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Synergistic Effects of Root Dipping and Foliar Application of NPK (19:19:19) on Growth and Yield in *Kharif* Rice (*Oryza sativa* L.)

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Abstract

A field experiment was conducted during the *kharif* season of 2025-26 at Seacom Skills University, West Bengal, to evaluate the effect of root dipping and foliar application of NPK (19:19:19) on the growth and yield of rice. The experiment was laid out in a randomized block design with nine treatments and three replications, involving different combinations of root dipping, recommended dose of fertilizers (RDF; 80:60:40 kg N:P_2O_5: K_2O ha^{-1}), and foliar nutrition. The treatments were treatments were: T_1-Absolute control, T_2-Only root dipping; T_3-RDF 100%; T_4-Root dipping+RDF 100%; T_5-Root dipping+RDF 50% (all basal); T_6-Root dipping+50% RDF (N in split 50%, 25%, 25%); T_7-Root dipping+(foliar application of NPK 19:19:19); T_8-All foliar spray only NPK 19:19:19; T_9-Root dipping+50% RDF (as basal)+foliar spray NPK 19:19:19. (Foliar spray: N:P: K 19:19:19 liquid fertilizer at 15-day intervals starting from 10 DAT up to milking stage, Root dipping: roots of uprooted seedlings dipped in NPK 19:19:19 @ 5 g l^{-1} water). Results showed that integrated nutrient management significantly improved growth and yield. T_6 recorded higher early plant height (65.17 cm at 30 DAT) and crop growth rate (6.29 g m^{-2} day^{-1} at 60 DAT). T_4 produced the tallest plants (97.0 cm), highest tillers (466.2 m^{-2}), and maximum dry matter (708.67 g m^{-2}). Highest grain yield was obtained in T_4 (4488.3 kg ha^{-1}), comparable with T_3 and T_9, while T_9 recorded the highest harvest index (42.9%). The study clearly demonstrates that integration of root dipping with soil and foliar application of NPK enhances nutrient use efficiency, improves growth and productivity of *kharif* rice.

Keywords: Assimilate partitioning, foliar application, intensive cultivation, root dipping

1. Introduction

Among various crops of India, Rice (*Oryza sativa* L.) is considered the most important staple food crop that helps in ensuring food security of the nation by providing sufficient calories and proteins to people of India (Birla et al., 2017). Recently, India has surpassed China in total rice production, with India producing about 150.18 mt, while China's production stood at around 145.28 mt Anonymous, 2026). Rice cultivation in India is carried out in diverse agro-climatic zones, from irrigated zones to rainfed zones, with the majority of the rice being cultivated during the *kharif* period (Kumar, 2025). Among all food grains of India, rice occupies a predominant place due to its huge contribution to total cereal production, which serves as the chief source of income for numerous farmers in India (Mahajan et al., 2017). But the intensification of agricultural practices and misuse of chemical fertilizers have resulted in poor quality of soil, loss of organic matter content from soils, and nutritional imbalance (Reda and Hailu, 2017). Low efficiency of chemical fertilizers is attributed to leaching, volatilization, and fixation. This results in poor efficiency and nutrient uptake by plants and has serious environmental implications (Tyagi et al., 2022). Balanced nutrient management beyond conventional NPK fertilization is essential for improving growth, yield, and overall productivity of rice (Mallick et al., 2025). Therefore, alternative nutrient management strategies are required to improve nutrient use efficiency while sustaining soil health. Integrated nutrient management enhances nutrient availability, uptake efficiency, and crop productivity by ensuring a balanced and continuous supply of nutrients (Ahmed and Mallick, 2025). Foliar nutrition has become an efficient and cost-effective method of providing nutrients to plants in situations where soil applications prove to be ineffective (Ray et al., 2024). The application of nutrients in the foliage results in immediate absorption and transportation of the nutrients by the plant, thus improving the growth and yield of the plants (Niu et al., 2021). In the last few years, foliar applications have found prominence in water-soluble fertilizers like NPK (19:19:19), owing to their balanced content of major nutrients and increased efficiency of utilization. Foliar feeding ensures rapid correction of nutrient deficiencies and enhances crop performance during critical growth stages (Vasundhara and Chhabra, 2021). Root dipping is another promising technique that facilitates direct contact of nutrients or beneficial inputs with plant roots at the time of transplanting (Kalidas-Singh and Thakuria, 2018). Improved seedling vigour and root development enhance nutrient uptake efficiency and contribute significantly to better growth and yield in rice (Mallick et al., 2024). This practice will ensure that the early establishment of the crop is improved and that proper nutrients can be absorbed by the plants. Compared to the traditional soil application method, root dipping ensures that there will be an efficient use of the inputs, since there are fewer chances of loss and more availability of nutrients in the rhizosphere. Considering the points discussed above, this experiment was carried out during the *kharif* cropping season of 2025–26 to study the influence of root dipping and foliar application of NPK (19:19:19) on growth, yield, and economics of rice.

