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Assessment of Nutrient Expert Tool for Fertilizer Management in Rice at Fulbari, Chitwan, Nepal

Milan Acharya[1*], Prabha Khanal[2] , Santosh Marahatta[2], Shrawan Kumar Sah and Purushottam Subedi[3]

[1]Agriculture Development Directorate, Gandaki Province, Pokhara
[2]Agriculture and Forestry University, Rampur, Chitwan
[3]Ministry of Agriculture and Livestock Development, Kathmandu
[*]Corresponding author email address: milan.new2007@gmail.com

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ABSTRACT

A field trial was conducted at Fulbari, Chitwan in 2017 to evaluate the growth, productivity and economics of rice production under different nutrient management practices. Trial was laid out in a split-plot design with five replications. The main plot factor consisted of two rice varieties (Radha-4; improved variety and Arize Tej Gold; a popular Hybrid) and subplot factor consisted of five different nutrient management practices farmers' applied dose (FAD;0-20:0-15:0-18 NPK kg ha^{-1}), government recommended dose (GRD; 100:30:30 NPK kg ha^{-1}), NARC recommended dose (NRD; 120:60:40 NPK kg ha^{-1}), LCC based N and NE® based P, K dose (LCC-N+NE-P,K; 90-115:5-22:17-50 NPK kg ha^{-1} for Radha-4 and 90-140:5-36:38-73 NPK kg ha^{-1} for Arize Tej Gold), Nutrient Expert® based NPK dose (NED; 93-109:5-22:17-50 NPK kg ha^{-1} for Radha-4 and 118-125:5-36:38-73 NPK kg ha^{-1} for Arize Tej Gold). Data regarding biometrical, phenological, and yield attributes were recorded at regular intervals. Results revealed that different nutrient management practices had a significant influence on growth, yield attributes, and yield of rice. Number of effective tillers per square meter (215.62), number of grains per panicle (132.52), panicle length (27.02 cm) was recorded higher in LCC-N+NE-P, K. Similarly, a number of grains per panicle and panicle length in LCC-N+NE-P, K were statistically similar to NED. Significantly higher grain yield (5.19 Mt ha^{-1}) and straw yield (6.43 Mt ha^{-1}) were recorded in LCC-N+NE-P, K compared to FAD but statistically similar to NED. Higher Benefit-cost (B:C) ratio (2.41) was obtained in LCC-N + NE – P, K which was statistically similar to FAD and NED. Thus, the combined use of LCC and Nutrient Expert software for nutrient management in rice was found productive and profitable in western Chitwan.

Keywords: Site specific nutrient management, rice, varieties, yield

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INTRODUCTION

Rice (*Oryza sativa* L.), the most important staple food of the world, is cultivated in more than a hundred countries. Rice contributes about 40% of the food calorie intake and adds approximately 20% to AGDP and nearly 7% to GDP (CDD 2015). In Nepal rice was cultivated in 1.47 million hectares of agricultural land with 5.62 million tons of production and productivity of 3.82 Mt ha^{-1} during 2020/21 (MOALD 2021).

Reasons for lower productivity of rice in the Nepalese context are rainfed rice farming (Tripathi et al 2019), abiotic stress, (Gauchan et al 2014), biotic stresses (Upadhyay, 1996), low fertilizer use (Shrestha 2012), soil fertility declination (Jaishy and Risal 2002), lack of high yielding fertilizer responsive variety (NARC 1997), delayed transplanting (Shrestha 2012), climate change, the increasing cost of cultivation and socioeconomic changes (Ladha et al 2009), shifting towards high-value agricultural commodity (Marahatta 2017).

The major limitation of achieving higher yields and profitability is due to the ineffective use of inputs particularly fertilizer and seed in a sustainable manner (Balasubramanian et al 2000). Lower nitrogen use efficiency is considered the most critical issue in South Asia including Nepal (Witt et al 2005). In South Asia, 90 percent of smallholder farmers do not get soil testing facilities (Parthasarathy 2014). Blanket fertilizer recommendations are practiced over large areas that ignore the temporal and spatial variations of soil fertility (Ladha et al 2003; Buresh 2010).

