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Effect of Different Levels of Potash on Growth, Yield Attributes and Yields of Transplanted Kharif Rice (*Oryza sativa* L.) in Southern Odisha

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Abstract: The occurrence of drought in the early monsoon period and the role of potassium in resisting water stress motivated me to imitate a field experiment which was conducted during *Kharif*, 2022-23 at the Post Graduate Research Farm (18.80537880^{0}N latitude, 84.179085^{0}E longitude) of the M.S. Swaminathan School of Agriculture, Gajapati, Odisha, on a sandy clay loam soil. The experiment was laid out in Randomized Block Design with three replications and eight treatments. The treatments were: K_0 (control) 0 Kg K ha^{-1}, K_{10} :10 Kg K ha^{-1}, K_{20}: 20 Kg K ha^{-1}, K_{30} : 30 Kg K ha^{-1}, K_{40} : 40 Kg K ha^{-1}, K_{50} : 50 Kg K ha^{-1}, K_{60}: 60 Kg K ha^{-1}, K_{70} : 70 Kg K ha^{-1}. Rice variety Shatabdi was the test crop. The recommended N and P_2O_5 (80-40 kg ha^{-1}) were applied to all treatments. The effect of Potassium levels significantly influenced the crop growth parameters like the number of tillers, dry matter accumulation, leaf area index, number of panicles per unit area, panicle length, number of spikelet's per panicle, number of filled spikelet's per panicle, percentage of filled spikelet's and finally grain and straw yields, the treatments K_{70} recorded best results in terms of dry matter accumulation (775g m^{-2}), leaf area index (3.3), number of tillers m^{-2} (350.6), number of panicles m^{-2} (351.6), panicle length (29.6cm), number of spikelet's panicle^{-1} (183), number of filled spikelet's panicle^{-1} (163), percentage of filled spikelet's (89.4)and grain and straw yields (5138kgha^{-1} and 6836 kgha^{-1}, respectively). A continuous increasing trend was recorded with an increase in potassium level from K_0 to K_{70}. The harvest index efficiency was maximum under K_{40}. In the present study, all parameters showed a positive response to an increase in potassium levels.

Introduction

Rice (*oryza sativa* L.), a staple food for over half of the world's population, holds immense cultural, economic and nutritional significance (De and Dey, 2022; Sitaresmi et al., 2023; Bera and Choudhury, 2023). Rice provides calories to around 40% of the Indian population (Vijay et al., 2013) and plays a crucial role in the nutritional security of the Indians. This crop is the major source of carbohydrates for millions of Asians (Kataoka et al., 2013 and Price and Tomos., 1997). In India, rice occupies an area of 43.9 million ha (m ha). It has an annual production of 117.94 m tons and a 2576 kg ha^{-1} productivity (GoI., 2021). In the year 2021, *kharif* rice cultivated area in India was 41.43 m ha, which decreased to 39.38 m ha in 2022 (Ministry of Agriculture & Farmer's Welfare., 2022). Odisha ranked 8th as rice rice-growing state of the country, with an acreage of 3.77 mha, production of 6.55 million tons and productivity of

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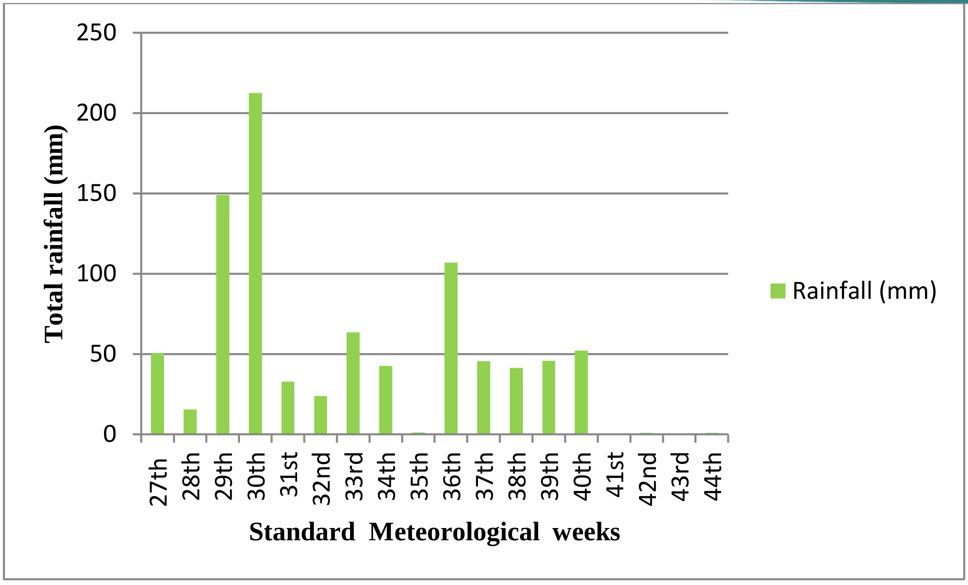