2. Materials and Methods

A field experiment entitled *"Effect of root dipping and foliar* application of NPK (19:19:19) on growth and yield of *kharif rice (Oryza sativa L.)"* was conducted during the *kharif* season of 2025-26 at the Instructional Farm, School of Agriculture, Seacom Skills University, Kendradangal, Birbhum, West Bengal (87°38' E; 23°42' N; 9.75 m altitude).

The soil of the experimental field was sandy loam in texture, slightly acidic in reaction (pH 5.3), and medium in organic carbon content (0.65%). The available phosphorus and potassium were 7.47 and 158.67 kg ha^{-1}, respectively. The experimental site falls under the Red and Lateritic soil zone of West Bengal.

The experiment was laid out in a randomized block design with three replications and nine treatments comprising different combinations of root dipping, recommended dose of fertilizers (RDF), and foliar application of NPK (19:19:19). The recommended dose of fertilizers was 80:60:40 kg N:P_2O_5: K_2O per hectare. Foliar application of NPK (19:19:19) at 5 g l^{-1} was carried out at 15-day intervals starting from 10 days after transplanting up to the milking stage, while root dipping of seedlings was done in the same solution before transplanting. A spacing of 20 cm×15 cm was maintained between rows and hills, respectively, and bunds were provided between plots to prevent lateral movement of water.

The field was prepared by thorough puddling followed by levelling. 22-day-old seedlings were uprooted from the nursery, subjected to root dipping treatment as per the experimental requirement, and transplanted in the main field. Fertilizers were applied as per treatment specifications, with nitrogen applied in split doses where applicable, while phosphorus and potassium were applied as basal. A water depth of about 5±2 cm was maintained through out the crop growth period, and irrigation was with held two weeks before harvest. Weed control was carried out manually, and no serious incidence of pests or diseases was observed during the crop period.

Observations on growth parameters such as plant height, number of tillers, dry matter accumulation, crop growth rate, root length, and root dry weight were recorded at different stages of crop growth. Yield attributes, including number of panicles, panicle length, number of filled grains panicle^{-1}, chaffy grain percentage, and test weight, were recorded at harvest. Grain and straw yields were recorded from the net plot area and expressed in kg ha^{-1}. Biological yield and harvest index were computed accordingly.

The statistical analysis was conducted using an analysis of variance (ANOVA) for a randomized complete block design (RCBD) and the collected data were subjected to average analysis as per the procedures outlined by Gomez and Gomez (1984). The F-values were compared, and the critical difference (CD) was computed at the 5% level of significance.

Pearson correlation coefficients were calculated using Microsoft Excel, and significance levels were interpreted based on standard correlation thresholds.

3. Results and Discussion

3.1. Effect on crop establishment and early vigour

The initial crop establishment and early vigour of *kharif* rice were markedly influenced by different nutrient management practices. At 30 DAT, treatments involving integrated nutrient application exhibited superior growth compared to sole applications and control. Notably, root dipping combined with split application of nitrogen (T_6) recorded the highest plant height (65.17 cm), followed closely by treatments receiving root dipping along with foliar nutrition (T_7) and full recommended dose of fertilizers (T_3).

