertilizers in field condition at the research farm of G.P. Koirala College of Agriculture and Research Center, Gothgaun, Morang, Nepal. The study was designed utilizing completely randomized block design with seven biofertilizers treatments and replicated three times. Biofertilizers treatments includes FYM, Goat manures, organic manures, NPK, Mycorrhiza, Mustard seed cake and the last one untreated control. Before data collection, ten plants were selected at random and tagged with ribbon so as to collect data uniformly. The data was collected on all vegetative and reproductive traits. The finding revealed significant differences among the treatments with maximum in NPK, Mustard seed cake treated plot and minimum in control group. The NPK treatment produced the tallest plants at harvest (113.86 cm), followed by mustard seed cake (111.64 cm) and goat manure (107.29 cm), while the control treatment yielded the shortest plants (99.51 cm). The application of mustard seed cake resulted in the biggest test weight (35.06 g) and the greatest number of tillers per hill (31.61). The highest grain yield was recorded in NPK (7621.47 kg/ha) and Mustard seed cake (7281.70 kg/ha), indicating its great potential as a sustainable organic nutrition source. Vegetative and reproductive traits improved little with goat manures, but the unfertilized plot shows inferior results on all parameters. Overall, the study concludes that balanced application of NPK and proper and timely application of Mustard seed cake and goat manures could be better alternatives to chemical fertilizers and can significantly improve the growth and yield of rice production..

KEYWORDS

Fertilizer rate, Paddy, Yield performance, Mycorrhiza

1. INTRODUCTION

One of the most significant and staple cereal crops, rice (Oryza sativa L.) is essential to Nepal's agricultural sector and provides a major source of nutrition for almost 85% of the world's population (Paudel et al., 2021; Shrestha et al., 2022). Rice plants are semi aquatic, annual self-pollinated crops that taxonomically belong to Poaceae family (Pant et al., 2020). Rice crops rank first among all other cereals crops like maize, wheat in Nepal in terms of importances and area cultivation (Ranabhat and Amgain, 2016). Thus making it a major centre of national agriculture sector. Currently, it occupies total approximately 1,491,744 hectares of total area for cultivation, with a production of 5.6 million metric tons annually (Krishi diary, 2008). The rice crops along contribute about 21% to the agricultural Gross Domestic Product (GDP) to the country's (Pant et al., 2020). From the nutritional point of view, it is noted that, rice forms the major sources of Nepalis diet, providing nearly 65% of total dietary energy, where rice alone accounts about 30% (Osti et al., 2017). In nepal, around 92% of rice is cultivated in kharif season (rainy season), while the remaining 7% is cultivated in Rabi season (sprig season). Rabi season rice cultivar are Chaite-2, Chaite-4, Hardinath-1, which are commonly cultivated in eastern terai region of Nepal (Parajuli et al., 2022 ; Regmi et al., 2023). Globally, it is found that nearly 50% of total caloric diet is met through rice alone (Jeson et al., 2022). However, the population rate of Nepal's is increasing at much faster rate, and current production rate shows that this level is insufficient to improve the national food security. Therefore, it is necessary and important to improve the yield per unit area, as the expansion of fertile land is highly constrained by several factors (Adhikari et al., 2021). So, improving rice productivity is thus key factor and crucial because it directly impacts both global and national food security (Sarwar et al., 2009 ; Devkota et al., 2019).

The two most important factors playing key role in influencing rice production are irrigation practices and nutrient management (qui et al., 2022). Plant fertilizers are only sources of nutrition which is crucial for proper growth and development of spring rice. Chemical fertilizers specifically, NPK fertilizers were used widely by farmers for immediate nutrient supplies like Nitrogen, Phosphorous, and potassium, also supplying other secondary nutrients like magnesium and calcium for good growth and yield of rice (Pramayudi et al., 2023). Different studies shows that, application of NPK and other synthetic fertilizers significantly enhances and improves crop growth and final yield, however, due to the indiscriminate use of such fertilizers and continuous use, instead of increasing productivity, they reduce the final yield, make soil toxic, reducing the fertility of soil, reducing the quality of crops, damage soil health and leading to reduced long term productivity, increasing the cost of cultivation, and lower production (Thu et al., 2022 ; Wang et al., 2023). Moreover, dure to overdependence on chemical fertilizers, it directly or indirectly destroys the natural resources, and affecting negatively to soil fertility and sustainable production of rice (Xing et al., 2023 ; Wang et al., 2023). The rising need for chemical fertilizers like NPK for rice cultivation poses a constant concern in Nepal. Though, its heavy uses improve growth and increase yield of crops for short term, it frequently causes the deterioration of soil quality, structures, rapidly accumulation of salt matters, decreasing the soil porosity, and thus leading to loss of land productivity (Naz et al., 2015 ; Mehata et al., 2023). Therefore, its sustainable managements strategies are needed to promote the fertility status of soil, reproductive developments and absorption of nutrient (Mehata et al., 2023).