Figure 1. Distribution of weekly total rainfall during the crop growing period.

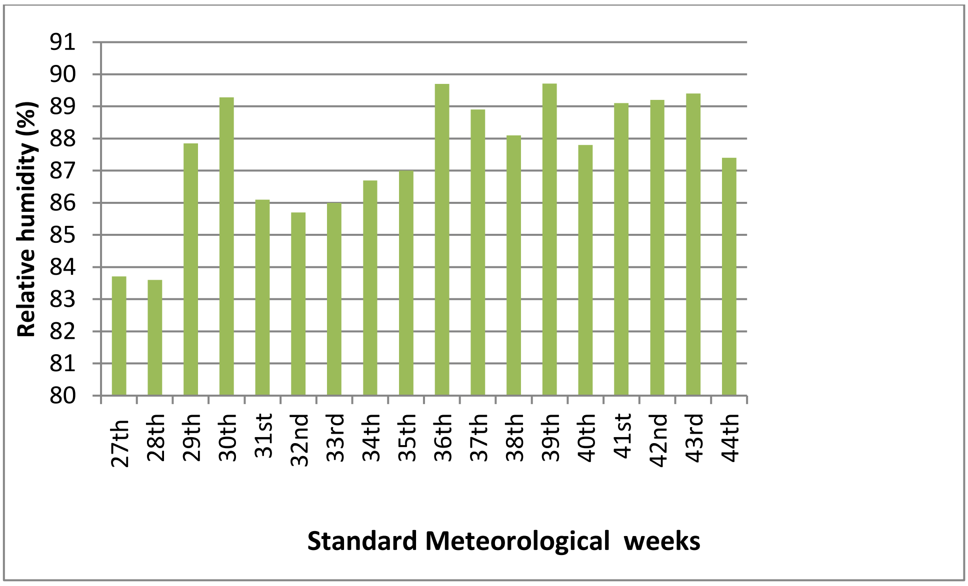

Figure 2. Distribution of weekly mean relative humidity during the crop growing period.

1.74 t ha^{-1}(GoO., 2020). In Gajapati district cultivated area, production and productivity of rice are respectively 0.3755 million ha, 0.33 million tons and 883 kg ha^{-1} (GOI., 2021). In India, 65% of rice production comes from a rainfed ecosystem during the rainy season, and Odisha contributed around 5% of the total (GOI., 2021).

In India, as most rice areas contribute to rice yield during the rainy season, climate, in general, and rainfall, in particular, play a crucial role in rice yield (Kumar, 2001). The occurrence of early drought in the monsoon season restricts farmers from going into time for crop transplanting. Such a situation forced the farmers to late-aged seedlings. So, thats why under this situation, yield will also low. Less availability of thermal energy and photoperiod is often responsible for the lower grain yield (Bashir et al., 2010). Date of transplanting significantly affected the yield and yield parameters like number of panicle-bearing tillers per unit area, grains per panicle, plant height, 1000 grain weight etc. of rice (Akram et al., 2007).

