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Impact of Integrated Nitrogen Management Practices on Nutrient Content and their Uptake by Transplanted Rice Crop (*Oryza sativa* L.)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Aim: Nitrogen is very crucial for production of rice and recently the uses of chemical fertilizers are increased for rice production, which are ruining our soils and environment. So, to evaluate the effect of integrated nitrogen management practices on nutrient content and their uptake by transplanted rice crop this study was conducted.
Study Design: Randomized block design.
Place and Duration of Study: One year field experiment at Research farm, School of Agriculture, Abhilashi University, Chail Chowk, Mandi, (H.P.).

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Methodology: The field study was conducted with eight treatments and three replications. The different treatments combinations were T_1 (absolute control), T_2 [100% RDN through Chemical Fertilizer (CF)], T_3 (75% RDN through CF + 25% N through FYM), T_4 (75% RDN through CF + 25% N through poultry manure), T_5 (75% RDN through CF + 25% N through vermicompost), T_6 (50% RDN through CF + 50% N through FYM), T_7 (50% RDN through CF + 50% N through poultry manure), T_8 (50% RDN through CF + 50% N through vermicompost).

Results: The study of results revealed that the nitrogen, phosphorus and potassium content in grains and straw of rice crop showed non-significant differences with the application of nitrogen through various treatments, while the maximum contents of these nutrients were higher in treatment T_2. However, the significantly highest uptake of nitrogen, phosphorus and potassium by grains and straw and total uptake of these nutrients by rice was noted in treatment T_2 which was statistically ($P = .05$) at par with treatment T_4 and T_5. Whereas, the minimum content in grains and straw and uptake of these nutrients by grains and straw along with their total uptake was found under control treatment.

Conclusion: This study suggests that the use of integrated nitrogen management enhances the nitrogen, phosphorus and potassium content and their uptake by rice crop.

Keywords: Rice; chemical fertilizer; poultry manure; vermicompost; nutrient content and nutrient uptake.

1. INTRODUCTION

"Rice (*Oryza sativa* L.) is the most important crop in the developing world and is the staple food of over half the world's population. For 40% of the world's population, it is their primary source of calories" [1]. "Almost 90% of the total rice is produced and consumed in Asia. Half of the world's population depends primarily on rice, which is farmed in more than hundred countries" [2]. "Rice is an excellent food and an excellent source of carbohydrates and energy. It is a high calorie food which contains carbohydrates, protein, fat, cellulose and ash. In Asia, more than two billion people are getting 60-70% of their energy requirement from rice and its derived products" [3-6]. "Rice is cultivated in approximately 120 countries; China grows 214 million tons and India (about 173 million tons)" [7]. "China was the world leader in rice production in 2019-20, producing 146.73 million metric tons, followed by India with 115.00 million metric tons" [8]. "In India, rice occupies an area of 45.77 million hectares with production of 124.37 million tons with an average productivity of 2717 kg ha^{-1}" [9].

"Nitrogen (N) is the most essential and limiting nutrient element required in large amounts for rice production and provision of adequate supply of N throughout the growing period is essential for realizing potential yields" [10]. Nitrogen promotes rapid plant growth and improves grain yield and quality through higher tillering, leaf area development, grain formation, grain filling and protein synthesis [11] and plays a crucial role in enhancing the yield. "Nitrogen plays a vital role in plant tissues and is a constituent of protein, enzyme, hormone, vitamins, alkaloids and chlorophyll etc. Nitrogen is highly mobile both in the plants and soil. Within a certain range, increased nitrogen fertilizer increase net photosynthesis rate. Nevertheless, too much nitrogen fertilizer causes the photosynthetic capacity decreases. Increasing nitrogen fertilization can enhance the nutritional quality and processing quality of rice" [12].

