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Effect of Balanced Nutrient Approaches on Nutrient Uptake and Nutrient use Efficiency of different Rice Varieties under Zero-tilled Upland Condition in Eastern India

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ABSTRACT: In rice based cropping system balanced fertigation through new approaches under zero till upland condition ensures high productivity and sustainability in long run. In this context, research was conducted to find out effect on nutrient uptake and nutrient use efficiency i.e. by balanced fertilization. Therefore, A field experiment was conducted at Central Rain-fed Upland Rice Research Station (CRURRS), Hazaribagh, research station in Jharkhand with the objective to determine better nutrient management practices for zero till upland rice and their effect on yield and nutrient use efficiency. The experiment was laid out in split-plot design with three replications having three rice cultivar Vandana, Anjali and CR Dhan 40 in main plot and four nutrient management practices [soil test fertilizer recommendation meter (STFR), integrated nutrient management (INM), soil test crop response equation (STCR) and recommended dose of fertilizers (RDF)] in sub-plot. Results indicated that CR Dhan 40 rice cultivar recorded the highest concentration and uptake of N, P and K in grain than other varieties. In different nutrient management practices, STFR based NPK dose (100 kg N, 44 kg P_2O_5, 20 kg K_2O + 5 t /ha lime) recorded the highest values of N, P and K uptake in grain, straw and total followed by INM (50 % RDF+ 50% Organics) based NPK dose [40 kg N, 28 kg P_2O_5, 10 kg K_2O (50%) + 6 t/ha FYM (50%) + lime 1 t/ha] and STCR based NPK fertilization. Therefore, based on research findings, it can be concluded that rice cultivar "CR Dhan 40" with STFR and INM based fertilization may enhance the productivity and profitability of upland rice in the Eastern regions of India.

Keywords: Split-plot design, integrated nutrient management (INM), zero till, nutrient use efficiency, rice cultivar.

INTRODUCTION

Rice (*Oryza sativa* L.) is the second most important grain crop in India, after wheat (FAO, 2017). It is cultivated in 43.38 million hectares (mha), with an annual production of 104.32 million tons (mt), and an average national productivity of 2.40 tons per hectare (t/ha) (FAO, 2017). To address the growing demand for the food, feed and industrial sectors, as well as to access the export markets, rice production would still need to increase by additional 143 mt to cope with 40% world population and to raise average food consumption to 3130 kcal/person/day by 2050 (FAO, 2017). In Asia, rice is commonly grown with wet tillage land preparation (puddled soil) by transplanting seedlings from nursery. Repeated puddling adversely affects soil physical properties by destroying soil aggregates, reducing permeability in subsurface layers, and forming hard-pans at shallow depths (Sharma *et al*., 2004).

Flooded rice culture with puddling and transplanting is considered one of the major sources of methane (CH_4) emissions and accounts for 10-20% (50-100 Tg/year) of total global annual CH_4 emissions (Pathak *et al*., 2005; IPCC, 2001) which limit inclusion of lowland rice in crop rotation (Tripathi *et al*., 2005). Puddling and transplanting require large amount of water and labour, both of which are becoming increasingly scarce and expensive, making rice production less profitable. Upland rice is recently getting momentum, which is grown in rain-fed, naturally well-drained soils, without surface water accumulation, normally without phreatic water supply, and normally not bunded (Saharawat *et al*., 2010). Upland rice is grown annually on about 17 million ha worldwide–10.5 million ha in Asia (Fairhurst *et al*., 2007). It is of utmost importance to change the present production practices to attain optimal yield with high nutrient use efficiency and high-water productivity in deficit areas. Globally 23%

of rice is being cultivated as direct seeded rice (DSR) (Rao *et al*., 2007). In DSR, rice crop is directly sown in the field rather than by transplanting, where seedlings are prepared in the nursery and then transplanted to the main field. There are three principal methods of DSR *viz*., dry seeding (sowing dry seeds into dry soil), wet seeding (sowing pre-germinated seeds on puddled conditions) and water seeding (sowing seeds into standing water). DSR methods have several advantages over transplanted rice (TPR) method. Dry–seeding of rice with subsequent aerobic soil conditions eliminates the need of puddling and subsequent submerged soil conditions, thus reducing the overall water demand and providing opportunities for water and labour savings (Sharma *et al*., 2004).