A similar trend was observed in early tiller production, where T_3 (360.75 m^{-2}) and T_4 (349.65 m^{-2}) showed a substantial increase over the control (225.33 m^{-2}), indicating enhanced early vegetative proliferation under balanced nutrient supply. The improvement in early biomass accumulation was also evident from higher dry matter production in treatments receiving combined nutrient inputs, particularly T_5 (275 g m^{-2}) and T_3 (273.67 g m^{-2}), compared to the control (209 g m^{-2}).

The enhanced early growth under these treatments can be attributed to improved nutrient availability during the critical establishment phase. Root dipping likely facilitated immediate nutrient uptake and better seedling establishment, while the presence of nitrogen, phosphorus, and potassium supported rapid cell division, root activation, and early tiller initiation (Zhang et al., 2023).

3.2. *Influence on vegetative growth dynamics*

The vegetative growth of *kharif* rice was significantly enhanced under integrated nutrient management practices, particularly during the active growth phases at 60 and 90 DAT. Treatments combining root dipping with recommended fertilizer doses demonstrated superior performance compared to individual or control treatments. Among these, T_4 (root dipping+100% RDF) recorded the highest plant height (85.67 and 97.00 cm at 60 and 90 DAT, respectively), closely followed by T_9 and T_3, indicating sustained vegetative development under balanced nutrient supply.

Tiller production exhibited a similar trend, with T_4 registering the maximum number of tillers (449.55 and 466.20 m^{-2} at 60 and 90 DAT), which was markedly higher than the control (305.25 and 311.91 m^{-2}). This increase reflects enhanced tiller initiation and survival due to improved nutrient availability throughout the growth period.

Dry matter accumulation further substantiated the positive influence of integrated treatments. T_4 recorded the highest biomass (447.67 and 708.67 g m^{-2} at 60 and 90 DAT), followed by T_3 and T_9, indicating efficient photosynthetic activity and biomass production. Similarly, crop growth rate was significantly higher in T_4 (5.93 and 8.70 g m^{-2} day^{-1}), demonstrating sustained growth momentum during later stages.

The trend in crop growth rate (CGR) further substantiates these observations. At 60 DAT, the highest CGR was recorded in T_6 (6.29 g m^{-2} day^{-1}), followed by T_4 (5.93 g m^{-2} day^{-1}), indicating rapid biomass accumulation during the active vegetative phase. At 90 DAT, however, T_9 (9.70 g m^{-2} day^{-1}) and T_4 (8.70 g m^{-2} day^{-1}) exhibited the highest CGR values, reflecting sustained growth momentum during later stages. In contrast, the control recorded consistently lower CGR values (3.63 and 2.16 g m^{-2} day^{-1} at 60 and 90 DAT, respectively), indicating limited growth potential under nutrient-deficient conditions.

The superior vegetative growth observed under these treatments can be attributed to the combined effect of early nutrient availability through root dipping and continuous nutrient supply via soil and foliar sources. This integrated approach likely enhanced nutrient uptake efficiency, chlorophyll synthesis, and photosynthetic capacity, resulting in greater biomass accumulation and sustained crop growth.

These findings were in close agreement with the observations of Kaur et al. (2023), Paramesh et al. (2023), Midya et al. (2021), Patel et al. (2020), and Afrin et al. (2022).

3.3. *Effect on root growth dynamics*

Perusal of data recorded on *root growth dynamics* are presented in table 1 and 2. Root growth was significantly influenced by different nutrient management practices throughout the crop growth period. The treatments involving root dipping in combination with fertilizer application showed better root development compared to the control and individual treatments.

Among the treatments, T_6 (root dipping+50% RDF with split nitrogen application) consistently recorded higher root length at all stages (19.87, 21.27 and 21.33 cm at 30, 60 and 90 DAT, respectively), followed closely by T_2 and T_4. In contrast, the control (T_1) showed the lowest root length across all stages.