Existing approach of blanket recommendation of fertilizer in rice lead to lower yield and profitability mainly due to its inefficient use. So, an adjustment in N, P, and K applications through appropriate nutrient management practice is essential to synchronize the site-specific needs of the crop (Buresh 2010). Site-specific nutrient management (SSNM) can be used to assess the gap between the nutrient demand of crop and the nutrient supply from natural sources, through which farmer can adjust the fertilizer requirement (Pampolino et al 2007). It has been demonstrated that 30% of the fertilizer N requirement could be reduced through SSNM approach (Wang et al 2007).

Leaf color chart (LCC) is SSNM based handy diagnostic tool for monitoring the relative greenness of leaf as an indicator for the plant Nitrogen status (Yang et al 2003). LCC based N management has consistently improved grain yield and profit compared to the farmers' nutrient management (Sen et al 2011). Further, Nutrient Expert (NE) is a newly developed innovative, information and communications technology (ICT)-based decision support tool for maize, rice, and wheat (Islam et al 2018). NE can quickly give site specific nutrient recommendations with or without soil testing data (Qureshi et al 2016). NE-Rice enables the rice grower to implement SSNM which utilizes the information collected from farmers to suggest attainable yield and appropriate fertilizer management strategy (Dutta et al 2014). Improving the equilibrium between crop Nitrogen demand and supply from all sources during the crop period is likely the most practical way to improve Nitrogen use efficiency and grain harvest (Singh 1994). Inbred and hybrid varieties have different yield potentials (Haque et al 2015). Developing countries like Nepal largely depend on foreign countries for hybrid varieties. Available inbreed varieties of rice could be effectively used with proper management practice without compromising the yield that obtained from hybrid (Sah and Joshi 2020).

It seems difficult to meet growing food demand with our conventional rice farming and fertilizer management approaches (Peng et al 2009). The wide adoption of blanket fertilizer recommendations without considering temporal and spatial variation in the farming system leads to reduced fertilizer use efficiency, suboptimal farm profitability, and increased environmental footprint (Dobermann et al 1998). Knowing all these facts, a field trial was accompanied in the inner Terai of Nepal with the objective of assessing the growth and yield of rice under different fertilizer management practices.

MATERIALS AND METHODS

The experiment was conducted in the farmers' fields of Fulbari, Chitwan during the rainy season of 2017. The experimental site was located at 27º37'N, 84º25'E about 256 m above the main sea level. The soil texture of the experimental site varied from sandy loam to clay loam. The site was characterized by the subtropical climate and was highly influenced by the southern monsoon. Farmers within the research area were selected based on the cropping pattern, soil properties, socioeconomic conditions, accessibility of field and farmers willingness to participate in nutrient management experiments. Split plot design was used with 10 treatments (main plot factor variety: Radha 4 and Arize Tej Gold; Subplot factor: five methods of fertilizer management and 5 replications (i.e 5 farmers' fields). There was a total of 50 plots and depending upon the farmer's field, the individual plot size varied from 25 m^2 to 50 m^2 and each farmer's field was considered as one replication. The spacing of 0.5 m was assigned between plots. And the plots were separated by the bunds to check nutrient overflow from one to another plot. The rice crop was grown with possible best agronomic package of practices. The net plot area (10 m^2) was harvested manually with the help of sickles for yield determination.

For N top dressing under LCC-based nitrogen management treatment, readings were made beginning from 25 days after transplanting (DAT) to flowering in each replication. LCC readings were taken at a regular interval of 10 days from the fully expanded uppermost leaf of randomly selected 10 disease-free plants. Readings were taken by placing the middle part of the leaf on top of the color strips in the chart. If six or more leaves read below a set of critical values (4), the predetermined rate of N was applied as 20 kg N ha^{-1} during 1st LCC reading and 25 kg N ha^{-1} thereafter. Biometrical observations were taken at the interval of 10 days. Data regarding yield attributing traits were taken during and after crop growth. Analysis of variance (ANOVA) of the recorded parameters was performed with the split-plot considering each farmer as a replication. Means were separated by Duncan's Multiple Range Test (DMRT) at a 0.05 level of significance. A simple correlation and regression, tables, and graphs based on Excel, and R-Studio was used for statistical analysis.