The development of early maturing varieties and improved nutrient management techniques along with increased availability of chemical weed management methods have encouraged many farmers in the Philippines, Thailand and India to switch from TPR to DSR (Farooq *et al*., 2011). Nutrient removed by the crops far exceeds the amount provided through fertilizer, causing a much greater strain on the native soil reserves. Among nutrients, nitrogen deficiency limits rice production the most worldwide. Fertilizer use is one of the major factors for the continuous increase in rice production; more than 20% of N fertilizer produced worldwide is used in the rice fields of Asia. Irrigated and rain-fed lowland rice systems account for 92% of total rice production and nutrients applied as fertilizers account for 20–25% of total production costs in these rice systems. Of the total 172.2 Mt fertilizer (N + P_2O_5 + K_2O) consumed globally during 2010–11, 14.3% (24.7 Mt) was used in rice fields (Heffer, 2013). The imbalance and indiscriminate use of fertilizer adversely affects the productivity and nutrient use efficiency in rice crop (Borah *et al*., 2016). Managing the location specific variability in nutrient supply is a key strategy to overcome the current mismatch of fertilizer rates and crop nutrient demand in upland rice environments. The effect of fertigation on rice soil organuc carbon was improved significantly due to increase in percentage of soil macroaggregates (Juhi *et al.*, 2022).

In India, conservation agriculture (CA) has been widely promoted in rice-wheat cropping system to sustain the productivity and soil health in a long run (FAO, 2012). Retention of crop residues on soil surface had substantially higher organic carbon than compare to residue incorporation (Saurabh *et al.*, 2021). CA is a farming system that promotes maintenance of a permanent soil cover, minimum soil disturbance (*i.e.,* zero tillage), and diversification of plant species. It enhances biodiversity and natural biological processes above and below the ground surface, which contribute to increased water and nutrient use efficiency and improved and sustained crop production (FAO, 2012). ZT rice has several advantages such as it involves low fuel consumption in land preparation, reduced labour costs, improved soil health and quality and conserves soil moisture with higher water use efficiency (WUE) and NUE of about 15-20% along with higher yield (Saharawat *et al*., 2010). Baligar *et al.* (2001) reported that NUE of applied fertilizers is about 25-35% or lower for N, less than 10% for P and close to 40% for K in rice crop. These lower NUE could be due to significant losses of nutrients by leaching, run-off, gaseous emission and fixation by soil. These losses can potentially contribute to degradation of soil and water quality and eventually lead to overall environmental degradation. Nutrient management could be one of the most important options to enhance the yield and NUE in ZT rice. Balanced nitrogen fertigation in rice followed by 400 mm irrigation in rice-lathyrus cropping system recorded higher yield in zero till direct seeded rice based cropping system (Juhi *et al* ., 2022). Balanced Fertilizer experiments under zero till upland conditions have shown comparatively higher yield of crops in comparison to local practices. The reason to conduct an experiment is research gap for nutrient uptake and nutrient use efficiency through balanced nutrient approaches like STCR STFR and INM in rice and most of past studies are done in transplanted rice giving less importance to zero till upland conditions.ZT with organic nutrient source is one more promising option to enhance the productivity and sustainability (Bhan and Behera 2014).

MATERIALS AND METHODS

A. Experimental site

The experiment was conducted at Shankarpura farm's Block A7-MP of ICAR-CRURRS, Hazaribagh, Jharkhand located at latitude of 23°56′N and longitude of 85°21′E, and an altitude of 614 meters above the mean sea level.

Hazaribagh district comes under NARP- classified agro-climatic zone Eastern plateau and hill regions, and sub region-central north-eastern plateau region of Jharkhand which is characterized by humid and sub-humid tropical climate. In Jharkhand, maximum temperature varies between 26ºC to 32ºC and minimum temperature varies between 12.9ºC to 22.6ºC during the crop growing season, respectively being warm and humid. April, May and June are the hottest and December, January and February are the coldest months in the Jharkhand. The maximum and minimum relative humidity recorded is 67.4% and 36.3%, respectively. The average rainfall of the district is 783 mm of which 700 mm of rainfall is precipitated during the months of June to September.

B. Treatment details

The experiment was laid out in split-plot design with three replications having three rice cultivars Vandana, Anjali and CR Dhan 40 in main plots and four nutrient management practices [soil test fertilizer recommendation meter (STFR), integrated nutrient management (INM), soil-test crop response equation (STCR) and recommended dose of fertilizers (RDF) in sub-plots. Treatments were allocated randomly on the experimental units. The experimental field was kept under zero-till conditions.