Table 1: Effect of root dipping and foliar application of NPK (19:19:19) on vegetative growth characteristics of *kharif* rice (*Oryza sativa* L.)

Treatments	Plant height (cm)			No of tillers m^{-2}			DMA (g m^{-2})			CGR (g m^{-2} day^{-1})		
	30 DAT	60 DAT	At Harvest	30 DAT	60 DAT	At Harvest	30 DAT	60 DAT	At Harvest	30 DAT	60 DAT	At Harvest
T_1	49.83	63	77.33	225.33	305.25	311.91	209	318	382.67	6.97	3.63	2.16
T_2	55.17	70.67	80.67	266.4	327.45	350.76	252	356.67	425.33	8.4	3.49	2.29
T_3	63.33	83.67	94.33	360.75	399.6	432.9	273.67	432.33	671.33	9.12	5.29	7.97
T_4	62.67	85.67	97	349.65	449.55	466.2	269.67	447.67	708.67	8.99	5.93	8.7
T_5	62.50	64.67	83	344.1	399.6	416.25	275	413.33	621.67	9.17	4.61	6.94
T_6	65.17	66	84.33	338.55	388.5	405.15	258	446.67	573.33	8.6	6.29	4.22
T_7	64.83	63	81	321.9	399.6	410.7	252	394	592.67	8.4	4.73	6.62
T_8	57.33	60.33	89	305.25	379.62	388.5	223.67	302.33	558.67	7.46	2.62	8.54
T_9	60.00	84.33	95.33	327.45	438.45	444	263.67	368	659	8.79	3.48	9.7
SEm±	2.53	4.38	3.71	22.44	22.29	20.96	10.98	14.89	25.44	0.37	0.45	1
CD (p=0.05)	7.36	12.72	10.78	65.22	64.81	60.94	31.92	43.29	73.95	1.06	1.3	2.89

T_1: Absolute control; T_2: Only root dipping; T_3: RDF 100%; T_4: Root dipping+RDF 100%; T_5: Root dipping+RDF 50% (all basal); T_6: Root dipping+50% RDF (N in split 50%, 25%, 25%); T_7: Root dipping+(foliar application of NPK 19:19:19); T_8: All foliar spray only NPK 19:19:19; T_9: Root dipping+50% RDF (as basal)+foliar spray NPK 19:19:19

Table 2: Effect of root dipping and foliar application of NPK (19:19:19) on root growth characteristics of *kharif* rice (*Oryza sativa* L.)

Treat-ments	Plant height (cm)			No of tillers m^{-2}		
	30 DAT	60 DAT	90 DAT	30 DAT	60 DAT	90 DAT
T_1	17.4	19.87	19.9	77.57	135.43	158.03
T_2	19.33	21.13	21.23	79.3	282.8	316.1
T_3	18.37	19.67	19.77	135.27	293.93	348.63
T_4	19.73	20.8	20.87	166.53	350.73	363.6
T_5	19.03	19.37	19.57	134.77	545.07	565.47
T_6	19.87	21.27	21.33	118.43	572.9	594.17
T_7	18.6	20.1	20.17	105.17	307.87	333.75
T_8	18.97	20.13	20.07	121.93	219.87	229.57
T_9	19.8	20.17	20.67	109.97	311.87	327.43
SEm±	0.45	0.49	0.58	3.34	5.84	9.21
CD (p=0.05)	1.32	1.43	1.7	9.72	16.99	26.76

A similar trend was observed in root dry weight, where integrated treatments produced higher root biomass. At 30 DAT, T_4 recorded the highest root dry weight, while at later stages, T_6 showed maximum values, indicating better root proliferation under balanced and continuous nutrient supply. Treatments with combined nutrient approaches were clearly superior to sole foliar or root dipping treatments.

The improved root growth under these treatments may be attributed to enhanced nutrient availability and uptake, which promoted root proliferation and activity. The combined effect of root dipping and split nutrient application ensured continuous nutrient supply, resulting in better root development and overall crop performance.