"Nitrogenous fertilizers are one of the main factors responsible for contributing to increase in rice yield in India. In rice production, farmers apply large amounts of N fertilizer to maximize yield, but only 20-50% of N is taken up by the crop" [13]. "The resulting loss of the applied N, which is a mobile nutrient leads to increased water and land pollution and greenhouse gas (GHG) emissions" [14]. "Continuous use of chemical fertilizers alone causes soil organic matter degradation, soil acidity and environmental pollution" [15]. The increasing fertility of soil and crop productivity through use of chemical or synthetic fertilizers has often negatively affected biogeochemical cycles. Also, usage of fertilizer cause leaching and run-off of nutrients, especially nitrogen and phosphorus results in degradation of environment. Nitrogen (N) can be lost from the soil by leaching, de-nitrification and volatilization. Practice like deep placement of urea super granule (USG), soil incorporation, use of slow release N fertilizer etc., that minimize N concentration in flood water can reduce its loss through runoff.

"Inorganic fertilizer has been shown to degrade soil and improve production rapidly when used during cropping, but not over a long period of time" [16]. "The integration of organic manure with inorganic fertilizers is essential to achieving sustained production of rice and maintains the soil fertility for a longer period" [17]. "Numerous research findings suggest that using nitrogen fertilizer in combination with organic sources can accelerate the process of organic N mineralization and immobilization, hence, lowering nitrogen losses" [18]. "Manures improve soil structure, water holding capacity of soil, organic matter contents as well as microbial populations. Integrated use of organics especially vermicompost, poultry manure, farmyard manure, green manure, neem cake and bio-fertilizers as sources of nitrogen application with inorganic fertilizers improve the growth, yield and yield attributing traits in rice. Poultry manure contains major, secondary and micro nutrients that can support crop production and enhance the physical and chemical properties of soil. It improves soil retention and uptake of plant nutrients" [19]. "Vermicompost is rich in plant nutrients like- nitrogen, phosphorus, potassium, calcium, vitamins, natural phyto-regulators and micro flora in balanced form that helps in re-establishment of the natural fertility of the soil" [20]. "Optimal crop yields and long term soil productivity may be maintained with the combined application of organic manures and inorganic fertilizers" [21]. "Integration of nutrients from organic manures and chemical fertilizers is necessary to maintain soil fertility, amount of nutrients in soil, production sustainability and good crop yield" [22].

2. MATERIALS AND METHODS

2.1 Details of the Experiment Site and Plant Material

This research was carried out at the research farm of the School of Agriculture, Abhilashi University, Chail Chowk, Mandi (H.P.) during the *Kharif* season of 2023. The experimental farm is situated at 30^0 32' N latitude and 74^0 53' E longitudes, with an elevation of 1391 m above mean sea level. The soil of the experimental field was slightly acidic in reaction, medium in organic carbon, low in available nitrogen and medium in available phosphorus and potassium. The pH (5.5) of the experimental soil was slightly acidic in reaction with an electrical conductivity of 0.011 dS m^{-1}, medium in organic carbon (0.70%), low in available nitrogen (218.37 kg ha^{-1}), medium in available phosphorus (17.89 kg ha^{-1}) and potassium (226.15 kg ha^{-1}). For the determination of the content of nitrogen, phosphorus and potassium in grains and straw of rice crop, the sample of grains and straw of the rice were collected after harvest of the crop from the each treated plots, separately.

2.2 Design of the Experiment and Cultural Practices

The spacing for the tested variety (Hybrid paddy super-120) was 20 × 10 cm row to row and plant to plant. The experiment was laid out in a randomized block design (RBD) with eight treatments and three replications. The treatments include:

Recommended doses of N, P and K were applied in the form of urea, diammonium phosphate (DAP) and muriate of potash (MOP). Well decomposed farm yard manure, poultry manure and vermicompost were used as organic sources for nitrogen. Urea was the source of nitrogen, and it was administered in three separate doses during the transplanting, tillering and panicle initiation stages. Equal doses of potassium and phosphorus (50 kg ha^{-1}) were applied to each treatment as basal application in the form of muriate of potash and diammonium phosphate (DAP), respectively. After harvest, plant samples from each treatments were gathered, cleaned and then allowed to dry in the shade at room temperature. A mixer was used to finely powder the samples after they had been shade-dried and oven-dried for 24 to 48 hours at 60 ± 2°C. N, P and K content as well as rice crop uptake were examined using the finely powdered plant samples. The modified Kjeldahl digestion and distillation method, which was used to estimate the amount of nitrogen in the plant sample described by Jackson, [23]. Using the vanadomolybdate phosphoric yellow color method, the phosphorus content of the plant was ascertained, and the phosphorus content of the plant sample was estimated as per Jackson, [23] instructions. A flame photometer was used to evaluate the potassium content of plants [23]. The N, P and K absorption (kg ha^{-1}) in each treatment was calculated by multiplying the N, P and K content (%) by the grain and straw yields (q ha^{-1}) of transplanted rice crop at harvest.

2.3 Analysis of Data with Statistical Method

The collected data were analyzed statistically following the one factor analysis of variance

List 1. List of treatments

S.N.	Treatments
T_1	Absolute control
T_2	100% RDN (Recommended dose of nitrogen) through CF (chemical fertilizer)
T_3	75% RDN through CF + 25% N through FYM
T_4	75% RDN through CF + 25% N through poultry manure
T_5	75% RDN through CF + 25% N through vermicompost
T_6	50% RDN through CF + 50% N through FYM
T_7	50% RDN through CF + 50% N through poultry manure
T_8	50% RDN through CF + 50% N through vermicompost

(ANOVA) technique and the mean differences were adjusted with operational statistics (OPSTAT) software.

3. RESULTS AND DISCUSSION

3.1 Nitrogen Content (%) and Uptake (kg ha^{-1})

The nitrogen (N) content and their uptake by grains and straw of transplanted rice is displayed in (Table 1) and predicted in the (Fig. 1). The study showed no significant differences of nitrogen concentration present in the grains and straw of the transplanted rice crop by various nitrogen management treatments. However, the maximum nitrogen content in grains and straw of transplanted rice crop was noticed in treatment of T_2 (100% RDN through CF) and minimum in treatment T_1 (absolute control).

The application N by organic manure and nitrogenous chemical fertilizer had a substantial impact on the uptake of N by grains and straw as well as the total N uptake. During the study, the highest nitrogen uptake by grains and straw of transplanted rice crop was recorded under treatment T_2 (100% RDN through CF), which was statistically (P = *.05*) at par with treatment T_4 (75% RDN through CF + 25% N through poultry manure) and T_5 (75% RDN through CF + 25% N through vermicompost). Though, treatment T_1 (absolute control) showed the minimum amount of N uptake by grains and straw of transplanted rice crop. The treatment T_2 also recorded the total uptake of nitrogen and was it was on par with treatments T_4 and T_5 and the minimum total nitrogen uptake was found under treatment T_1.

The nitrogen uptake by rice grains and straw increased significantly with the combined application of organic manure and chemical fertilizers as compared to control. The reason for the increased uptake of N with incremental dosages could be that the plant absorbed the nutrients proportionately as the amount of accessible nutrients in the soil solution increased. Integrated application of nutrients might enhance nitrogen uptake in rice by providing a controlled release of nutrients, ensuring sustained availability to rice crop. This might be due to only larger fertilizer doses are able to fill the absorption sites in the soil and increase the nutrient status. Organic manure nutrient release rate is usually very slow and high depends on microbial activity. Whereas, chemical fertilizer are highly concentrated with less leaching and quick release of N compared to organic manure can be attributed for higher uptake of nitrogen in grains and straw of transplanted rice crop. Similar results also reported by Sahu and Chaubey [24].