Fertilizer management

Under the nutrient management, the full amount of P and K were applied as basal before transplanting of a seedling but N was applied depending upon the treatments (Table 1).

Nutrient Expert® Rice-based NPK dose (NED): Based on the household survey form of the NE-based questionnaire and the soil analysis of the farmers' field, the fertilizer rates and application timings were formulated by Nutrient Expert® Rice.

Chemical fertilizer use was very less at Fulbari locality. Most of the farmers grow crop without using chemical fertilizer; organic growers are prominent on that locality. Besides, farmers who apply chemical fertilizer also apply fertilizer in very small doze.

Table 1. Fertilizer application details for the experiment at Fulbari, Chitwan, Nepal, 2017

S. N	Treatment details	Fertilizer dose	Application details
1	Farmers applied dose (FAD)	0-20:0-15:0-18 N, P_2O_5, K_2O kg ha^{-1}	Based on the survey
2	Government recommended dose (GRD)	100: 30: 30 N, P_2O_5, K_2O kg ha^{-1}	1/3 as basal and remaining N is applied at maximum tillering and Panicle initiation stage.
3	NARC recommended dose (NRD)	120: 60: 40 N, P_2O_5, K_2O kg ha^{-1}	1/3 as basal and remaining N is applied at maximum tillering and Panicle initiation stage.
4	LCC-based N & NE based P and K dose (LCC-N+ NE-P,K)	90-115:5-22:17-50 N, P_2O_5, K_2O kg ha^{-1} for Radha-4 and 90-140:5-36:38-73 N, P_2O_5, K_2O kg ha^{-1} for Arize Tej Gold	The full dose of P, K as derived from the NE tool and 20 kg N $ha^{-1}$was applied as basal. Split application of N was made based on LCC readings at 10 days interval. 20 kg N ha^{-1} was applied at 1st LCC reading and 25 kg N ha^{-1} thereafter.
5	Nutrient Expert based NPK dose (NED)	93-109:5-22:17-50 N, P_2O_5, K_2O kg ha^{-1} for Radha-4 and 118-125:5-36:38-73 N, P_2O_5, K_2O kg ha^{-1} for Arize Tej Gold.	The full dose of P,K and 20% N was applied as basal and the remaining 50% N & 30% N was applied during maximum tillering and Panicle initiation stage respectively.

Table 2. FAD obtained from the survey of selected farmers at Fulbari, Chitwan, Nepal, 2017

Farmers	NE dose kg ha^{-1} (Radha-4 and Arize Tej Gold)		
	N	**P_2O_5**	**K_2O**
Farmer1	0	0	0
Farmer2	20	15	18
Farmer3	0	0	0
Farmer4	0	0	0
Farmer5	0	0	0
Average	**4**	**3**	**3.6**

Table 3. NE dose obtained from Nutrient Expert for rice tool and LCC-N+NE-P,K dose for an experimental site at Fulbari, Chitwan, Nepal, 2017

Farmers	NE dose kg ha^{-1} (Radha-4)			NE dose kg ha^{-1} (Arize Tej Gold)			LCC-N+NE-P,K dose kg ha^{-1} (Radha-4)			LCC-N+NE-P,K dose kg ha^{-1} (Arize Tej Gold)		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
Farmer 1	93	20	40	125	36	73	90	20	40	140	36	73
Farmer 2	100	22	50	125	36	73	90	22	50	90	36	73
Farmer 3	99	22	50	124	36	73	90	22	50	140	36	73
Farmer 4	109	5	17	118	5	38	115	5	17	115	5	38
Farmer 5	109	5	17	118	5	38	115	5	17	115	5	38
Average	**102**	**14.8**	**34.8**	**122**	**23.6**	**59**	**100**	**14.8**	**34.8**	**120**	**23.6**	**59**

Data collection

Various biometrical observations on plant height, tillers per square meter, leaf area index, dry matter accumulation were taken beginning on the 60 DAS to maturity at 10 days interval. Plant height was taken from 10 plants of 10 hills from 4^{th} and 6^{th} rows of each plot. Tiller numbers were recorded from 4 destructive and 2 non-destructive hills of each plot. Destructive hills were also used to take data of leaf area and dry matter accumulation also. Destructive sample was taken from the row after border row, keeping at least two hills in between two consecutive destructive sampling. The observation regarding the effective tillers per square meter, number of grains per panicle, sterility percentage, thousand grains weight were recorded.