To meet the demand for rice by the steadily increasing Indian population, there is a need to increase the total rice production. The productivity level of the presently available high-yielding yielding varieties with existing management practices has reached near a plateau. Therefore, the breeder can go for new genotypes, or agronomists can go for new crop management options to increase yield. Under an agronomic point of view, input management practices play a crucial role. Nutrients are one of the major inputs; specifically, researchers pay attention to nitrogen, Zn, potassium, etc. (Pal et al., 2024). Besides nitrogen, potassium, the most abundant cation in the crop system, provides tolerance to various abiotic stresses like thermal and water (Vijaykumar et al., 2021). Potassium plays a crucial role in photosynthesis, activation of enzymes, osmoregulation, synthesis of protein, ion homoeostasis and built stability between

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monovalent and divalent cations (Kanai et al., 2007; Amtmann et al., 2008). A long back, Sekhon (1999) reported that potassium activates around 60 enzymes that actively participate in plant metabolism, thus regulating rice growth and yield. By ensuring optimum potassium levels, farmers can enhance crop yield, improve plant vigor and increase resistance to water stress. Potassium is considered next to Nitrogen (N) as regards to its role in rice production because rice usually uptake more K than N. Analysing K levels in rice grains is important for assessing the nutritional quality of rice and ensuring food security and health of the consumers. The K requirement of rice crops varies depending on their growth stages. Rice plants have higher K demands for root development and early shoot growth during the early growth stages. K becomes crucial for grain filling and quality as the plants progress to reproductive stages. Adjustments to potassium fertilization in its dose at a proper amount with its split application positively impact vegetative growth, the status of yield attributes and yield of rice. Considering the above situation, a field experiment was designed to assess the performance of rice crops under a wide range of potassium levels.

Materials and Methods

The field experiment was conducted at Post Graduate Research Farm, M.S. Swaminathan School of Agriculture, Gajapati district, Odisha (18.8053^{0}N latitude, 84.1790^{0}E longitude with an altitude of 65 m above the mean sea level) during *kharif* season of 2023. The experimental crop was transplanted on 5th August, 2023 and harvested on 4th November, 2023. The soil of the experimental field was loam. The experiment was laid out in randomized block design (RBD) with eight potassium levels as: K_0(control) 0 Kg K ha^{-1}, K_{10}:10 Kg K ha^{-1}, K_{20}: 20 Kg K ha^{-1},K_{30}: 30 Kg K ha^{-1}, K_{40}: 40 Kg K ha^{-1}K_{50}: 50 Kg K ha^{-1}, K_{60}: 60 Kg K ha^{-1}:, K_{70}: 70 Kg K ha^{-1}. Rice genotype Shatabdi was the test crop that was transplanted in 20 cm x 15 cm spacing, and all the recommended agronomic practices were practised to raise the crop successfully. The recommended fertilizer dose of 80:40: 40 kg ha^{-1} N: P_2O_5: K_2O and the sources of fertilizers were Urea (N), SSP (P_2O_5), and MOP (K_2O). The data were analysed statistically by following the standard ANOVA techniques. The difference between the treatment means was tested for their statistical significance with appropriate critical difference (CD) values at 5% significance level (Gomez and Gomez., 1984).

Results and Discussion

Effect of Potassium doses on the growth parameters

Different levels of potassium play a crucial role in growth parameters such as dry matter accumulation (g m^{-2}), number of tillers per m^2 and leaf area index. The significantly highest growth parameters were recorded in application of 70 kg ha^{-1} potassium with a recommended dose of nitrogen and phosphorus recorded the maximum growth parameters which might be attributed to the fact that different doses of potassium and, as a result, all the growth parameters increased due to sufficient availability of potassium and nutrient uptake. The application of potassium resulted in the lowest growth parameters.

The number of tillers in rice is an important agronomic characteristic that directly affects its productivity and yield. Number of tillers of the crop increased significantly, reaching its highest at 60 DAT. The application of 70 kg K ha^{-1} with recommended dose of N and P_2O_5 recorded the maximum number of tillers m^{-2} (191) at 30 DAT, which was statistically at par with 60 kg k ha^{-1}. Application of 70 kg k ha^{-1} with recommended dose of N and P2O5 recorded the highest number of tillers m^{-2} (350) at 60 DAT followed by 60 kg k ha^{-1} with a recommended dose of N and P_2O_5. At 30 & 60 DAT, the lowest number of tillers (136,274, respectively) were recorded in the control plot. The possible reason for this result is that an adequate potassium supply promotes tillers' formation and growth in rice plants (Phyo et al., 2024; Vinothkumar et al., 2021; Akanda et al., 2009).