3.2 Phosphorus Content (%) and Uptake (kg ha^{-1})

Along with their uptake by grains, straw and total uptake, the P content in grains and straw of the transplanted rice crop is provided in (Table 2) and illustrated in (Fig. 2). The study of data shows that the amount of P in the grains and straw of the transplanted rice crop did not vary significantly (P = *.05*) by the application of the various nitrogen management treatments. While, the treatment T_2= 100% RDN through CF had the highest P content in grains and straw of transplanted rice crop, however, the minimum P content in grain and straw of transplanted rice crop was reported under treatment T_1 (absolute control).

Nitrogen application through organic and inorganic sources had an adequate effect on the uptake of phosphorus by grains and straw. The study of the data shows that treatment T_2= (100% RDN through CF) recorded the maximum nitrogen uptake by grains and straw of transplanted rice crop and it was statistically (P = *.05*) on par with treatment T_4 (75% RDN through CF + 25% N through poultry manure) and T_5

(75% RDN through CF + 25% N through vermicompost). However, the minimum uptake of P by grains and straw of transplanted rice crop was recorded under treatment T_1 (absolute control). Likewise, uptake of P by grains and straw, the total P uptake by transplanted rice crop was highest under treatment T_2, which was statistically comparable with treatment T_4 and T_5. While, the lowest P uptake by transplanted rice crop were found in treatment T_1.

The integration of the chemical fertilizers with organic manure noted the higher content and uptake of phosphorus and was more effective than control treatment in promoting phosphorus uptake in rice crop. Nitrogen might enhance the efficacy of phosphorus-absorbing mechanisms and encourages root growth, which in turn helps in uptake of phosphorus by transplanted rice crop. Phosphorus moves to the root surface through diffusion. However, the presence of the organic matters in the different organic manures increases the activity and population of the microbes into the soil, which might increases the absorption of phosphorus in grains and straw of transplanted rice crop. Eventually, integrated nitrogen application enhancing root development, soil characteristics, nutrient interaction and efficiency promotes rice to absorb the maximum amount of phosphorus available. Tiwari et al. [25] also noted the similar finding related to this study.

Table 1. Effect of integrated nitrogen management on nitrogen content and their uptake by grain and straw of transplanted rice crop

S.N.	Treatments	Nitrogen content (%)		Nitrogen uptake (kg ha^{-1})		
		Grain	Straw	Grain	Straw	Total
T_1	Absolute control	1.31	0.40	37.74	15.87	53.61
T_2	100% RDN through CF (Chemical Fertilizer)	1.39	0.44	69.12	25.15	93.27
T_3	75% RDN through CF + 25% N through FYM	1.36	0.42	61.30	21.16	82.46
T_4	75% RDN through CF + 25% N through poultry manure	1.38	0.43	66.78	23.07	89.85
T_5	75% RDN through CF + 25% N through vermicompost	1.37	0.43	64.55	22.57	87.12
T_6	50% RDN through CF + 50% N through FYM	1.34	0.41	53.56	19.11	72.67
T_7	50% RDN through CF + 50% N through poultry manure	1.36	0.42	58.18	20.39	78.57
T_8	50% RDN through CF + 50% N through vermicompost	1.35	0.42	55.42	20.01	75.43
	S.Em.±	0.04	0.01	1.89	0.61	2.51
	C.D. (P = .05)	NS	NS	5.78	1.88	7.70