These findings in close conformity with the reports of Pang et al. (2024), who highlighted that integrated nutrient management practices significantly improve root growth, nutrient use efficiency, and crop performance in rice cultivated under red and lateritic soils of eastern India. These findings are also in close conformity with recent studies of Du et al. (2021), Das et al. (2021).

3.4. *Impact on yield attributing characters*

The data on yield attributing characters were statistically analyzed and presented in table 3. Yield attributing characters of *kharif* rice were significantly influenced by different nutrient management practices involving root dipping and foliar application of NPK (19:19:19). The integrated treatments consistently performed better than individual applications and control, indicating the importance of balanced nutrient supply for reproductive development.

Treatments combining root dipping with RDF and foliar nutrition recorded higher values of yield attributes, particularly number of panicles, panicle length, grains per panicle and test weight. Among the treatments, T_9 (root dipping+50% RDF+foliar spray) and T_4 (root dipping+100% RDF) produced the highest number of panicles, indicating better tiller survival and conversion into productive tillers. This improvement may be attributed to continuous nutrient availability during critical growth stages, which supported tiller development and panicle initiation. The findings were in close agreement with the reports of Upadhyaya et al., 2025, who also observed that among the water-soluble fertilizers evaluated, foliar spray of TNAU water-soluble fertilizers 19:19:19 @ 2%+TNAU Liquid Multi Micronutrient @ 1% concentration at active tillering, panicle initiation, 50% flowering, and harvest stage, along with a recommended dose of fertilizers, recorded the maximum plant height, number of panicles m^{-2}, number of grains panicle^{-2}, and number of filled grains panicle^{-1}.

Table 3: Effect of root dipping and foliar application of NPK (19:19:19) on yield attributes of *kharif* rice (*Oryza sativa* L.)

Treatments	No of panicles m^{-2}	Panicle length (cm)	No of grains panicles^{-1}	Test weight (g)
T_1	261.90	24.3	126.3	22.2
T_2	310.67	26.0	140.7	22.4
T_3	396.03	28.8	193.5	24.5
T_4	409.67	30.0	196.4	24.9
T_5	382.60	27.0	162.6	23.3
T_6	378.33	25.8	154.3	23.4
T_7	369.83	26.7	147.5	22.6
T_8	343.33	26.0	143.1	21.7
T_9	413.70	29.8	144.9	24.5
SEm±	8	1.06	4.7	0.17
CD (p=0.05)	23.24	3.09	13.66	0.5

Similarly, panicle length and grain panicle^{-1} were higher under treatments receiving balanced and sustained nutrient supply, particularly T_4 and T_3, suggesting improved reproductive efficiency and assimilate translocation. The enhanced grain number reflects better spikelet formation and reduced sterility under adequate nutrient conditions. In contrast, the control treatment recorded the lowest values for these parameters, indicating poor growth and reproductive performance under nutrient deficiency. These findings are consistent with the report of Dhakar (2022) who also observed that integrated nutrient management involving root dipping and foliar application of balanced NPK formulations significantly improved yield attributes such as panicle length, number of panicles, grain yield or straw yield and overall productivity in rice.

Test weight also followed a similar trend, with higher values observed under integrated nutrient treatments, while lower values were recorded under sole foliar application. This indicates that foliar feeding alone was insufficient to meet the crop's nutrient requirement, particularly during the grain filling stage.

The improvement in yield attributing characters under integrated nutrient management may be due to enhanced nutrient uptake, better photosynthetic activity, and efficient translocation of assimilates from source to sink. These findings are in agreement with earlier study of Paramanik et al. (2024) which reported that the combined application of RDF with foliar nutrition significantly improves test weight and overall yield components of rice.

3.5. *Effect on yield*

The data regarding yield of kharif rice have been presented in table 4. Grain and straw yield of *kharif* rice were significantly influenced by different nutrient management practices involving root dipping and foliar application of NPK (19:19:19).

Table 4: Effect of root dipping and foliar application of NPK (19:19:19) on grain yield, straw yield and harvest index of kharif rice (*Oryza sativa* L.)