N content and uptake (kg/ha). Nitrogen content at harvest in straw as well as grain (0.5 g each) was digested by using 10 ml of analytical grade concentrated sulphuric acid (H_2SO_4) along with a pinch of digestion mixture ($CuSO_4$ + K_2SO_4 + selenium + mercury oxide) to evaluate total nitrogen concentration. Samples were analyzed by using Kjeldahl's apparatus (Piper, 1966) and were expressed as percentage. Thereafter, N uptake by grains and straw were analyzed by multiplying N content of grain and straw with grain and straw yield respectively.

Phosphorus content and uptake (kg/ha). The straw and grain samples were digested separately in di-acid mixture (HNO_3 $HClO_4$ in the ration of 10:3). Later, P content was determined by using Vanado-molybdo-phosphoric yellow colour method, in nitric acid system (Piper, 1966). The intensity of yellow colour developed was measured by spectronic–20 photoelectric colorimeter at a wavelength of 420 nm using blue filter. P content was expressed in percentage. P uptake was calculated similarly as in case of N and was expressed in kg/ha.

Potassium content and uptake (kg/ha). Similarly, after digesting the samples in di acid mixture as for P, K content was determined by using the flame photometer and expressed in percentage. K uptake was calculated thereafter and expressed in kg/ha.

$$\frac{\text{N/P/K concentration (\%)} \times \text{grain or straw yield (kg/ha)}}{100}$$

Total uptake (kg/ha) = Uptake in grain + Uptake in straw

Nitrogen use efficiency. The NUE addresses the N outputs in harvested produce only. For crop production systems, the N output in harvested crop removed from the land is considered.

NUE = N output in harvested products / N input.

RESULTS

A. Nutrient concentration and uptake in rice grain

(i) N concentration. The N concentration in grain was significantly influenced by different rice varieties except in straw (Table 1). The rice variety CR Dhan 40 highest N (1.30 %) concentration in grain followed by Anjali and Vandana. Nutrient management (NM) practices significantly influenced the N concentration in grain and straw (Table 1). In different nutrient management practices, STFR based NPK dose (100 kg N, 44 kg P_2O_5, 20 kg K_2O + 5 t /ha lime) and INM (50 % RDF+ 50% Organics) based NPK dose (40 kg N, 28 kg P_2O_5, 10 kg K_2O lime 1 t/ha +6 t/ha FYM) recorded the at par values of N concentration in grain and straw followed by STCR based fertilization and RDF practices.

The interaction between rice varieties and nutrient management practices on N concentration in grain and strawwas found non-significant (Table 1).

(ii) Uptake of N in grain and straw. The N uptake in grain, straw and totalwas significantly influenced with different rice varieties (Table 1). The rice variety CR Dhan 40 recorded the highest values of N uptake in grain, straw and total followed by Anjali and Vandana.

Nutrient management (NM) practices significantly influenced the N uptake in grain, straw and total (Table 1). In different nutrient management practices, STFR based NPK dose (100 kg N, 44 kg P_2O_5, 20 kg K_2O + 5 t /ha lime) recorded the highest values of N uptake in grain, straw and total followed by INM (50 % RDF+ 50% Organics) based NPK dose [40 kg N, 28 kg P_2O_5, 10 kg K_2O (50%) + 6 t/ha FYM (50%) + lime 1 t/ha], STCR based fertilization and RDF practices.

The interaction between rice varieties and nutrient management practices on N uptake in grain and straw was found non-significant (Table 1).

Table 1: Effect of varieties and nutrient management on N concentration and uptake in direct-seeded upland rice.

Treatment	N concentration (%)		N uptake (kg N/ha)		Total uptake
	Grain	Straw	Grain	Straw	
Varieties (V)					
Vandana	1.21	0.54	38.4	30.3	68.6
Anjali	1.23	0.58	41.6	32.2	73.8
CR Dhan 40	1.30	0.61	50.0	38.0	88.0
SEm±	0.01	0.01	0.73	0.78	1.28
CD (P=0.05)	0.04	NS	2.86	3.05	5.01
Nutrient management (NM)					
STCR	1.25	0.56	44.1	32.5	76.6
STFR	1.30	0.65	51.0	39.3	90.3
INM	1.29	0.62	47.3	37.5	85.0
RDF	1.15	0.48	31.5	25.5	57.0
SEm±	0.01	0.01	0.29	0.63	0.78
CD (P=0.05)	0.03	0.03	0.86	1.87	2.32
Interactions (V×NM)	NS	NS	NS	NS	NS

B. P concentration

The P concentration in grain was significantly influenced with different rice varieties except in straw (Table 2). The rice variety CR Dhan 40 recorded the highest values of P concentration (0.17%) in grain followed by Vandana and Anjali.