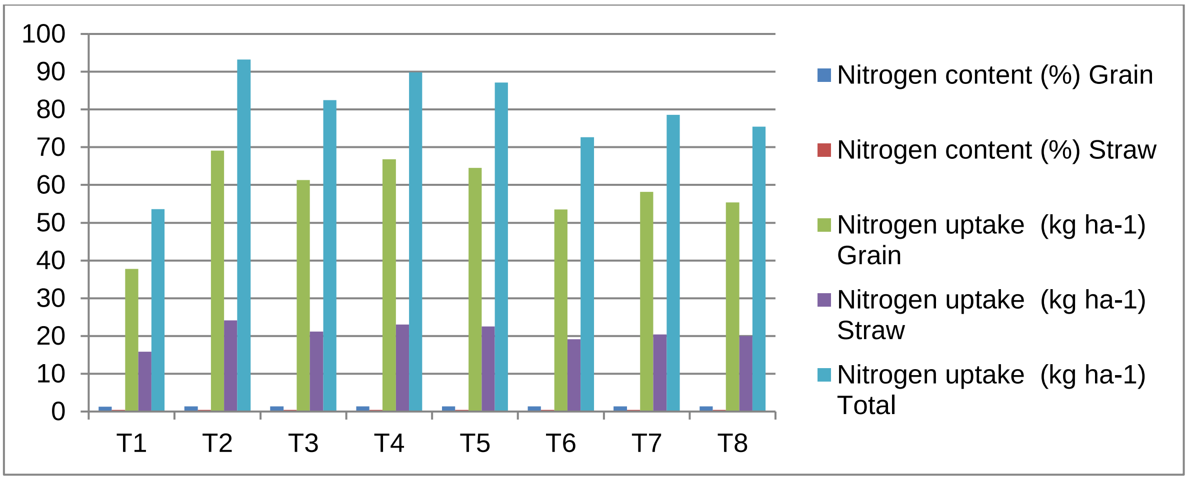

Fig. 1. Effect of integrated nitrogen management on nitrogen content and their uptake by grain and straw of transplanted rice crop

Table 2. Effect of integrated nitrogen management on phosphorus content and their uptake by grain and straw of transplanted rice crop

S.N.	Treatments	Phosphorus content (%)		Phosphorus uptake (kg ha^{-1})		
		Grain	Straw	Grain	Straw	Total
T_1	Absolute control	0.21	0.100	6.05	3.97	10.02
T_2	100% RDN through CF (Chemical Fertilizer)	0.24	0.108	11.94	5.93	17.87
T_3	75% RDN through CF + 25% N through FYM	0.23	0.105	10.37	5.29	15.66
T_4	75% RDN through CF + 25% N through poultry manure	0.24	0.106	11.61	5.69	17.30
T_5	75% RDN through CF + 25% N through vermicompost	0.23	0.106	11.31	5.56	16.87
T_6	50% RDN through CF + 50% N through FYM	0.21	0.102	8.39	4.76	13.15
T_7	50% RDN through CF + 50% N through poultry manure	0.22	0.104	9.41	5.05	14.46
T_8	50% RDN through CF + 50% N through vermicompost	0.22	0.103	9.03	4.91	13.94
	S.Em.±	0.01	0.003	0.28	0.16	0.49
	C.D. (P = .05)	NS	NS	0.86	0.50	1.51