The amount of grains (kg) obtained from the net plot area (10 m^2) of each plot was recorded and converted into tons per hectare. At the same time, the moisture content of the grains was also taken with a digital moisture meter. Then, the grain yield (Mt ha^{-1}) adjusted at 14 % moisture level was calculated by the following formula (Shahidullah et al 2009)

$$\text{Grain yield (Mt ha}^{-1}\text{) at 14\% moisture} = \frac{(100 - \text{MC}) \times \text{plot yield (kg)} \times 1000\ (\text{m}^2)}{(100 - 14) \times \text{net plot area (m}^2) \times 100}$$

RESULTS AND DISCUSSION

Plant height and effective tillers per square meter

The growth of rice was not influenced by varieties but was significantly influenced by nutrient management practice (Table 4). Plant height was higher in LCC-N+NE-P,K in most of the observations and lower in farmer applied dose (FAD) in all the observations during the experiment. Similar result was also found by Acharya et al (2019) who observed significantly higher plant height on nutrient expert-based fertilizer recommendation and LCC- N+NE-P,K application compared to farmer’s dose. Tiller per square meter was found higher in NARC recommended dose (NRD) but was not significantly different from LCC-N+NE-P,K. Acharya et al (2019) also reported non-significant difference on tiller number due to different nutrient doses (NED, LCC- N+NE-P,K and GRD) and less tiller number on FAD.

Better plant growth in LCC-N+NE-P,K might be due to greater availability, uptake, and utilization of soil nutrients due to a greater number of N splitting. Better rice growth was due to the split application of nitrogen according to crop demand (Sathiya and Ramesh 2009). Cell wall extensibility is affected by cytokinin levels which can be increased by N application

(Arnold 2006). So, Nitrogen was involved in increasing cell number and cell volume that subsequently increases plant growth. Nitrogen has a growth-promoting effect as its supply influences the size and number of meristematic cells leading to the formation of new shoots (Lawlor 2002).

Split application of nitrogen significantly influences plant height and N application at pre-sowing and tillering stage performed better (Biloni and Bocchi 2003). The highest plant height was observed in high and balanced NPK fertilization (Khan 2011).

Table 4. Plant height (cm) and number of tillers per square meter as influenced by nutrient management practices at Fulbari, Chitwan, 2017

Treatments	Plant height (cm)				Number of tillers per square meter			
	60 DAS	**70 DAS**	**80 DAS**	**90 DAS**	**60 DAS**	**70 DAS**	**80 DAS**	**90 DAS**
Varieties								
Radha 4	59.61	71.93	83.46	97.60	194.00	273.68	294.23	242.22
Arize Tej Gold	60.73	73.41	85.69	104.40	199.50	272.95	270.81	250.13
SEm (±)	0.56	0.74	1.11	3.40	2.75	0.36	11.71	3.96
LSD(<0.05)	ns	ns	ns	ns	ns	ns	ns	ns
CV (%)	7.2	7.2	6.3	10.7	35.50	28.9	16.4	16.2
Nutrient management practices								
FAD	56.02[b]	67.07[b]	80.37[c]	94.36[b]	170.00[b]	226.67[b]	256.25[c]	225.70[b]
GRD	60.83[a]	73.47[a]	84.00[b]	100.88[a]	199.17[ab]	282.38[a]	279.75[abc]	236.10[ab]
NRD	62.20[a]	73.86[a]	86.67[a]	103.46[a]	225.42[a]	297.12[a]	310.63[a]	262.27[a]
LCC-N+NE-P&K	60.29[a]	75.89[a]	86.81[a]	104.07[a]	201.25[ab]	292.92[a]	296.93[ab]	264.88[a]
NED	61.51[a]	73.05[a]	85.03[ab]	102.24[a]	187.92[b]	267.50[ab]	269.03[bc]	241.93[ab]
SEm (±)	1.09	1.48	1.17	1.75	9.06	12.73	9.69	7.58
LSD (<0.05)	3.45	3.56	2.63	3.75	34.21	39.92	37.30	27.52
CV (%)	6.3	5.4	3.4	4.1	19.1	16	14.5	12.3
Grand mean	**60.17**	**72.67**	**84.57**	**101.00**	**196.75**	**273.32**	**282.52**	**246.18**