The integration of biofertilizers with good agricultural practices might be the best promising solution to overcome the negative impact of chemical fertilizers in rice production (Choong et al., 2021 ; Lestari et al., 2021 ; Eginarta et al., 2021). Biofertilizers are those plants or living organism-based fertilizers which are environmentally and eco-friendly inputs that promote the growth and development of crops in a sustainable manner with or without minimum impact on environment. Further, these biofertilizers specially, microbial inoculants establish symbiotic relationships with plants therefor enhancing growth and developments (Islam et al., 2012 ; Ghimire et al., 2021). Application of these bio-based fertilizers significantly and constantly influenced the growth and developments of the rice plants, yield, and soil health (Siavoshi et al., 2011 ; Noraida and Hisyamuddin, 2021). Among these biofertilizers, Growth supporting Rhizobacteria plays a key role in atmospheric nitrogen fixation, synthesizing of phytohormones, and enhancing nutrients bioavailability without any symbiotic association with plants (Jalal et al., 2022). Furthermore, biofertilizers improves the structures and porosity of soil by improving the water holding capacity, boosting the formation of soil aggregates, and protecting the soil form Salt, heavy metals, soil pH, and pesticides residues respectively (Li et al., 2023 ; Mehata et al., 2023). Biofertilizers are not only ecologically friendly, but also renewable, and economically viable as compared to synthetic chemicals fertilizers (Sarkar et al., 2018). Besides this, enhancing fertility of soil and productivity, they also help in pollution reduction, reduction of reliance on chemical inputs and speed up composting processes (Sarwar et al., 2009 ; Palanivell et al., 2013 ; Patriyawaty et al., 2022). Thus, using biofertilizers continuously provides a green, cost effective, and sustainable practice to regenerative agricultural growth.

The present study, therefore, aimed to evaluate the influence of different biofertilizer sources on the growth and yield attributes of spring rice, and to identify the most effective biofertilizer capable of enhancing rice productivity and key agronomic traits.

2. Materials And Methodologies

2.1 Description of Experimental Site

The experimental site was selected at the rice station farm of G.P. Koirala College of Agriculture and research Center, Gothgaun, Morang, Nepal. The research was carried out during the Kharif season 2025 to examine the effects of different biofertilizer sources on growth and yield traits of spring rice. The study site is located in the eastern Teari region of nepal, and geographically it lies at an altitude of 151 masl, with average annual rainfall of 131.88 mm and mean temperature ranges from 21.8 to 34.5 degree Celsius.

2.2 Variety and Treatment Selection

The variety chosen was Hardinath-1 rice, a spring rice cultivar. It is thought to be resistant to important rice pests and diseases such as bacterial leaf blight, blast, and others. It takes around 120 to 125 days to reach full maturity after transplanting and produces an average yield of 4-6 tonnes per hectare. To address the treatments employed in our investigation, there were seven total treatments, comprising six different biofertilizer sources and one control, which is shown in table 1.

Table 1: Various treatments utilized in research.

Treatments	Dose	Notations
FYM	12 t/ha	T1
Goat manures	8 t/ha	T2
Organic manures	11.25 kg/ha	T3
NPK	120:40:50 kg/ha	T4
Mycorrhiza	11.25 kg/ha	T5
Mustard seed cake	3.75 t/ha	T6
Control	-	T7

2.3 Experimental Set-Up and Cultural Practices

The research was designed using completely randomized block design, with seven treatments which is replicated three times. There are all together twenty-one research plots and each plot area measure about 3 x 2 m^2. The spacing between plant to plant was maintained as 30 cm and between row to row as 20 cm so there were all together ten rows and each row there were ten hills. The seedlings were raised in raised nursery bed and after 25 days after sowing, the seedlings were transplanted in main field, placing two to three seedlings per hill. The respective treatments were applied after the transplanting and separate and proper bunds were made in each plot to minimize the leaching and treatments effects so to reduce experimental errors. Weed control was managed manually through hand weeding at 30 and 45 days after transplanting. Irrigation was done throughout all critical growing period, and stages that includes tillering, panicle initiation, flowering, grain filling stages.

2.4 Data Observation and Collection:

Before observation and data collection, 10 hills were randomly selected and were tagged using ribbon so as to take data uniformly throughout the research period and data observation and collected on 11 different parameters at various growth and development phase. Vegetative data includes plant height, tillers numbers, days to 50% flowering and effective tiller. Similarly, reproductives traits include Days to maturity, panicle length, weight, grains per panicle, test weight, Biomass yield, Grain yield. Grain yield was calculated using the method suggested by (Shrestha et al., 2021), which is given in 1.

$$\text{Grain yield (Kg/ha)}_{12\%} = \frac{(100 - M)\times \text{Plot yield (Kg)}\times 10{,}000\ (m^2)}{(100-12)\times \text{Net plot area}\ (m^2)} \quad (1)$$

M= grain moisture content

2.5 Statistical Analysis

The raw data collected through field trial on different growth and yield traits of rice under different treatments were entered in Microsoft Excell, 2021 in a sequential order based on treatments and replications. After the data entry, their normality test was carried out and after the data shows normal distribution, it is then used for ANOVA in RStudio statistical software (Version 4.2.3). After Anova, Least significance difference (LSD) at 5% level of significance was used to compare the mean among the treatments. Moreover, regressions analysis was carried out to study the correlation and regression between dependent variables and independent variables. Other visualizations were also analysed using RStudio to study the effect and relationships of treatments with growth and yield traits.