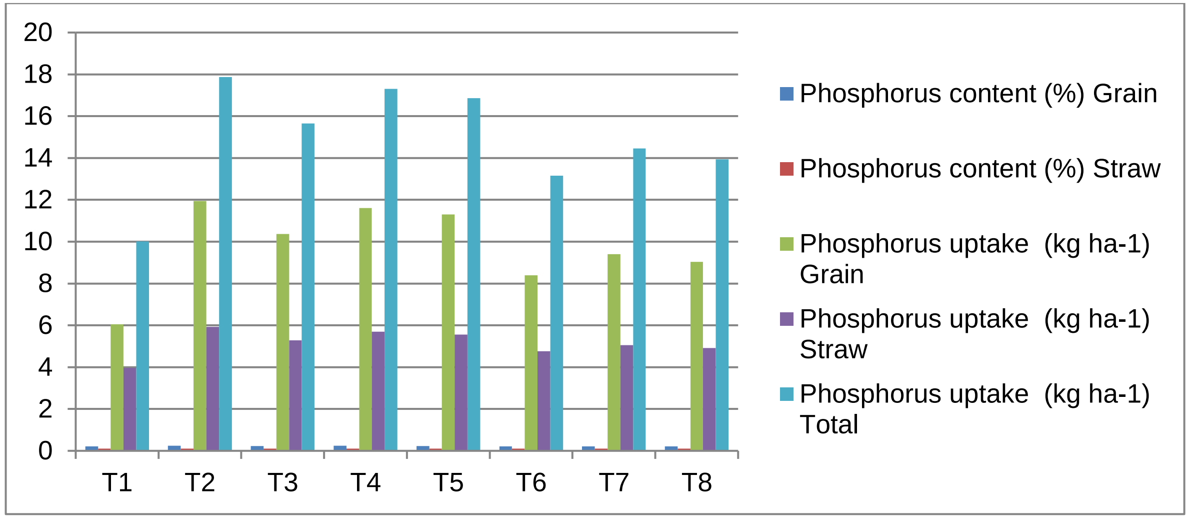

Fig. 2. Effect of integrated nitrogen management on phosphorus content and their uptake by grain and straw of transplanted rice crop

3.3 Potassium Content (%) and Uptake (kg ha^{-1})

The K content and their uptake by grains and straw of transplanted rice are presented in (Table 3) and depicted in (Fig. 3). The analysis of the data of the research trial showed that there are no significant (*P = .05*) differences of the K content in the grains and straw of the transplanted rice crop. However, the highest K content in grains and straw of the transplanted rice crop was recorded under treatment T_2= 100% RDN through CF (chemical fertilizer), whereas, the lowest was observed to be in treatment T_1 (absolute control).

The uptake of potassium (K) by transplanted rice crop grains and straw was found to be significantly (*P = .05*) impacted by integrated nitrogen management. In this study, T_2 (100% RDN through CF) recorded the maximum K uptake by grains and straw of transplanted rice crop, which was statistically (*P = .05*) at par with treatment T_4 (75% RDN through CF + 25% N through poultry manure) and T_5 (75% RDN through CF + 25% N through vermicompost). While, the treatment T_1 (absolute control) noticed the lowest K uptake by grains and straw. The total uptake of K by transplanted rice crop was also recorded under treatment T_2, which was statistically (*P = .05*) on par with treatment T_4 and T_5. Even so, treatment T_1 (absolute control) had the minimum uptake of K by transplanted rice crop during the research.

The application of organic manures and chemical fertilizer might have changed the physical, chemical and most importantly biological conditions of the soil and assisted in the transportation and absorption of nutrients from the soil. Nitrogen fertilization encourages root growth, which increases the surface area available for the absorption of nutrients, which include potassium. Rice plants with longer root systems area able to reach more soils, resulting in they get into interaction with more potassium ions. Increased nitrogen can help the movement of potassium from the roots to various areas of the plant facilitating its uptake and effective utilization. Adequate nitrogen and potassium supply are necessary for enzymatic activity and the metabolism of carbohydrates, increased photosynthesis activity which all might result in a higher uptake of potassium. The application of organic and inorganic sources of nutrients in combination remarkably improved potassium uptake by (promoting root development, ensuring balanced nutrient uptake and transport and physico-chemical properties) in grains and straw of transplanted rice crop. Similar results related to this study were also reported by Sharma and Singh [26].

Table 3. Effect of integrated potassium management on potassium content and their uptake by grain and straw of transplanted rice crop

S.N.	Treatments	Potassium content (%)		Potassium uptake (kg ha^{-1})		
		Grain	Straw	Grain	Straw	Total
T_1	Absolute control	0.27	1.30	7.78	51.58	59.36
T_2	100% RDN through CF (Chemical Fertilizer)	0.31	1.36	15.42	74.64	90.06
T_3	75% RDN through CF + 25% N through FYM	0.29	1.34	13.07	67.50	80.57
T_4	75% RDN through CF + 25% N through poultry manure	0.31	1.35	15.00	72.41	87.41
T_5	75% RDN through CF + 25% N through vermicompost	0.30	1.34	14.14	70.32	84.46
T_6	50% RDN through CF + 50% N through FYM	0.28	1.31	11.19	61.07	72.26
T_7	50% RDN through CF + 50% N through poultry manure	0.29	1.33	12.41	64.56	76.97
T_8	50% RDN through CF + 50% N through vermicompost	0.28	1.32	11.49	62.90	74.39
	S.Em.±	0.01	0.04	0.43	2.12	2.40
	C.D. (P = .05)	NS	NS	1.32	6.51	7.36