Dry matter accumulation is critical to rice crop growth and development, as it reflects the crop's overall biomass production and potential yield. The application of 70 kg K ha^{-1} with the recommended dose of N and P_2O_5 recorded the maximum dry matter accumulation (300) at 30 DAT which was statistically at par with 60 kg k ha^{-1}. Application of 70kg k ha^{-1} with recommended dose of N and P_2O_5 recorded the highest dry matter accumulation (628) at 60 DAT followed by 60 kg k ha^{-1} with recommended dose of N and P_2O_5. At 30 & 60 DAT, the lowest number of tillers (245,509, respectively) were recorded in control (Devi et al., 2020; Zhang et al., 2014).

At 30 DAT, the highest leaf area index (2.92) was recorded with 70 kg K ha-1 application. The lowest leaf area index(0.58) was recorded in the control plot. At the peak growth stage(60 DAT), The application of 70 kg K ha^{-1} with a recommended dose of N and P_2O_5 recorded the maximum leaf area index (5.2), followed by the application of 60 kg k ha^{-1} at 60 DAT. The lowest leaf area index(2.3) was recorded in the control plot. Due to

Table 1. Impact of potassium levels on growth parameters of rice crop.

Potassium levels, (kg ha^{-1})	Number of tillers m^{-2}			Leaf area index			Dry matter Accumulation (g m^{-2})		
	30 DAT	60 DAT	Harvest	30 DAT	60 DAT	Harvest	30 DAT	60 DAT	Harvest
K_0	136	274	188	0.58	2.3	1.0	245	509	408
K_{10}	147	287	192	1.03	2.7	1.8	240	517	469
K_{20}	148	290	205	1.16	3.5	2.1	247	520	510
K_{30}	156	298	217	1.24	3.4	2.1	290	595	525
K_{40}	159	325	227	1.35	4.0	2.2	285	603	568
K_{50}	186	330	240	1.47	4.4	2.8	294	613	672
K_{60}	188	340	245	2.50	4.8	2.9	298	623	754
K_{70}	191	350	267	2.92	5.2	3.3	300	628	775
S.Em.(±)	10	16	8	0.1	0.2	0.2	13	30	21
C.D	31	49	25	0.3	0.8	0.6	41	91	65

the high amount of potassium, it resulted in an enlarged leaf area that increased the LAI and pushed rice plants to grow faster during the vegetative growth stage and ultimately, it enhanced the leaf area and, consequently the leaf area index in Rice crops (Zayed et al., 2007).