3. Results

3.1 Growth Observation Parameters

3.1.1 Plant Height

Table 2 shows the effect of different biofertilizers on plant height of spring rice at different days after transplanting. The results clearly show the significant differences in plant height among different treatments. The grand means increases gradually from 30 days after transplanting to at harvest (55.80 cm at 30DAT to 99.51 cm at harvest). The pooled height from 30 Dat to harvest shows that the maximum height was attained in NPK (97.18 cm), which was closely followed by mustard seed cake (94.40 cm) and Goat manures (89.88 cm). The minimum or lowest height was observed on control group which was (83.55 cm).

Table 2: Plant height influenced by fertilizer treatments.

Treatments	Plant Height (cm)				At harvest	Pooled height
	30DAT	45DAT	60DAT	75DAT		

Table 2 (Cont): Plant height influenced by fertilizer treatments.						
FYM	50.80cd	74.97cd	95.15d	100.22de	105.07c	85.03cd
Goat manures	56.26bc	79.28b	100.75bc	105.81bc	107.29bc	89.88a
Organic manures	53.80cd	78.43bc	98.24cd	103.30cd	105.23c	87.80bc
NPK	65.06a	87.50a	107.30a	112.20a	113.86a	97.18a
Mycorrhiza	54.00cd	79.94b	98.03cd	102.17cde	103.70cd	87.57bc
Mustard seed cake	60.96ab	86.30a	103.91ab	109.20ab	111.64ab	94.40a
Control	49.76d	74.42d	94.37d	98.64e	99.51d	83.55d
Grand mean	55.80	80.12	99.68	104.50	106.61	89.34
LSD	5.57	3.89	4.19	4.56	4.92	3.02
CV (%)	5.61	2.73	2.36	2.45	2.59	1.90
F-test	***	***	***	***	***	***

3.2 Number Of Tillers Per Hill

Application of different biofertilizer sources showed significant difference for tiller number per hill at different growth periods. The highest number of tillers at harvest was observed in the mustard seed cake treatment (31.61), which was closely followed by NPK (29.73) and superior to all other biofertilizers. The lowest or minimum number of tillers per hill was recorded in control plot that was just 18.10. The grand mean shows gradual increases from 30Dat to at harvest which clearly indicate the direct effect of treatments.

Table 3 : The number of tillers per hill is influenced by the fertilizer treatments.						
Treatments	**Tiller number per hill**				**At harvest**	**Pooled tiller**
	30DAT	**45DAT**	**60DAT**	**75DAT**		
FYM	16.56d	19.60d	20.50d	20.76d	20.83d	19.65d
Goat manures	23.68bc	26.78bc	27.71bc	28.04bc	28.08bc	26.86bc
Organic manures	21.70c	24.80c	25.76c	26.00c	25.76c	24.80c
NPK	25.76ab	28.23ab	29.20ab	29.73ab	29.73ab	28.53ab
Mycorrhiza	22.43c	25.80c	26.10bc	25.90c	25.80c	25.12c
Mustard seed cake	27.64a	30.11a	31.08a	31.61a	31.61a	30.41a
Control	14.70d	17.13d	17.96d	18.23d	18.10d	17.22d
Grand mean	21.78	24.57	25.47	25.75	25.70	24.65
LSD	3.26	3.17	3.13	3.10	2.88	3.10
CV (%)	8.42	7.26	6.92	6.78	6.31	7.07
F-test	***	***	***	***	***	***

3.3 Effective Tillers Per Hill

Table 4 provides the results of effective tiller per hill under different treatments used, which are significantly differ among each other. The results revealed that the highest number of effective tillers was recorded in mustard seed cake (29.18), closely followed by NPK, Goat manures respectively. The lowest number of effective tillers was observed on control plot that was just 15.63.

3.4 Yield Attributing Traits

3.4.1 Panicle length

Panicle length also shows the highly significant among the biofertilizers used. Among the treatments used, the highest panicle length was recorded in NPK (7.53) and Mustard cake (7.46) which was closely followed by Goat manures, organic manures and Mycorrhiza respectively. The lowest length was measured in control group might be due to the lack of nutrients that results in poor growth of plants and lowest length of panicle.

3.4.2 Panicle weight

Panicle weight among the treatments used showed the highest significant differences. The maximum weight was recorded in Mustard seed cake (5.76 g) and NPK (5.83 g), which is followed by other biofertilizers sources. The lowest weight was recorded in control group that was just 3.30 grams. The grand mean recorded was 4.75 grams which is clearly higher than individual control plots, which clearly indicates that proper and balanced utilizations of biofertilizers and NPK directly promotes the proper growth of plants and yield traits.

3.4.3 Grains per panicle

The application of different biofertilizers shows very highly significant differences in grains per panicles. The highest grains per panicles was recorded in mustard seed cake (114.66) and NPK (116.66) closely followed by other biofertilizers. The lowest grains per panicle was recorded in control group (91.33) which is clearly lowest than grand mean of all treatments that was 106.04. It clearly reflects the direct effects of how biofertilizers impact the grains filling per panicle as compared to unfertilized plot.