Nutrient management (NM) practices significantly influenced the P concentration in grain and straw (Table 2). In different nutrient management practices, STFR based NPK dose (100 kg N, 44 kg P_2O_5, 20 kg K_2O, 5 t /ha lime) and INM (50 % RDF+ 50% Organics) based NPK dose [40 kg N, 28 kg P_2O_5, 10 kg K_2O (50%) + 6 t/ha FYM (50%) + lime 1 t/ha] recorded at par values of

P concentration in grain and straw followed by STCR based fertilization and RDF practices.

The interaction between rice varieties and nutrient management practices on P concentration in grain and strawwas found non-significant (Table 2).

(i) Uptake of P in grain and straw. The P uptake in grain, straw and total was significantly influenced with different rice varieties (Table 2). The rice variety CR Dhan 40 recorded the highest values of P uptake in grain, straw and total followed by Vandana and Anjali.

Nutrient management (NM) practices significantly influenced the P uptake in grain, straw and total (Table 2). In different nutrient management practices, STFR based NPK dose (100 kg N, 44 kg P_2O_5, 20 kg K_2O + 5 t /ha lime) recorded the highest values of P uptake in grain, straw and total followed by INM (50 % RDF+ 50% Organics) based NPK dose [40 kg N, 28 kg P_2O_5, 10 kg K_2O (50%) + 6 t/ha FYM (50%) + lime 1 t/ha], STCR based fertilization and RDF practices.

The interaction between rice varieties and nutrient management practices on P uptake in grain and straw was found non-significant except total P uptake (Table 3).

Interaction results for Table 3 shows that adoption of NM2 in the variety Vandana, Anjali and CR Dhan 40 increased total P uptake by 58.76%, 63.63 % and 14.08% respectively than adoption of NM1, whereas the adoption of NM4 in variety Vandana, Anjali and CR Dhan 40 decreased Total P uptake by 53.38%, 59% and 53.95% respectively than NM3.

Table 2: Effect of varieties and nutrient management on P concentration and uptake in direct-seeded upland rice.

Treatment	**P concentration (%)**		**P uptake (kg P/ha)**		**Total uptake (kg/ha)**
	Grain	**Straw**	**Grain**	**Straw**	
Varieties (V)					
Vandana	0.162	0.090	5.18	5.04	10.22
Anjali	0.168	0.090	5.71	5.04	10.75
CR Dhan 40	0.176	0.095	6.77	6.09	12.86
SEm±	0.002	0.002	0.11	0.16	0.34
CD (P=0.05)	0.008	0.008	0.43	0.62	1.86
Nutrient management (NM)					
STCR	0.152	0.090	5.32	5.22	10.54
STFR	0.208	0.130	8.36	7.87	16.23
INM	0.203	0.100	7.47	6.05	13.52
RDF	0.109	0.050	2.97	2.65	05.62
SEm±	0.001	0.001	0.05	0.13	0.47
CD (P=0.05)	0.003	0.003	0.14	0.39	0.141
Interactions (V×NM)	NS	NS	NS	NS	S

Table 3: Interactive effect of rice varieties and nutrient management practices on total P uptake (kg/ha).

Nutrient management (NM)	**Varieties (V)**			
	Vandana	**Anjali**	**CR Dhan 40**	**Mean**
NM1	8.44	9.9	14.2	**10.5**
NM2	13.4	16.2	16.2	**16.2**
NM3	13	12	14.4	**13.5**
NM4	6.06	4.92	6.63	**5.62**
Mean	**10.22**	**10.75**	**12.86**	
			SEm±	**CD (P=0.05)**
Between two sub-plot at same level of main plot			0.82	0.8
Between two main-plot at same/different level of sub-plot			2.44	2.5

Table 3.3 Interactive effect of rice varieties and nutrient management practices on total P uptake (kg/ha)