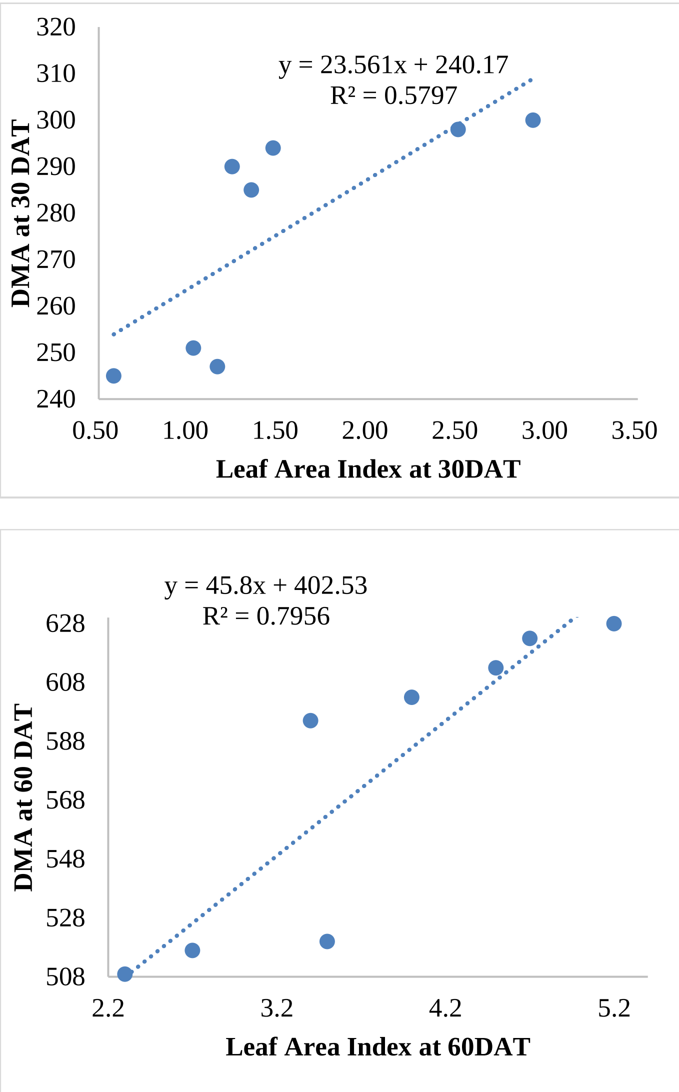

Figure 3. Regression between dry matter accumulation and leaf area index at 30 DAT and 60 DAT.

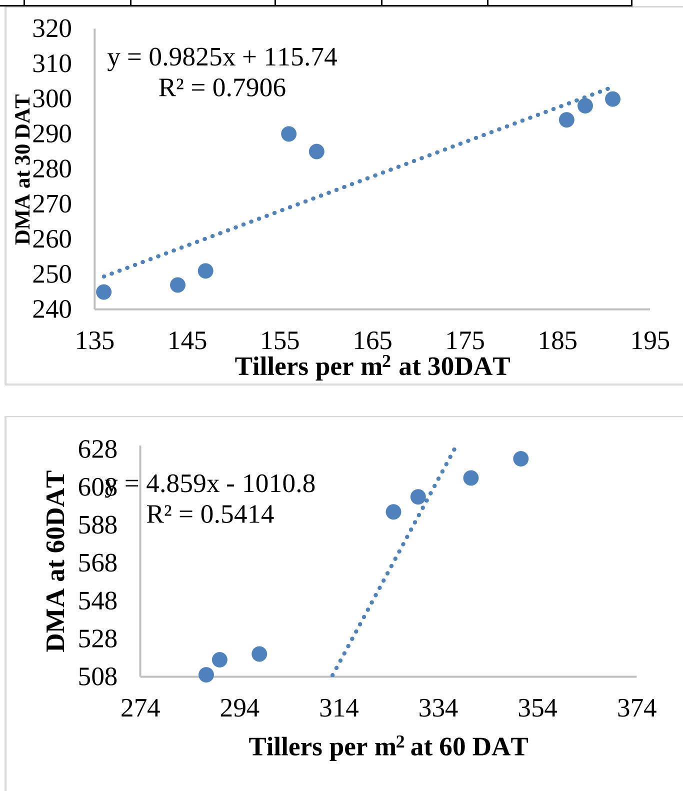

Figure 4. Regression between dry matter accumulation and the number of tillers m-2 at 30 and 60 DAT.

Relationship between crop growth parameter and dry matter accumulation

It is well-known that different crop growth parameters like leaf area index and total tillers number influence the status of dry matter accumulation. In the present study, observations on these plant growth parameters, such as leaf area index and total tillers number, were recorded and efforts have been made to correlate them with that of dry matter accumulation. The relationship was worked separately with different parameters, and it was found that the covariance between the different growth parameters was high in the number of tillers m^{-2} compared to others.

Effect of potassium on the yield attributes

Yield attributes *viz.*, Panicle length (cm), number of panicle meter^{-2}, number of spikelets, number of filled grain panicle^{-1} were influenced significantly with the application of different doses of potassium.

This might be due to increased doses of potassium, which influenced the number of filled grain panicle^{-1} (Ismail et al., 2007).