Treatments	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest index (%)
T_1	2438.3	4830.0	33.34
T_2	2680.0	5134.3	34.21
T_3	4339.3	6707.7	39.39
T_4	4488.3	6699.3	40.17
T_5	3960.0	6295.0	38.57
T_6	3721.7	5650.0	39.76
T_7	3663.3	5306.0	40.78
T_8	3376.7	5155.0	39.48
T_9	4296.7	5709.3	42.9
SEm±	222.73	301.16	2.27
CD (p=0.05)	647.46	875.45	6.59

Among the treatments, T_4 (root dipping+100% RDF) recorded the highest grain yield (4488.33 kg ha^{-1}), which was statistically at par with T_3 (4339.33 kg ha^{-1}) and T_9 (4296.67 kg ha^{-1}). The higher yield under these treatments may be attributed to balanced and continuous nutrient supply, which improved root activity, nutrient uptake and assimilate translocation towards the developing grains. Moderate yields were observed in T_5, T_6 and T_7, indicating that a reduction in fertilizer dose resulted in comparatively lower productivity, although these treatments performed better than the control. The lowest grain yield was recorded in T_1 (2438.33 kg ha^{-1}), followed by T_2 and T_8, showing that root dipping or foliar spray alone was not sufficient to meet the crop nutrient requirement.

These findings are in agreement with Deo et al. (2022), Sadhukhan et al. (2023), Biswakarma et al. (2025) who also reported higher grain yield under integrated nutrient management involving combined application of soil and foliar nutrients.

A similar trend was observed in straw yield, where T_3 (6707.67 kg ha^{-1}) and T_4 (6699.33 kg ha^{-1}) recorded the highest values and were statistically at par. This may be due to better vegetative growth, higher tillering and greater biomass accumulation under adequate nutrient supply. Treatments such as T_5 and T_9 produced moderate straw yield, indicating that partial RDF combined with foliar nutrition can sustain biomass production to some extent. Lower straw yield was recorded under T_6, T_7, T_8 and T_2, while the control (T_1) showed the minimum value (4830 kg ha^{-1}) due to nutrient deficiency and poor growth.

These results are in conformity with Sahoo et al., 2024 who reported that balanced fertilization along with foliar supplementation significantly improves biomass production and straw yield in rice.

Overall, the results clearly indicate that integrated nutrient management, particularly root dipping combined with the recommended dose of fertilizers, is more effective in improving both grain and straw yield of *kharif* rice.

3.6. *Effect on assimilate partitioning*

The variation among treatments clearly indicates the effect of nutrient management on assimilate partitioning between grain and straw yield.

Among the treatments, T_9 (root dipping+50% RDF as basal+foliar spray of NPK 19:19:19) recorded the highest harvest index (42.9%), which was superior to all other treatments. This improvement may be attributed to improved nutrient availability through both soil and foliar applications, resulting in efficient translocation of photosynthates toward grain formation.

Treatments such as T_3, T_4, T_6, T_7 and T_8 recorded moderate harvest index values ranging from 38.57 to 40.78%, indicating effective partitioning of assimilates under balanced nutrient supply. These treatments were statistically comparable and showed that both root dipping and adequate fertilization contributed positively to yield efficiency.

In contrast, the lowest harvest index was recorded in T_1 (33.34%), followed by T_2 (34.21%), which may be due to inadequate nutrient availability leading to poor reproductive growth and reduced translocation of assimilates towards the grain.

The results indicate that integrated nutrient management involving root dipping, basal fertilization, and foliar feeding is effective in improving harvest index by enhancing physiological efficiency and improving the distribution of assimilates in *kharif* rice.

The findings of this investigation fall in line with those observed by Nandy et al. (2023), Deng et al. (2022), Song et al.

(2024), Bhatta et al. (2021) who demonstrated that integrated nutrient management, particularly the combined application of soil and foliar nutrients, significantly improves harvest index by enhancing assimilate partitioning and physiological efficiency in rice.