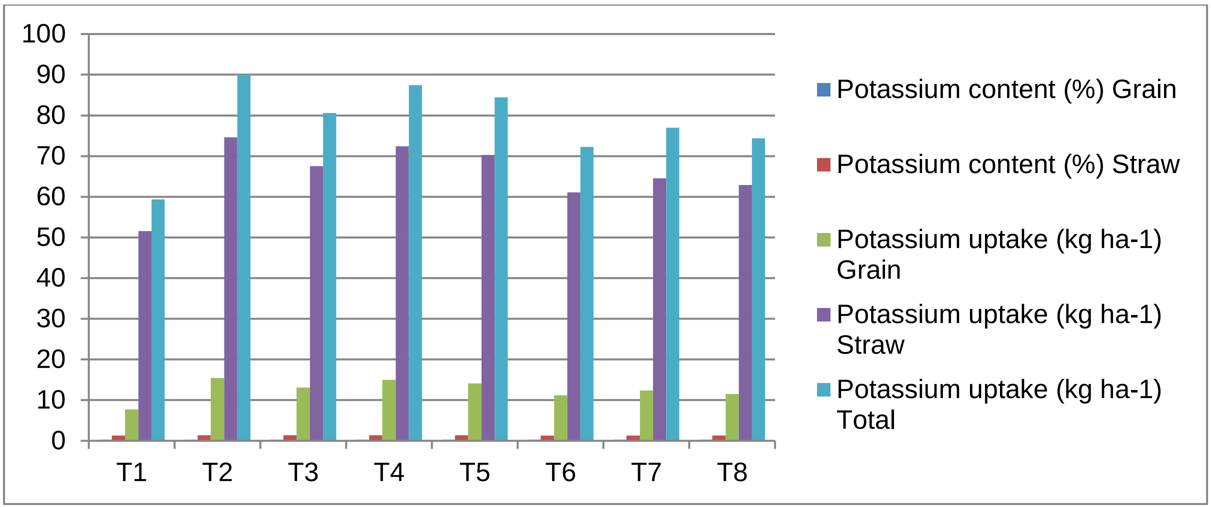

Fig. 3. Effect of integrated nitrogen management on potassium content and their uptake by grain and straw of transplanted rice crop

4. CONCLUSION

In conclusion, this study shows that the application of the chemical fertilizers alone or integration of the chemical fertilizers with organic manures, to provide the nitrogen to rice crop has been found significant to attain the higher nutrients content and uptake (*viz.*-nitrogen, phosphorus and potassium) by rice crop. The content of the nitrogen, phosphorus and potassium were non-significant in grains and straw of rice, while, found maximum under 100% RDN by chemical fertilizers, however, uptake of these nutrients by grains, straw and total uptake by rice crop were also noted maximum with 100% RDN through chemical fertilizers and it was statistically at par with alteration of 75% RDF by chemical fertilizers with 25% poultry manure and 25% vermicompost, respectively. This study concluded that the alteration of the nitrogen supply can be done through chemical fertilizers with 25 or 50% organic manures for higher nutrients content and their uptake by rice crop. This is very important because the rice crop is most important cereal crop for most of the world's population, which can be produced with integration of inorganic fertilizers and organic manure and it has significance for maintaining the soil fertility and sustaining the environment by less use of the chemical fertilizers for the production of the rice crop.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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