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Partial Substitution of Soil-applied Potassium with Nano-Potassium for Enhancing Grain Yield of Kharif Rice (*Oryza sativa*)

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ABSTRACT

A field experiment was conducted with the objective of enhancing the grain yield of Kharif rice by substituting soil-applied potassium with nano-potassium. The result revealed that significantly highest mean total chlorophyll content (3.5 Mg/g), potassium content of leaves (2.61%), root length (16.4 cm) root volume (20.22 cc), plant height (116 cm), panicle length (22.2cm), panicles/hill (7.1), spikelet/panicle (119), filled grains/panicle (92) and test weight (25.4gm) was recorded with T_5 [100% of soil test dose (STD)+ Twice foliar spray of Nano K at 14 and 28 days after transplanting (DAT)]. This treatment (T_5) also recorded the highest grain yield of 2570 kg/ha and straw yield of 3469 kg/ha as compared to T_2 (Nitrogen and phosphorus were applied as per 100% of STD) having the grain and straw yield of 2494 and 3367 kg/ha respectively. Similarly, the grain and straw yield of 2421 and 3178 kg/ha was recorded with T_6 (100% STD for N&P + 75% STD for K + twice foliar spray of nano-K at 14 and 28 DAT) which was not significantly lower than that of T_2. The highest K content (0.48% in grain, 2.35% in straw) and K uptake (12.22 kg/ha in grain, 81.5 kg/ha in straw) was recorded with T_5 which was not significantly higher than that of T_6. The grain and straw yields were not significantly reduced with T_6, indicated that reduction of soil-applied potassium by 25% was effectively managed with twice foliar application of nano-K without sacrificing yield.

Key words: Rice, chlorophyll content, foliar application, nano-potassium

INTRODUCTION

It has been reported that yields of many crops have stagnated because of imbalanced fertilization and decline in organic matter content of soils. The fertilizer response in the irrigated areas of the country has decreased for which more amounts of fertilizers are required to get the same economic yield. Application of inorganic fertilizers through soil or foliar application for management of nutrient deficiencies is one of the easiest and quickest methods. Reduction in nutrient use efficiencies through inorganic fertilizers are associated with higher nutrient losses such as leaching, immobilization and volatilization etc. minimization of nutrient losses from soil may be reduced to target extent by foliar application of nutrients which is the fastest way to boost up the crop growth by improving the nutrients availability to plants at different critical stages as and when required. Sole foliar fertilization is not enough to maintain the requirement of plant for which it can be applied as complementary amount with soil fertilization (Fageria *et al.,* 2009). Foliar fertilization will work as a visible economic way to supplement the plant with required nutrients for more efficient and effective utilization of specific nutrients (Girma *et al.*, 2007). Foliar application is credited with the advantage of quick and efficient utilization of nutrients, reduction of losses as well as regulating the uptake of nutrients by plant (Manonmani and Srimathi, 2009). If foliar fertilization is mixed with post emergence herbicides, insecticides or fungicides, the probability of yield response could be increased, and cost of application can be decreased.

Water soluble inorganic fertilizers are effectively applied to the crop as foliar spray (Monica *et. al.,* 2020). Potassium is an important nutrient element for the plants which needs to be applied in sufficient amount to produce healthy and productive crop (Fairhurst *et al.,* 2007).

Nano fertilizers are the nano sized particles contain specific nutrient which was applied as foliar application for getting maximum plant growth by stimulating the plant capability with higher use efficiency, increasing the availability of plant unavailable nutrients in the rhizosphere, as well as applied on real time basis for effective and efficient utilization by plot. The safe and sustainable application of nano fertilizers in agriculture depends upon the standardization of the materials, their method of application well as their effect on soil and water used for agricultural activity. Highest no. of leaves/plant, leaf length and chlorophyll content were recorded due to basal application of nano potassium in the form of Zeolite along with kale than that of basal application conventional fertilizer along with top dressing (Li *et al.* 2013). Application of nano-K fertilizer at the rate of 20 kg K_2O ha^{-1} showed significant increase in grain yield over 0 kg K_2O ha^{-1} in rice. The grain yield was increases due to application of nano-K-fertilizer than that of MOP at 20 kg K_2O ha^{-1} (Sirisena *et al.,* 2013). It was also observed that information related to standardization of potassic nano fertilizers is very less in Odisha. So, attempt has been made in present investigation to study the effect of foliar application of nano potassium on yield and yield attributing characters of rice.