Table 4: Different yields attributing parameters as influenced by the application of different treatments						
Treatments	**ET/H**	**DF**	**DM**	**PW**	**PL**	**G/P**
FYM	18.53d	59.00b	81.00b	3.86d	5.56d	101.00bc
Goat manures	25.54bc	60.66ab	82.00b	5.13b	6.83b	112.66a
Organic manures	23.40c	60.00ab	80.66b	4.80bc	6.50bc	98.33bc

Table 4 (Cont): Different yields attributing parameters as influenced by the application of different treatments						
NPK	27.30ab	56.66b	81.33b	5.83a	7.53a	116.66a
Mycorrhiza	23.33c	60.66ab	82.33b	4.56c	6.26c	107.66ab
Mustard seed cake	29.18a	63.33a	88.66a	5.76a	7.46a	114.66a
Control	15.63e	59.66ab	84.00b	3.30e	5.00e	91.33c
Grand mean	23.27	60	82.85	4.75	6.45	106.04
LSD	2.75	4.22	3.40	0.42	0.42	9.71
CV (%)	6.65	13.95	2.30	5.08	3.74	5.14
F-test	***	NS	**	**	**	***

3.5 Test Weight

Treatments applications show the clear significant difference between different biofertilizers that how test weight differs significantly. The results revealed that the highest weight was recorded in mustard seed cake that was (35.06 g) closely followed by NPK (33.60 g), Goat manures (32.30 g) respectively. The lowest weight was recorded in control group (25.26 g) which is also lower than grand mean (30.88 g), clearly indicating that how application of treatments significantly effects and promote the growth and test weight of grains of spring rice.

3.6 Days To 50% Flowering

The treatments effects on the flowering trait shows non-significant statistically however, mean comparison shows least differences among the treatments used clearly highlighting the effect of nutrients on flowering of plants. Among the treatments used, the minimum days taken to complete 50% flowering in rice was recorded in NPK and slightly higher in control and other biofertilizers. The grand mean days taken to flower at least 50% was 60 days. There is no any such significant effect of treatments on flowering, might be genetical factor that shows similar results.

3.7 Days To 75% Maturity

Days to maturity show significant differences among the treatments used that might be the direct effect of treatments that promotes the early growth and yield leading to faster maturity. The minimum days taken to mature was Organic manures (80.66 days), NPK (81.33 days), and FYM (81.00 days), whereas other shows maximum days to take maturity that ranges from 82 to 88 days. The maximum days taken to matures was mustard seed cake.

3.8 Grain Yield

Grain yield significantly influenced by the applications of different biofertilizers. Among the treatments used, the highest grain yield was recorded on NPK (7621.47 kg/ha) and mustard seed cake (7281.70 kg/ha), closely followed by Goat manures (5728.35 kg/ha). The lowest grain yield was recorded in control group that was (4571.64 kg/ha). The grand mean yield of rice was recorded as 5725.08 kg/ha.

3.9 Biomass Yield

Biomass yield also clearly resulted significant differences among the treatments used in the study. The maximum biomass yield was recorded in NPK (11637.33 kg/ha) and mustard seed cake (11244.16 kg/ha). The intermediate yield was recorded on all other biofertilizers, whereas the control group recorded the lowest yield of (8281.66 kg/ha).

Table 5: Different yield attributing parameters as influenced by the application of different treatments

Treatments	TW (gram)	Biomass yield (kg/ha)	Grain yield (kg/ha)
FYM	31.03bc	8916.66c	5082.78c
Goat manures	32.30ab	951583b	5728.35b
Organic manures	28.20cd	8957.50c	4935.79cd
NPK	33.60ab	11637.50a	7621.47a
Mycorrhiza	30.70bc	8863.33c	4853.80cd
Mustard seed cake	35.06a	11244.16a	7281.70a
Control	25.26d	8281.66d	4571.64d
Grand mean	30.88	9630.95	5725.08
LSD	3.46	539.63	502.92
CV (%)	6.31	13.14	4.93
F-test	***	***	***

TW: Test weight, GY: Grain yield, BY: Biomass yield, CV: Coefficient of variation, ***Significant at 0.1% level of significance

Figure 3 clearly displays that how the biofertilizers influences the growth and yield traits of spring rice. The below presented treatments wise effects of biofertilizers on vegetative and reproductive traits of spring rice. Horizontal X-axis shows the different treatments while vertical Y-axis shows the means values of different traits of rice. Line graph and trends on each graph clearly illustrated the effect of treatments. On each graph, biofertilizers and NPK shows maximum and increasing trends while in control group showing minimum. Moreover, figure 4 illustrates that the graphs clearly match the tabulated Analysis of variance outcomes, indicating that the used treatments applications specially, NPK and mustard seed cake significantly enhances the growth and production of rice.