Grain filling plays an important role in grain weight, which is an essential determinant of grain yield in cereal crops. The application of 70 kg k ha^{-1} with the recommended dose of N and P_2O_5 recorded the highest number of plot-filled grain percentage (89 %), followed by 60 kg K ha^{-1}. The lowest number of panicle m^{-2} (75) was recorded in the control plot. This might be due to Basal application of K showing a positive effect on the percentage of filled grains. Potassium helped in the proper filling of seeds, which resulted in a higher number of plump seeds and thus increased the number of grains panicle^{-1} potassium fertilizer has a positive effect on filled grains in rice, while its deficiency caused pollen sterility and decreased rice-filled grains number. It was found that most of the highest filled grain percentage values have resulted from potassium balanced fertilization (Zhang et al., 2014 ; Oo et al., 2024).

Table 2. Impact of potassium levels on yield attributes of rice crop.

Potassium levels (kg ha^{-1})	No. of panicles m^{-2}	Panicle length(cm)	No.of Spikelet's panicle^{-1}	No.of filled grain panicle^{-1}	Filled grain percentage (%)
K_0	238	17	82	62	75
K_{10}	243	19	131	105	81
K_{20}	244	20	153	127	83
K_{30}	249	21	166	140	84
K_{40}	291	21	175	148	85
K_{50}	330	22	178	154	86
K_{60}	337	27	181	158	87
K_{70}	351	29	183	163	89
S.Em.(±)	17	1	7	4	4
C.D	52	3	24	14	13

The application of 70 kg k ha^{-1} with recommended dose of N and P_2O_5 recorded the highest number of panicle meter^{-2} (351), followed by 60 kg K ha^{-1}. The lowest panicle m-2 (238) was recorded in the control plot. The probable reason for the enhancement of the number of panicles per unit area due to the application of a sample dose in comparison to the application of treatments might be due to nutrient availability, particularly potassium (K_2O), which plays a significant role in promoting panicle development and the number of panicles per unit area in rice (Banerjee et al., 2018 ; Mondal et al., 2015).

At harvest, the highest Panicle length (29.67 cm) was recorded with the application of 70 kg K ha$^{-1,}$ which is statistically at par with 60 kg K ha^{-1}. The lowest panicle length (17.33 cm) was recorded in the control plot. This might be attributed to physiological stimulation for increasing the panicle length and the lowest panicle length is due to nutrient deficiencies or imbalances that can lead to reduced panicle elongation, shorter panicles, and decreased yield potential. (Kurmi et al., 2022; Talukdar et al., 2000 ; Aminah et al., 2019).

In the current study 70 kg K ha^{-1} increased the number of spikelets panicle^{-1}(183), followed by 60 kg K ha^{-1}. The lowest number of spikelets panicle^{-1} (82) was recorded in the control plot. This might be due to the increasing rate of potassium increasing the number of spikelets panicle-1and due to the unavailability of nutrients in the control plot, resulting in fewer spikelets panicle^{-1} (Uddin et al., 2013).

At harvest, the maximum No.of filled grain panicle^{-1} (163) was recorded with the application of 70 kg K ha$^{-1,}$ which is statistically at par with 60 kg K ha^{-1}. The lowest panicle length (62) was recorded in control plot.

Effect of potassium levels on the yield

Yield parameters include grain yield, straw yield and harvest index. Potassium levels had a significant influence on the yield parameters.

Yield is the function of all the growth parameters application of Potassium with 70kg K ha^{-1} had recorded the maximum value of yield viz., grain yield (5138) due to proper availability of nutrients, the dry matter accumulation leaf area index as well as number of tillers per m^2 was highest which resulted in higher grain yield. Lowest was found in the control plot (3519) due to less availability of potassium and it ultimately reduced photosynthesis and translocation of carbohydrates from source to sink (Zayed et al., 2007; Birla et al., 2020; Ismail et al., 2007; Khan et al., 2024). The straw yield of rice crops, which refers to the above-ground biomass remaining after harvesting the grains, is an important aspect to consider in agricultural production. The straw

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yield recorded in each plot after harvesting, threshing and drying in the sun was analysed. The straw yield was found to be maximum with the application of 70kg ha^{-1} K (6836) and it was closely followed by the treatment with the 60kg ha^{-1} K_2O and as per expectation the lowest straw yield was found in control plot (5264), this might be due to increased metabolic activities such as photosynthesis, enzymatic activity etc. (Islam et al., 2015; Huang et al., 2024).