MATERIALS AND METHODS

Study site

The study was carried out in Regional Research and Technology Transfer Station, Coastal Zone, Odisha University of Agriculture and Technology, Bhubaneswar**.**

Physico-chemical properties of soil

The soil of the experimental site was characterized by sandy loam (Sand 70.4 %, Silt 14.5 % and clay 15.1%), acidic soil reaction (pH: 5.2), non-hazardous salt content (0.004 dS m^{-1}), low organic carbon content (4.35 g kg^{-1}), low in available N (223 kg ha^{-1}), low in available P (2.2 kg ha^{-1}) and low in available K (68 kg ha^{-1}).

Treatments and experimental design

This field experiment was carried out with randomized block design (RBD) with 3 replications along with following 7 treatments (**Table 1**). The treatments are T_1: Control (No potassium), T_2: The nitrogen and phosphorus were applied as per 100% of STD, T_3: 100 % of STD for K + Once foliar spray (FS) of water at 14 Days after transplanting (DAT), T_4: 100 % of STD for K + Once FS of Nano K at 14 DAT, T_5: 100 % of STD for K + Twice FS of Nano K at 14 and 28 DAT, T_6: 75 % of STD for K + Twice FS of Nano K at 14 and 28 DAT, T_7: 50 % of STD for K + Twice FS of Nano K at 14 and 28 DAT. Rice (CV-Mandakini) was sown in the nursery bed with proper management and care. The main experimental field was divided into 21 plots for imposition of treatments. The nitrogen and phosphorus were applied in form of urea, DAP as per 100% 0f STD (75: 37.5: 37.5) to all treatments whereas MOP was applied as per the experimental plan. The nitrogen was in three splits viz, 25% basal, 50% at active tillering stage and 25% at panicle initiation stage where as phosphorus was applied as 100% basal in each plot in form of DAP. Nano Potassium was applied as foliar spray on the rice plant as per the treatment plan.

Table 1. Treatment

Treatment	Treatment details
T_1	Control (No potassium)
T_2	100 % of Soil Test Dose (STD) (75:37.5:37.5) for K
T_3	100 % of STD for K + Once foliar spray (FS) of water at 14 Days after transplanting (DAT)
T_4	100 % of STD for K + Once FS of Nano K at 14 DAT
T_5	100 % of STD for K + Twice FS of Nano K at 14 and 28 DAT
T_6	75 % of STD for K + Twice FS of Nano K at 14 and 28 DAT
T_7	50 % of STD for K + Twice FS of Nano K at 14 and 28 DAT

Laboratory and statistical analysis

Leaf samples were collected from all plots before application of nano potassium as well as 7 days after application to determine the total chlorophyll. Plant protection measures were taken as and when required. Grain and Straw yield of each field was recorded and analyzed statistical by as outlined by Gomez and Gomez (1984). Soil samples were collected after harvest of rice crops. Composite soil sample was collected from each experimental plot before initiation of experiment and from different treated plots after completion of the experiment for analysis of different parameters as per the standard procedure. Neutral normal ammonium acetate method was employed to estimate the available K_2O content of the soil sample (Page *et al.,* 1982). The length of the root was determined in centimetre from the base to the tip of root using ruler. The root volume was measured by putting the entire root into a measuring cylinder containing water and determining the increase of water level inside the cylinder and expressed as cm^3 $hill^{-1}$ (Bridgit *et al.*, 2002).

RESULT AND DISCUSSION

Total chlorophyll content of rice leaves collected at different growth stages

Total chlorophyll content of rice leaves was determined at 27, 34, 41 and 48 days after transplanting (DAT) represented and in (**Figure 1**). It was observed that the highest mean total chlorophyll content of 3.61, 5.0, 5.08, and 3.49 mg g^{-1} of fresh weight was recorded at 27, 34, 41 48 DAT respectively with T_5 which was at par with the values of 2.91, 4.32, 4.54, and 2.93 mg g^{-1} recorded with T_6 at different growth stages. This might be due to increase in vegetative growth up to 41 DAT and there after decline in vegetative growth reduces the chlorophyll content during reproductive stages of rice. This result in line with result reported by Rose *et al*. (2015), Al-Shahmani *et al*. (2022) and Devi *et al.* (2023).