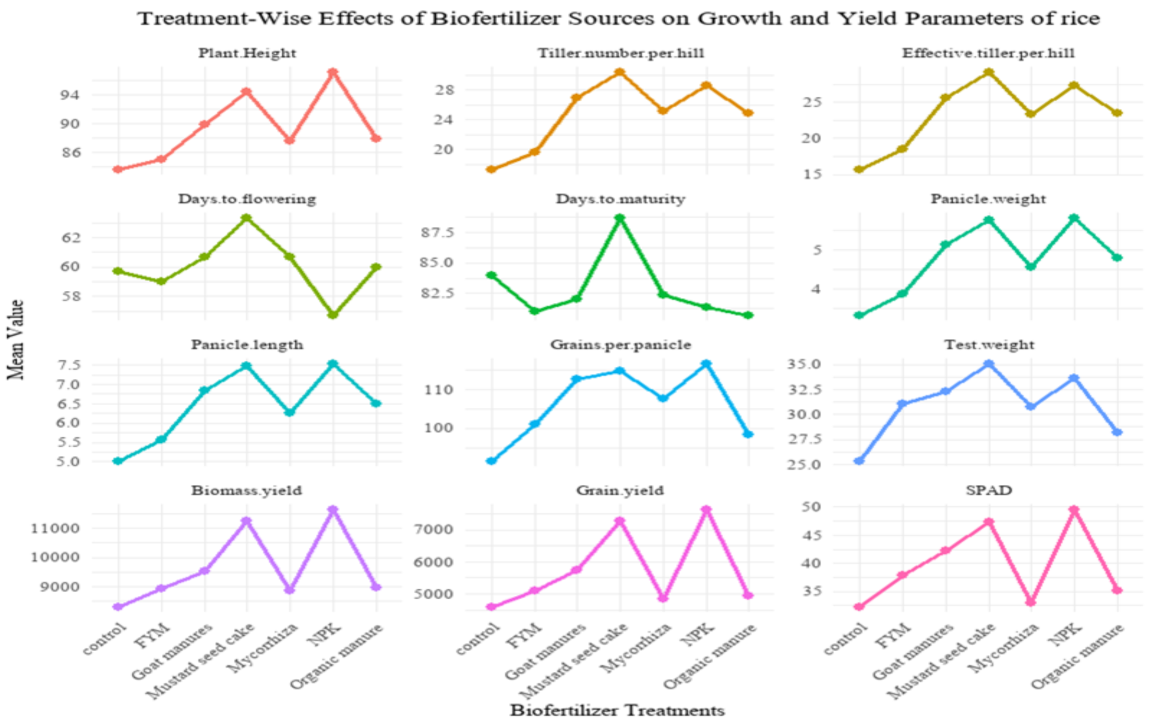

Figure 3: Line graph showing treatment-wise effects of biofertilizers on growth and yield parameters of rice

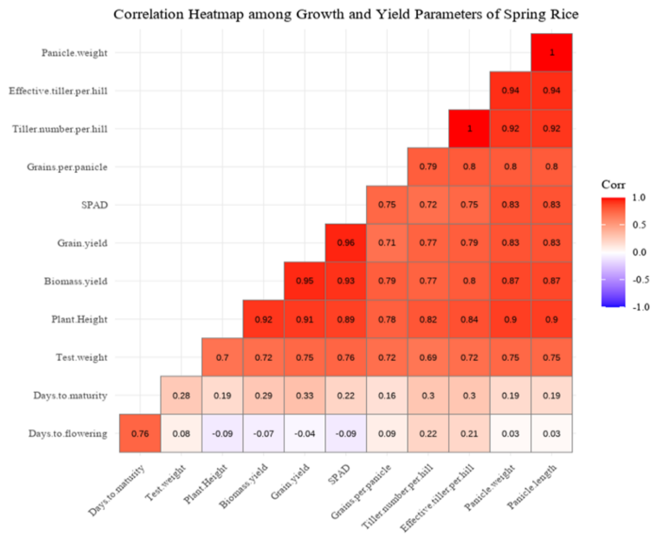

Figure 4: Box plot showing variation in grain yield under different biofertilizers

Figure 5: Correlation Heatmap among growth and yield parameters of spring rice

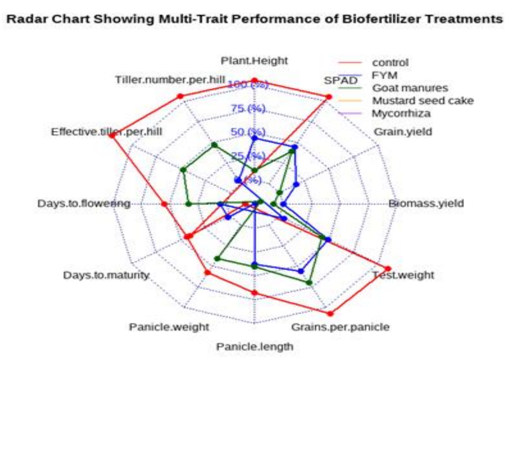

Figure 6: Radar Chart Showing Multi-trait performance of biofertilizer treatment Figure 7 : Heatmap showing overall performance of biofertilizer treatments on spring rice