Nutrient management (NM)	**Varieties (V)**			
	Vandana	Anjali	CR Dhan 40	**Mean**
NM1	8.44	9.9	14.2	**10.5**
NM2	13.4	16.2	16.2	**16.2**
NM3	13	12	14.4	**13.5**
NM4	6.06	4.92	6.63	**5.62**
Mean	**10.22**	**10.75**	**12.86**	
			SEm±	**CD (P=0.05)**
Between two sub-plot at same level of main plot			0.82	0.8
Between two main-plot at same/different level of sub-plot			2.44	2.5

C. K Concentration

In grain the effect of K concentration in different rice varieties was found non- significant while the K in straw was significantly influenced with different rice varieties (Table 4). The rice variety CR Dhan 40 recorded the highest values of K concentration in straw followed by Anjali and Vandana.

Nutrient management (NM) practices significantly influenced the K concentration in grain and straw (Table 4). In different nutrient management practices, STFR based NPK dose (100 kg N, 44 kg P_2O_5, 20 kg K_2O + 5 t /ha lime) and INM (50 % RDF+ 50% Organics) based NPK dose [40 kg N, 28 kg P_2O_5, 10 kg K_2O (50%) + 6 t/ha FYM (50%) + lime 1 t/ha] recorded the at par values of K concentration in grain and straw followed by STCR based fertilization and RDF practices.

The interaction between rice varieties and nutrient management practices on K concentration in grain and straw was found non-significant (Table 4).

(i) Uptake of K in grain and straw. The Potassium (K) uptake in grain, straw and corresponding total uptake were significantly influenced by different rice varieties (Table 4). The rice variety CR Dhan 40 recorded the highest values of K uptake in grain, straw and total followed by Anjali and Vandana.

Nutrient management (NM) practices significantly influenced the K uptake in grain, straw and total uptake (Table 4). In different nutrient management practices, STFR based NPK dose (100 kg N, 44 kg P_2O_5, 20 kg K_2O + 5 t /ha lime) and INM (50 % RDF+ 50% Organics) based NPK dose [40 kg N, 28 kg P_2O_5, 10 kg K_2O (50%) + 6 t/ha FYM (50%) + lime 1 t/ha] recorded at par K uptake in grain, straw and total followed by STCR based fertilization and RDF practices.

The interaction between rice varieties and nutrient management practices on K uptake in grain, straw and total was found non-significant (Table 4).

Table 4: Effect of varieties and nutrient management on K concentration and uptake in direct-seeded upland rice.

Treatment	K concentration (%)		K uptake (kg K/ha)		Total uptake(kg/ha)
	Grain	Straw	Grain	Straw	
Varieties (V)					
Vandana	0.25	1.43	8.00	80.2	88.2
Anjali	0.25	1.46	8.45	81.2	89.6
CR Dhan 40	0.27	1.55	10.4	96.4	107
SEm±	0.06	0.02	0.24	1.84	1.75
CD (P=0.05)	NS	0.06	0.94	7.21	6.86
Nutrient management (NM)					
STCR	0.26	1.46	9.17	84.7	94.0
STFR	0.28	1.55	11.0	94.0	106
INM	0.28	1.55	10.3	93.8	104
RDF	0.22	1.36	6.02	72.0	77.0
SEm±	0.04	0.03	0.14	1.73	1.66
CD (P=0.05)	0.12	0.09	0.42	5.24	5.03
Interactions (V×NM)	NS	NS	NS	NS	NS

D. Effect of nutrient management on soil fertility after harvest

(i) Soil organic carbon. Soil organic carbon in soil was not influenced with different rice varieties (Fig. 1). Nutrient management (NM) practices had non-significantly influenced the soil organic carbon (Fig. 1).

(ii) Available nitrogen. The available soil N was not influenced by different rice varieties (Fig. 1). Nutrient management (NM) practices significantly influenced the available soil N (Fig. 1). In different nutrient management practices, STFR based NPK dose (100 kg N, 44 kg P_2O_5, 20 kg K_2O + 5 t /ha lime) and STCR based fertilization recorded higher values of available soil N followed by INM (50 %RDF+ 50%Organics) based NPK dose [40 kg N, 28 kg P_2O_5, 10 kg K_2O (50%) + 6 t/ha FYM (50%) + lime 1 t/ha] and RDF practices.