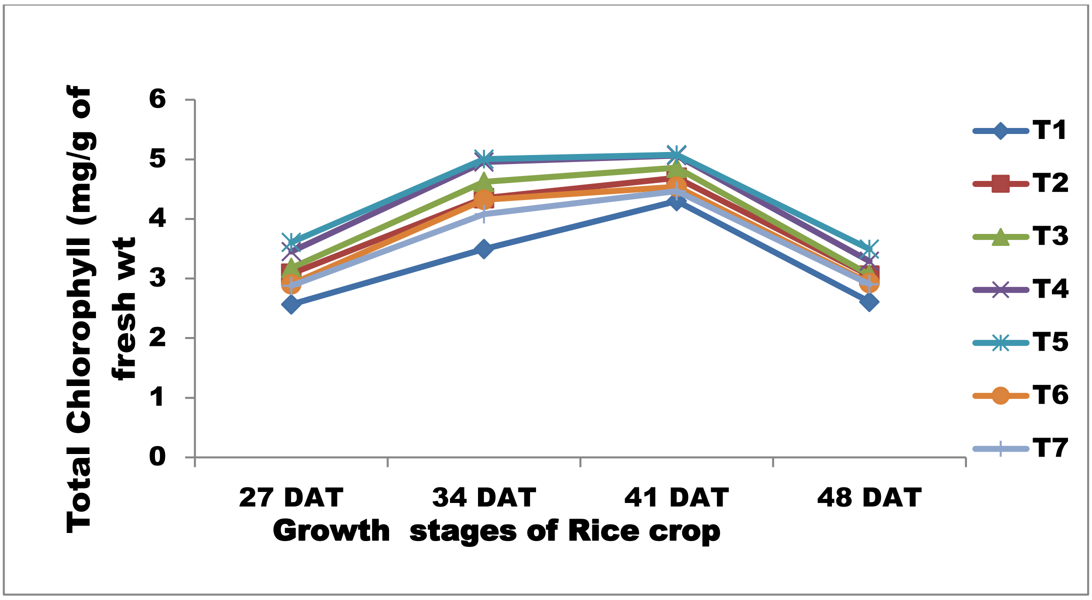

Figure 1. Total Chlorophyll content (mg/g of fresh weight) of rice leaves at different growth stages

Effect of foliar application of nano-potassium on growth and yield attributing characters of rice

The yield attributing characters of rice due to foliar application or nano potassium was recorded and presented in **Table 2**. Significant mean highest plant height of 117.2 cm was observed with T_4 which was statistically at par with the value of 116.2, 115.4 cm of T_5 and T_6 but significantly more than T_2. The highest panicle length of 22.93cm was observed with T_7 which was at par with the 22.13cm and 22.53cm for T_5 and T_7 respectively. The significantly highest value for panicles per hill of 7.07 was observed with T_5 which was statistically at par with value of 6.47 in T_4 and T_6 respectively. Significantly highest spikelet per panicle value of 119.3 was recorded with T_5 which was at par with T_6 and T_7. This might be due to effect of Nano K which increased translocation of assimilates from source to sink, as potassium was directly involved in biosynthesis and translocation of sugars (Sirisena *et al.*, 2013; Mehrdad *et al.,* 2017).

The highest root length of 16.4 cm was recorded with T_5 found statistically at par with all other treatments except T_1 and T_3. Significantly highest root volume of 20.22 cc was recorded with T_5 followed by 17.69 cc in T_6 and 17.15 cc in T_7 respectively. It showed that root properties were enhanced by interactions between K and N. As a result, we hypothesized that a balanced fertilization supply might enhance root development (Kaysar *et al.,* 2023). Moreover, the filled grains/ panicle ranged from 84.7 to 92.4. Significantly highest mean value of 92.4 for filled grains/ panicle of 92.4 was observed with T_5 which was at per with the value of 90.08 for filled grains/ panicle with T_6 followed by the value of 88.2 ,84.3 % for T_2 and T_7 respectively. Unfilled grains/ panicle indicated the similar trend with significant highest value of 9.7 % with T_6 followed by T_5 in the value of 8.6 %. Result indicated that significantly highest mean value of 25.4g was observed with T_5 whereas lowest value of 22.7g was observed with T_1. Mean 1000 seed weight due to imposition of different treatments was non-significant statistically. However, mean 1000 seed weight was slightly decreased due to reduced potassium application at T_6 (25.1g) and T_7 (24.4g) than that of T_5 (25.4g).