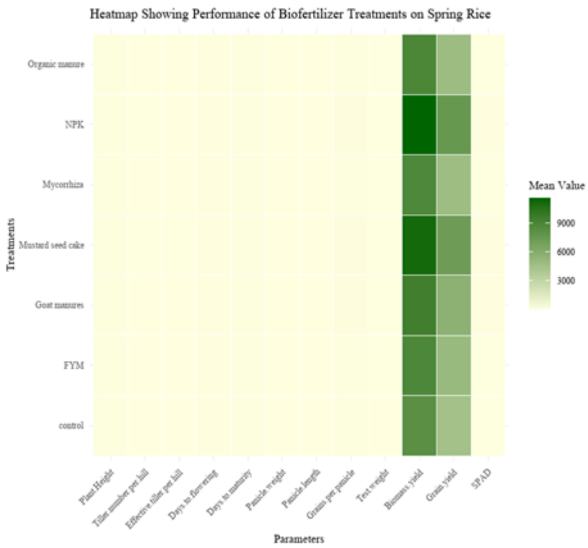

Figure 7: Heatmap showing overall performance of biofertilizer treatments on spring rice

The comprehensive interrelationships among the growth and yield attributes of spring rice with different treatments clearly illustrated in figures 5, 6 and 7 respectively, where figure 5 displays the relationships through correlation heatmap among the traits while figure 6 illustrates through radar chart and figure 7 through heatmap. In figure 5, the correlation heatmap shows the close relationships between different parameters like plant height, tiller number per hill, effective tiller per hill, grains per panicle, panicle weight, biomass yield, grain yield, and SPAD value. The correlation coefficients range from negative 1 to positive 1 value that clearly indicates that there are direct relationships. It is clearly visible that there is strong positive correlation between grain yield and biomass yield (r=0.96), plant height and biomass, and panicle weight with effective tiller number. This means that, higher tiller per hill and biomass accumulation in plant significantly contributes to grain yield of rice. Similarly, Days to 50% flowering and maturity days shows weaker relationship with yield traits clearly reflecting that early maturity or flowering does not favour grain yield. Figure 6, radar chart illustrates multitrate performance of biofertilizers, which compares the overall influence of organic and biofertilizers. Different vegetative and yield traits represented by radar chat with each axis and the polygon shows the individual treatments relative performances. The NPK, goat manures and farmyard manures covers the maximum area on the radar chart clearly indicating the dominating performance, whereas control shows minimum values across the parameters. Mustard seed cake and mycorrhiza illustrate the moderate improvements indicating their overall potentials in promoting and improving the reproductive attributes of rice traits as compared to control. Similarly, heatmap illustrates the overall performances of treatments on spring rice. The different color intensity from light to darker intensity clearly indicates the effects of biofertilizers compared to control group. The color intensisty of darker green indicates that the treatment effects were superior on biomass yield and grain yield, which was observed in NPK, Organic and fym. Light shades were seen in control plot for all parameters which indicates inferior performances due to low or insufficient nutrients content.

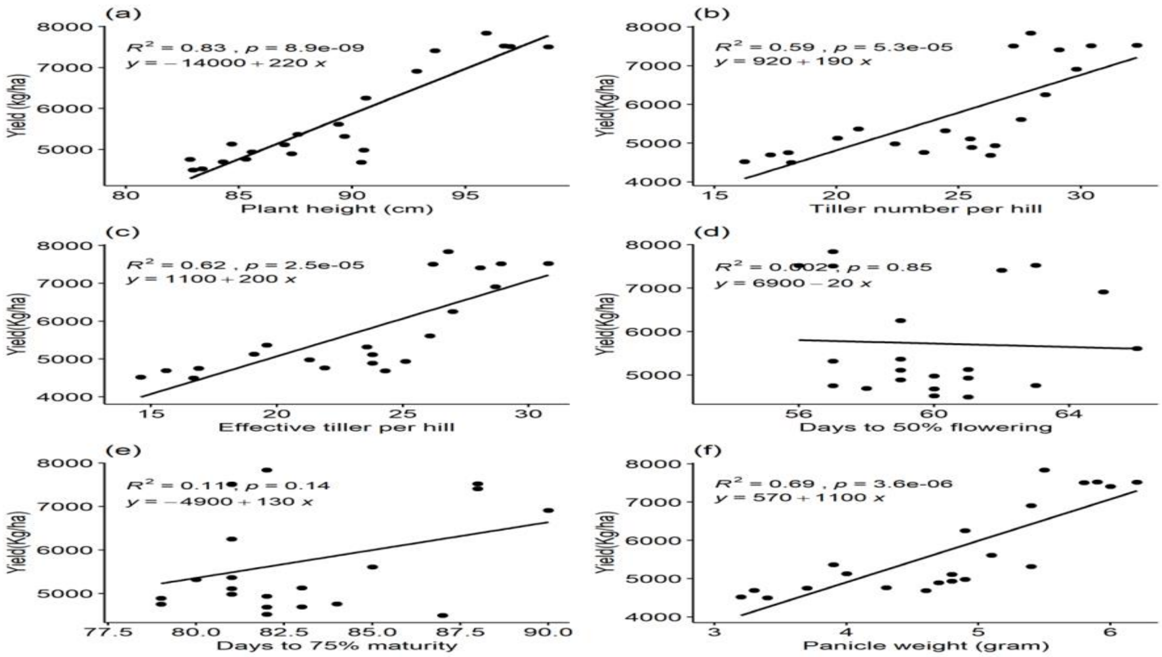

Figure 8: Coefficient of determination (R2), Linear regression equation, and scatter diagram showing the fitted simple regression line of Y (Yield) on X ((a)Plant heights, (b)Number of tillers per hill, (c)Effective tiller per hill, (d)Days to 50% flowering, (e)Days to 75% maturity, (f)Panicle weights).