3.7. Correlation and regression analysis

The correlation analysis revealed strong and positive associations among grain yield and major growth and yield attributes of *kharif* rice (Figure 1). Grain yield exhibited the highest correlation with dry matter accumulation (r=0.993), followed by tiller density (r=0.981) and number of panicles (r=0.974). This indicates that biomass production and tiller proliferation are the primary determinants of yield under integrated nutrient management practices. The strong relationship between dry matter and grain yield suggests that enhanced photosynthetic efficiency and assimilate production played a crucial role in improving grain filling and overall productivity.

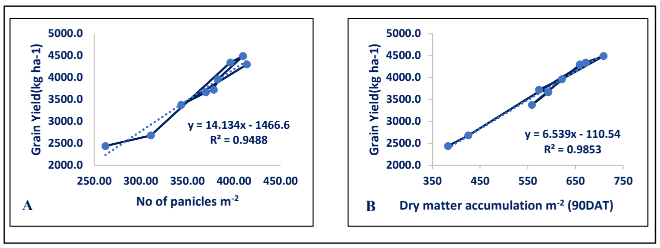

Figure 1: Relationship between grain yield and key growth parameters of *kharif* rice under integrated nutrient management. (A) Linear regression between grain yield and number of panicles m^{-2} showing a strong positive relationship (R^2=0.9488). (B) Linear regression between grain yield and dry matter accumulation at 90 DAT indicates a highly significant positive relationship (R^2=0.9853). Each point represents a treatment mean

Tiller density also showed a very strong positive association with grain yield, which may be attributed to its direct contribution to panicle formation and sink capacity. Likewise, the number of panicles exhibited a strong correlation with yield, reflecting improved conversion of vegetative growth into productive reproductive structures. In contrast, plant height showed a comparatively weaker correlation with grain yield (r=0.827), indicating that increased plant stature alone does not necessarily contribute to higher productivity unless accompanied by efficient biomass accumulation and partitioning.

Regression analysis further supported these findings by demonstrating significant linear relationships between grain yield and key growth parameters (Figure 2: Pearson's correlation matrix depicting the relationship among grain yield, tiller density, dry matter accumulation, number of panicles and plant height in *kharif* rice.). Grain yield showed a strong positive relationship with the number of panicles,

Traits	*GY*	*T*	*DMA*	*P*	*PH*
GY	1				
T	0.981235	1			
DMA	0.992614	0.985822	1		
P	0.974089	0.982148	0.9671	1	
PH	0.826905	0.824912	0.822716	0.776113	1

Figure 2: Pearson's correlation matrix depicting the relationship among grain yield, tiller density, dry matter accumulation, number of panicles and plant height in *kharif* rice. Strong positive correlations were observed between grain yield and dry matter accumulation, tiller density and panicle number, indicating their significant contribution to yield enhancement under integrated nutrient management; GY: Grain yield; T: No of tillers m^{-2}; DMA: Dry matter accumulation; P: No of panicles m^{-2}; PH: Plant height

with a coefficient of determination (R^2=0.9488), indicating that approximately 95% of the variation in yield could be explained by panicle density. Similarly, a highly significant linear relationship was observed between grain yield and dry matter accumulation (R^2=0.9853), suggesting that biomass production was the most influential factor governing yield. The higher R^2 value in this relationship highlights the dominant role of dry matter accumulation in determining grain yield.

The strong positive correlations observed between grain yield and dry matter accumulation, tiller density, and panicle number are consistent with earlier findings with Li et al.(2019), Zhou et al.(2019).

4. Conclusion

Integrated nutrient management significantly improved the growth and productivity of *kharif* rice. Root dipping combined with 100% recommended fertilizers produced the highest plant height, dry matter accumulation, and grain yield (4488.33 kg ha^{-1}). The yield improvement was associated with balanced nutrient availability and enhanced nutrient uptake. Grain yield exhibited strong positive relationships with dry matter accumulation, tiller density, and panicle number. The findings indicated that integrating root dipping with recommended fertilization effectively enhanced nutrient use efficiency and rice productivity.

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