Table 2. Effect of foliar application of nano-potassium on yield attributing characters of rice

Treatments	Plant height (cm)	Panicle length (cm)	Panicles/ hill	Filled grains/ panicle (%)	1000 seed weight (g)	Root length (cm)	Root length (cc)
T_1	108.7^{a}	21.13	4.53^{a}	83.70	22.67^{a}	12.5^{a}	8.81^{a}
T_2	112.8^{b}	21.33	6.0^{d}	88.22	24.87^{e}	15.6^{efg}	14.55^{d}
T_3	114.2^{c}	21.73	5.93^{cde}	90.17	24.7^{bc}	14.7^{bc}	13.94^{cd}
T_4	117.2^{fg}	22.20	6.47^{ef}	91.28	24.77^{bcd}	15.7^{f}	17.15^{ef}
T_5	116.2^{ef}	22.13	7.07^{f}	92.36	25.43^{g}	16.4^{g}	20.22^{g}
T_6	115.4^{cde}	22.53	6.47^{ef}	90.77	25.07^{fg}	15.3^{dfg}	17.69^{f}
T_7	114.5^{cde}	22.93	5.07^{ab}	84.26	24.37^{bc}	14.9^{cdef}	12.23^{bc}
CD (0.05)	1.8	NS	0.83	3.62	1.03	1.6	2.14
SEM (±)	0.59	NS	0.27	1.21	0.34	0.53	0.69

The result indicated that higher yield attributing characters was recorded with T_5 (100% of STD + Twice foliar spray of Nano K at 14 and 28 DAT) than that of T_2 (100% of STD) due to combined application of nano potassium along with twice foliar application of nano-K which facilitates more k availability in root zone, higher nutrient absorption through longer root growth and nutrient translocation inside the plant. Number of filled grains/panicle and 1000 grain weight was increased due to more availability of potassium. Reduction of soil applied potassium amount by 25% (in T_6) and 50% (in T_7) recorded slightly reduction in yield attributing characters because of less potassium availability in rhizosphere. The yield attributing characters was not reduced significantly due to application of T_6 (100% of STD for N&P + 75% of STD for K + Twice foliar spray of Nano-K at 14 and 28 DAT) whereas these values were significantly reduced when potassium was applied @50% of STD (T_7). Irrespective of soil applied nutrients, application of twice foliar spray of nano-K (T_5) recorded higher yield attributing characters than that of once foliar spray of nano-K (T_4). Experimental result revealed that application of more potassium for longer period provide a conducive environment for effective and efficient utilization of potassium for improvement of different yield attribute parameters. This result corroborated with the result of Lemraski *et al.* (2017), Chavan *et al.* (2019) and Al-Shahmani *et al.* (2022).

Effect of foliar application of nano- potassium on yield of rice

Significantly highest grain and straw yield of 2569.6 and 3468.9kg ha^{-1} respectively (**Table 3**) was recorded with T_5 than that of all treatments but it was found statistical at par with T_2 (2493.9 and 3366.7 kg ha^{-1}), T_3 (2520.4 and 3040.5 kg ha^{-1}) and T_4 (2555.4 and 3449.8 kg ha^{-1}), whereas lowest value of 1724.57 kg ha^{-1} was recorded with T_1 (control). Similarly, the grain and straw yield of 2420.6 and 3177.8 kg ha^{-1} respectively was observed with T_6 which was at par with T_2. The highest harvest index of 42.5 % was recorded with T_4, T_5, T_6 and T_7.

Reduction of rice grain yield was non-significant due to imposition of T_6 than that of T_2 whereas reduction was significant due to imposition of T_7 (soil applied K with 50% of STD). Rice grain yield due to imposition of T_3, T_4 and T_5 was not increased significantly than T_2. Straw yield was increased non- significantly due to imposition of T_3 and T_5, whereas straw yield was reduced significantly due to T_6 and T_7 than that of T_2.

Combine application of soil nutrients with nano-K foliar spray (T_5) outperformed sole soil nutrient application, might be due to more and prolonged potassium supplementation. Nano-K applied via leaves facilitated efficient nutrient uptake and photosynthate translocation. Grain yield was not significantly affected by T_6 (75% K + nano-K foliar) as compared to T_2 (100% soil nutrients), possibly due to effective potassium utilization from foliar application. This highlights the effectiveness of foliar nano-K supplementation in enhancing grain production despite reduced soil nutrient application. Results showed that twice foliar application of nano-K for longer periods increased grain yield compared to once. Highest harvest index of 42.5% (**Table 3**) was recorded with T_4, T_5, T_6 and T_7 due to more grain yield and proportionately less straw yield as compared to other treatments.