Regression analysis: Figure 8 and 9 displayed the regression analysis that shows the relationships between the dependent and independent variables of different spring rice traits. The coefficient of determination (R2) indicates the directions and strength of individual relationships among traits, and also their corresponding regression equations provides valuable insights on further predictions of grain yields. In this figure, the horizontal X-axis is considered, and the independent variables and vertical Y-axis indicates the dependent variable (yield kg/ha), here the increase or decrease in independent variables directly or indirectly affects the dependent variable (yield). Among all parameters, all independent variables except, days to 50% flowerings, shows the positive correlations. The plant height contributed 83%, tiller number per hill 59%, Effective tillers per hills 62%, panicle weight 69%, panicle length 69%, grains per panicle and test weight 51% and 56%, and the highest percentage was contributed by biomass yield that was 90%. This relation indicates that regression analysis clearly shows that biomass yield, plant height, panicle length, weight, effective tillers, test weights were the most valuable and top contributing variables to grain yield. So, taking in consideration, these traits serves as a promising indicator for selecting high yielding varieties and cultivars and nutrients management in rice ecosystem.

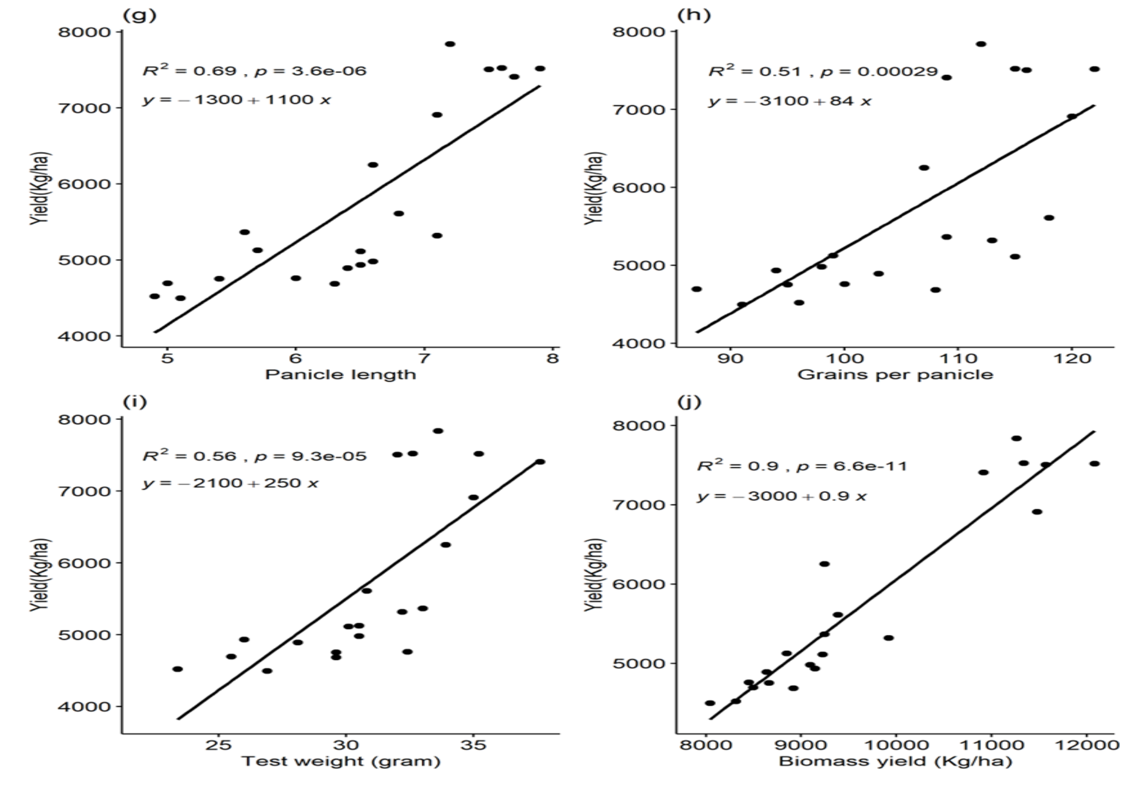

Figure 9: Coefficient of determination (R2), Linear regression equation, and scatter diagram showing the fitted simple regression line of Y (Yield) on X ((g)panicle length, (h)grains per panicle, (i)test weight, (j)biomass yield).