Note: FAD, Farmer applied dose (0-20:0-15:0-18 NPK kg ha^{-1}); GRD, Government recommended dose (100: 30: 30 NPK kg ha^{-1}); NRD, NARC recommended dose (120: 60: 40 NPK kg ha^{-1}); LCC-N+NE-P&K, LCC-based N & NE® based P and K dose (90-115:5-22:17-50 NPK kg ha^{-1} for Radha-4 and 90-140:5-36:38-73 NPK kg ha^{-1} for Arize Tej Gold); NED, Nutrient Expert® based NPK dose (93-109:5-22:17-50 NPK kg ha^{-1} for Radha-4 and 118-125:5-36:38-73 NPK kg ha^{-1} for Arize Tej Gold); DAS, Days after sowing; ns, non-significant; treatments means followed by common letter (s) are not significantly different among each other based on DMRT at 5 % level of significance.

Leaf area index

The leaf area index was found to be increasing during all dates of observations. The rapid increase in LAI was found between 60 and 70 DAS, thereafter increased at a lower rate. LAI was not significantly differed among the varieties up to 80 DAS but at 90 DAS significantly higher LAI was observed on hybrid Arize Tej Gold (Table 5). LAI was significantly different among different nutrient management practices after 70 days of sowing. The least value of LAI was observed in FAD while the greatest was observed in LCC - N + NE - P , K. After 80 days of sowing similar LAI was observed in all nutrient management practices except FAD. The result was supported by the finding of Acharya et al (2019) who obtained similar LAI on NED and LCC - N + NE - P , K and least LAI on FAD. Similar result was obtained by Budathoki et al (2018).

Table 5. Leaf area index (LAI) of rice as influenced by nutrient management practices at Fulbari, Chitwan, Nepal, 2017

Treatments	Leaf area index			
	60 DAS	**70 DAS**	**80 DAS**	**90 DAS**
Varieties				
Radha 4	0.85	1.74	2.12	2.09[b]
Arize Tej Gold	0.91	1.72	2.30	2.66[a]
SEm (±)	0.03	0.01	0.09	0.29
LSD (<0.05)	ns	ns	ns	0.26
CV (%)	24.7	14.8	41.3	13.7
Nutrient management practices				
FAD	0.75	1.30[c]	1.52[b]	1.78[b]
GRD	0.79	1.77[ab]	2.52[a]	2.27[ab]
NRD	0.95	1.74[b]	2.42[a]	2.94[a]
LCC-N+NE-P,K	1.07	2.18[a]	2.53[a]	2.45[ab]
NED	0.81	1.66[bc]	2.06[ab]	2.44[ab]
SEm (±)	0.06	0.11	0.19	0.19
LSD (<0.05)	ns	0.14	0.61	0.72
CV (%)	30.2	25.3	30.1	33.3
Grand mean	**0.88**	**1.73**	**2.21**	**2.38**

Note: FAD, Farmer applied dose (0-20:0-15:0-18 NPK kg ha^{-1}); GRD, Government recommended dose (100: 30: 30 NPK kg ha^{-1}); NRD, NARC recommended dose (120: 60: 40 NPK kg ha^{-1}); LCC-N+NE-P,K, LCC-based N , NE® based P and K dose (90-115:5-22:17-50 NPK kg ha^{-1} for Radha-4 and 90-140:5-36:38-73 NPK kg ha^{-1} for Arize Tej Gold); NED, Nutrient Expert® based NPK dose (93-109:5-22:17-50 NPK kg ha^{-1} for Radha-4 and 118-125:5-36:38-73 NPK kg ha^{-1} for Arize Tej Gold); DAS, Days after sowing; ns, non-significant; treatments means followed by common letter (s) are not significantly different among each other based on DMRT at 5 % level of significance.