Table 3. Effect of foliar application of nano-potassium on yield of rice

Treatments	Seed yield (kg/ha)	Straw yield (kg) /ha)	Harvest index (%)
T_1	1724.6^{a}	2328.2^{a}	41
T_2	2493.9^{de}	3366.7^{d}	42
T_3	2520.4^{ef}	3402.5^{efg}	42
T_4	2555.4^{fg}	3449.8^{fg}	42.5
T_5	2569.6^{g}	3468.9^{g}	42.5
T_6	2420.6^{cd}	3177.8^{c}	42.5
T_7	2210.3^{b}	2983.9^{b}	42.5
CD (0.05)	86.88	104.22	
SEM (±)	28.97	34.75	

The lowest value of 41% was recorded with T_1 indicating less grain yield and proportionately less straw yield. This result is corroborated with the findings of Dissanayake *et al.* (2012) and Rose *et al.* (2015). Potassium is supplied through nano K increased the synthesis and indirectly, enhanced translocation from source to sink as indicated by Al-Shahmani *et al.* (2022) and Al-Badiri *et al.* (2022).

Effect of foliar application of nano-potassium on total Potassium uptake by rice

From the result shown in Table 4, it was revealed that, significantly highest Potassium content of 0.48 and 2.35% was recorded in grain and straw respectively with T_5 whereas lowest value of 0.40 and 1.73% for grain and straw respectively was recorded with T_1 (control). Grain Potassium content of 0.48% was recorded with T_5 which was also significantly higher than that of T_4 (0.45 %), T_6 (0.42%) and T_7 (0.41) whereas statistically at par with T_2 (0.43%) and T_3 (0.44). The Potassium uptake by rice grain and straw was calculated for different treatment plots by multiplying Potassium content of each treatment with grain and straw yield of rice. Total K uptake was calculated by adding the uptake of K by rice grain and rice straw. The K content, uptake by grain and straw as well as total K uptake was presented in table 7. Significantly the highest total potassium uptake of 93.7 kg ha^{-1} was recorded with T_5 (100 % of STD for K + Twice FS of Nano K at 14 and 28 DAT) whereas the lowest value of 47.2 kg ha^{-1} was recorded with T_1 (control). Total potassium uptake of 78.2, 81.3 and 87.1 kg ha^{-1} was recorded with T_2, T_3 and T_4 respectively which are non-significant with each other but all the values are significantly higher than T_1 (control). Total potassium uptake of 65.9 kg ha^{-1} was recorded with T_6 which 75% of RDF for K was applied in soil which was non-significantly higher with the value of 61.3 kg ha^{-1} recorded with T_7 where 50% RDF for K was applied in soil as well as T_1 where no potassium was applied.

The potassium content and uptake were increased with increase in foliar application of nano K as compared to soil application due to more available of k to plant as nanoparticles possess dynamic properties like high surface area, activity, and catalytic surface, enabling rapid chemical reactions and water adsorption. Studies reveal their entry into plant cells via stomatal or vascular systems. This aligns with Fageria *et al.* (2010), Chavan *et al.* (2019) and Al-Shahmani *et al.* (2022).

Table 4. Effect of foliar application of nano-potassium on Potassium content (%) and uptake(kg/ha) of rice

	K content (%)		K uptake (kg/ha)		
Treatments	**Grain**	**Straw**	**Grain uptake**	**Straw uptake**	**Total uptake**
T_1	0.4^{abc}	1.73	6.9^{a}	40.3^{abcd}	47.2
T_2	0.43^{def}	2.00	10.9^{de}	67.3^{defg}	78.2
T_3	0.44^{ef}	2.07	10.9^{ef}	70.4^{efg}	81.3
T_4	0.45f	2.19	11.5^{f}	75.6^{fg}	87.1
T_5	0.48^{g}	2.35	12.22^{g}	81.5^{g}	93.74
T_6	0.42^{c}	1.76	10^{c}	55.9^{cdef}	65.9
T_7	0.41^{bcd}	1.75	9.1^{b}	52.2^{bcd}	61.3
CD (0.05)	0.025	NS	0.60	28.40	28.72
SEM (±)	0.008	-	0.21	9.45	9.57

CONCLUSION

Grain yield due to application of K + 75% of STD for K + Twice foliar spray of Nano-K at 14 and 28 DAT was reduced non significantly due to application of 100% of STD for K indicated that the 25% of inorganic potassic fertilizer as per soil test dose can be substituted by twice foliar spray of nano-K at 14 and 28 DAT without sacrificing the grain yield. From the above-mentioned study, it may be concluded that combine application of granular fertilizer along with nano K has a great impact on growth, yield and nutrition quality of rice.

CONFLICT OF INTERESTS

The authors declare that no conflict of interest exists.

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