4. Discussions

4.1 Effect of different biofertilizer on growth and yield of spring rice

The finding of our study revealed that application of biofertilizers and other chemical sources significantly effects the vegetative and reproductive attributes of spring rice, with Mustard cake and NPK emerging as the most promising and best treatments for sustainable growth and yield across most parameters of spring rice. Our findings are in parallel with a wide range of previous research and findings, conforming their beneficial role of nutrient availability thus improving the growth and yield of rice crops. Our findings show that, treatments Mustard seed cake and NPK shows highest plant height at all growth stages. This finding aligns with the observation, who documented that improved biomass accumulation and shoot elongation in paddy when applied with balanced mustard seed cake and NPK fertilizers (Devkota et al., 2019 ; Adhikari et al., 2021). Similarly, also recorded that significant increase in plant height, tiller numbers, and other parameters in cereals specially paddy when synthetic fertilizers were used, resulting it to efficiently and better assimilation of nutrients and photosynthetic activity (Ali et al., 2012). Moreover, application of NPK and mustard seed cake, proved highly effective, particularly in enhancing number of tillers per hill, effective tiller per hills, 1000 grains weight, biomass yield, grains per panicle and grain yield. Our findings are also consistent with the findings who documented that the utilization of oilseed cakes plays a key role in promoting fertility of soil, root elongation, higher nutrients uptake, improved microbial activity, and productivity of crops (Karki et al., 2018 ; Giri et al., 2022). Also, the application of mustard seed cake and goat manures as a biofertilizers sources, it plays a significant role in tiller number per hill and effective tiller number per hill increments due to continuous release of nutrients and soil porosity, water holding capacity improvements. Further, rhizosphere as favourable conditions caused by the application of organic and biofertilizers that improves the organic matter content of soil, thus making favourable environment for microorganisms in soil (Ghimire et al., 2021). Due to this, it promotes the gradual increase in tiller numbers, and panicle emergence. Biofertilizers and chemical fertilizers showed significant variation in panicle weight and duration, also highest values on all traits as compared to control. The nutrient availability specially, P and K greatly affect the reproductive characteristics such as pollination, floral developments, grain formation. Furthermore, these findings are also supported by the (Gupta et al., 2016 ; Dang et al., 2023). The nutrients requirements in plants during the time of panicle initiation, flowering, booting, and grain filing stages can be achieved by the balanced and need based application of fertilizers along with biofertilizers played a key role which directly resulted in the improved and increments in number of grain per panicle and weight per panicles (Adhikari et al., 2021). This is also supported with who recorded that those fertilizers rice in nutrients significantly enhance the grain weight and plant density thus increasing the yield (Devkota et al., 2019 ; Ghimire et al., 2021). The lowest data was observed in control group, due to lack of nutrients thus lacking nutrients leads to poor growth and developments of crops and then inferior performances in all parameters. According to the study, revealed that inferior performances in all parameters under controlled conditions is mainly due to lack of nutrients in the field (Ali et al., 2012). This is closely aligned with our findings, while small variations in flowering days indicate that fertilizer source effects flowering time, with mustard seed cake delaying flowering due to slow nutrient release and chemical fertilizer promoting earlier flowering through rapid nutrient availability. Plants supplied with mustard seed cake showed delayed plant maturity, might be due to the outcomes of prolonged growth and development under constant and slow nutrient release (Dang et al., 2023 ; Gupta et al., 2016). The research plot applied with goat manures recorded intermediate performance, while, grain yield and biomass production were superior under NPK and mustard seed cake fertilizer, suggesting that both fast and persistent nutrient availability encourage greater development and productivity. Furthermore, our finding revealed that the research plot which are supplied with farmyard manures and Control plot where no fertilizers were given consistently gave inferior results, lower yields indicating the needs for balanced application fertilizers for sustainable and higher yield production in rice ecosystem. These results are in parallel with the earlier finding of (Adhikari et al., 2021). The ability of plants to absorbs the solar radiation energy, to produce dry matter, promote canopy growth of plant, expansion of leaf area, and chlorophyll content that all helps to get high biomass yield can be improved by balanced application of fertilizers sources to the soil.

5. Conclusions

The study concluded that application of different biofertilizers treatments significantly influenced the growth and yield traits of spring rice, conforming that with Mustard seed cake and synthetic fertilizer NPK as a promising and most effective nutrients sources. Most of the growth and yield traits including plant height, tiller numbers, panicle length, weight, grains per panicles, test weight, yield and biomass yield, shows superior performance in both these nutrients sources indicating the immediate nutrient availability and uptake of essential primary and secondary nutrients. Moreover, biofertilizers significantly increases the biomass of soil, and making favourable environment for microbial activity thus further aids on nitrogen fixation and nutrients availability roles. Goat manures emerged as another alternatives sources and if it is applied with balanced dose with NPK then, the yield can be significantly increased. However, control recorded the lowest for all traits indicating the inferior performances, that must be due to nutrients deficient, which shows the beneficial and advantageous role of biofertilizer on rice growth and yield. Therefore, based on our finding, it is recommended that NPK and mustard seed cake as a better option for rice cultivation to achieve better results. However, for those thinking of dependences of chemical fertilizers and enhance soil health in long run, the use of mustard seed cake is strongly encouraged. Farmers are also advised to use the goat manures and organic manures with lowest dose of NPK so the farmers can gain maximum outputs with minimum or zero negative impact on environments thus supporting the sustainable rice cultivation.

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