The harvest index of rice did not show any significant effect among the potassium doses the maximum harvest index was found with the application of 70 kg K ha^{-1}(44.5), followed by 60kg K ha^{-1} and the lowest was found in the control plot (40.0) (Islam et al., 2015; Darthiya et al., 2021 ; El-Rafaey et al., 2024).

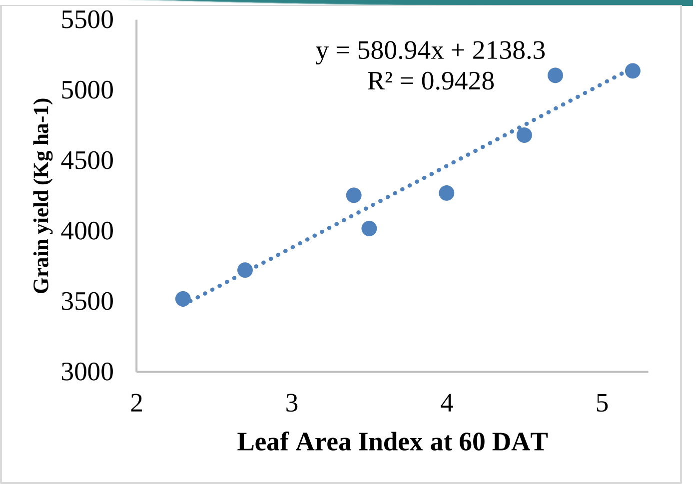

Figure 5. Regression between grain yield and leaf area index at 60 DAT.

Table 3. Impact of potassium levels on yield of rice crop.

Potassium levels (kg ha^{-1})	Grain yield	Straw yield	Harvest Index
	kg ha^{-1}		%
K_0	3519	5264	40.0
K_{10}	3723	5628	39.7
K_{20}	4018	5778	40.8
K_{30}	4254	5946	41.5
K_{40}	4271	6124	41.0
K_{50}	4681	6376	42.4
K_{60}	5105	6516	43.9
K_{70}	5138	6836	44.5
S.Em.(±)	225	273	1.4
C.D	682	831	NS

Relationship between crop growth parameter and yield

It is well-known that different crop growth parameters like plant height, leaf area index and total tiller number and yield attributes influence Yield's status. In the present study, observations on three plant growth parameters e.g., plant height, leaf area index and total tiller number a were recorded and efforts have been made to correlate them with that of Yield. The relationships have been workout. It was found that the covariance was high in the dry matter production parameter compared to all other parameters.

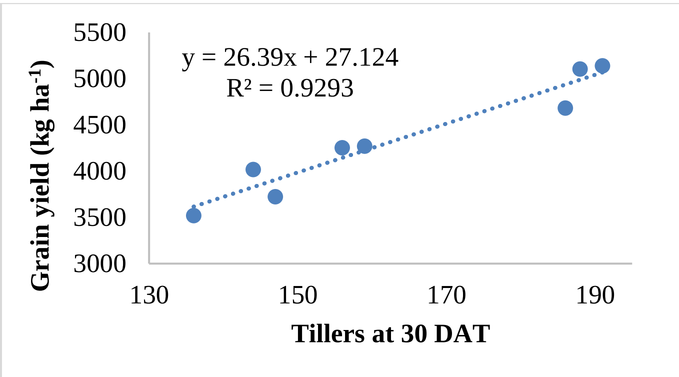

Figure 6. Regression between grain yield and tillers at 30 DAT.

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Conclusion

From the present study it is concluded that treatment consisting of 70 kg K $ha^{-1}(K_{70})$ resulted in the highest growth parameters, yield attributes as well as yield, which remain statistically at par with K_{60} and as well as it is statistically at par with the K_{50}. Electromagnetic radiation's reflective and absorptive property attains the highest level under 70 kg ha K_2O. So, that soil potassium availability and plant potassium content recorded maximum values when 70 kg ha K_2O was applied per hectare.

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Conflict of interest

The is no conflict of interest between authors.

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