(iii) Phosphorus. The phosphorus in the soil was not influenced by different rice varieties (Fig. 1). Nutrient management (NM) practices significantly influenced the phosphorus in the soil (Fig. 1). In different nutrient management practices, STFR based NPK dose (100 kg N, 44 kg P_2O_5, 20 kg K_2O + 5 t /ha lime) recorded the highest values of phosphorus in the soil followed by INM (50 %RDF+ 50%Organics) based NPK dose [40 kg N, 28 kg P_2O_5, 10 kg K_2O (50%) + 6 t/ha FYM (50%) + lime 1 t/ha], STCR based fertilization and RDF practices.

(iv) Potassium. Soil available K remained to be highest after harvest of Vandana (18.8 kg K/ha) and Anjali (17.4 kg K/ha) and least was observed in CR Dhan 40 (16.4 kg K/ha). The different rice varieties significantly influenced the available potassium in soil (Fig. 1). The rice variety Vandana and Anjali recorded the highest values of available potassium in soil followed by CR Dhan 40.

Nutrient management (NM) practices significantly influenced the available potassium in soil (Fig. 1). In different nutrient management practices, STFR, INM and STCR based fertilization recorded at par values of available potassium followed by RDF based NPK dose (100 kg N, 44 kg P_2O_5, 20 kg K_2O+ 5 t /ha lime).

DISCUSSION

A. Nutrient concentration and uptake

N, P and K concentrations were significantly influenced by the different varieties and nutrient management practices. CR Dhan 40 rice cultivar recorded the highest concentration and uptake of N, P and K in grain than other varieties. The vigorous growth and high yield potential of CR Dhan 40 enhanced and accumulated higher nutrients compared to the rest of varieties (Fageria *et al.,* 2010). The concentration and uptake of N, P and K was recorded higher in STFR and INM followed by STCR and RDF. The balanced application of nutrient enhanced the synchronized availability of nutrients in the soil to the crop plant (Fageria *et al.*, 2004). In STCR and INM, the increase in nutrient uptake was enhanced with the application of lime and FYM (Fageria *et al.*, 2014). Furthermore, activated microbial community and organic acid in the soil enhanced the availability of P in soil from to the plant rhizosphere (Fageria *et al*., 1995; Fageria *et al*., 2014).

B. Nutrient status after harvest

The nutrient status after the harvest of rice crop was not influenced with the rice varieties. The rice varieties, Vandana and Anjali recorded higher values of available nitrogen, phosphorus and potassium in soil followed by CR Dhan 40 due to more yield and more nutrient uptake in CR Dhan 40 available nutrients left in soil comparatively lower than other cultivars (Aruna *et al*., 2012). Balanced and optimum fertilization resulted into high nutrient uptake and more yield in STFR based fertilization and also had residual impact [higher values of available nutrients (154 N, 24.7 P_2O_5, 311 K_2O kg/ha)] on fertility of soil followed by STCR, INM and RDF (Dass *et al*., 2009).

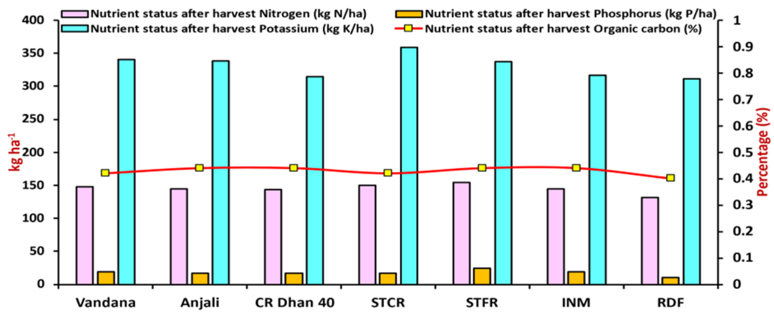

Fig. 1. Effect of varieties and nutrient management on residual soil fertility after harvest of rice crop.

CONCLUSIONS

Based on the research findings, it can be concluded that rice cultivar CR Dhan 40 rice cultivar recorded the highest concentration and uptake of N, P and K in grain than other varieties. The concentration and uptake of N, P and K was recorded higher in STFR and INM followed by STCR based NPK fertilization.

FUTURE SCOPE

The research conducted can be helpful to researchers for further analysingthe impact of balanced nutrient management on productivity of rice which ensures agriculture sustainability and may be helpful to the crop growers for opting suitable cultivation practice in rice.

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Conflict of Interest. None.

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