Above-ground dry matter (Mt ha^{-1})

The above-ground dry matter (AGDM) was found to be increasing at an increasing rate up to 80 DAS and increasing at a decreasing rate thereafter (Table 6). Higher above-ground dry matter accumulation was observed in Arize Tej Gold but there was no significant difference up to 80 DAS while at 90 DAS, significantly higher AGDM was observed in hybrid Arize Tej Gold. Above-ground dry matter is significantly influenced by nutrient management practices from 70 to 90 DAS. The highest above-ground dry matter was found in LCC - N + NE - P , K applied plot up to 80 DAS while at 90 DAS, the highest AGDM was recorded on NED applied. In all dates of observations lowest above-ground dry matter was observed in FAD. After 70 days of sowing similar above-ground, dry matter accumulation was recorded in all other nutrient management practices except FAD. Thapa et al (2020) also recorded similar straw yields on NED, LCC - N + NE - P , K and NRD.

Table 6. Total above-ground dry matter (Mt ha^{-1}) of rice as influenced by nutrient management practices at Fulbari, Chitwan, Nepal, 2017

Treatments	Above-ground dry matter (Mt ha^{-1})			
	60 DAS	**60 DAS**	**60 DAS**	**60 DAS**
Varieties				
Radha 4	1.10	1.10	1.10	1.10
Arize Tej Gold	1.15	1.15	1.15	1.15
SEm (±)	0.03	0.03	0.03	0.03
LSD (<0.05)	ns	ns	ns	ns
CV (%)	15.2	15.2	15.2	15.2
Nutrient management practices				
FAD	1.00	1.00	1.00	1.00
GRD	1.19	1.19	1.19	1.19
NRD	1.18	1.18	1.18	1.18
LCC-N+NE-P,K	1.21	1.21	1.21	1.21
NED	1.06	1.06	1.06	1.06
SEm (±)	0.04	0.04	0.04	0.04
LSD (<0.05)	ns	ns	ns	ns
CV (%)	23.5	23.5	23.5	23.5
Grand mean	**1.13**	**1.13**	**1.13**	**1.13**

Note: FAD, Farmer applied dose (0-20:0-15:0-18 NPK kg ha^{-1}); GRD, Government recommended dose (100: 30: 30 NPK kg ha^{-1}); NRD, NARC recommended dose (120: 60: 40 NPK kg ha^{-1}); LCC-N+NE-P,K, LCC-based N , NE® based P and K dose (90-115:5-22:17-50 NPK kg ha^{-1} for Radha-4 and 90-140:5-36:38-73 NPK kg ha^{-1} for Arize Tej Gold); NED, Nutrient Expert® based NPK dose (93-109:5-22:17-50 NPK kg ha^{-1} for Radha-4 and 118-125:5-36:38-73 NPK kg ha^{-1} for Arize Tej Gold); DAS, Days after sowing; ns, non-significant; treatments means followed by common letter (s) are not significantly different among each other based on DMRT at 5 % level of significance.

Yield attributes

Yield attributes like effective tiller per square meter, grain per panicle, and panicle length was significantly influenced by nutrient management practice. Thousand-grain weight and sterility percentage were not influenced significantly by nutrient management practices (Table 7). Effective tiller per square meter, grain per panicle, and panicle length were significantly higher in LCC-N + NE–P , K (215.62, 132.02, 25.76 cm respectively) and lower in farmer applied dose (185.55, 111.12, 25.07 cm respectively). Grain per panicle and panicle length were found similar in LCC-N+NE-P,K and NED. Grain per panicle and panicle length was found similar in LCC-N+NE-P,K and NED.

Thapa et al (2020) also reported 13% more filled grains per panicle in LCC-N plot compare to farmer's plot. A similar finding of greatest number of filled grains and low sterility percentage in LCC-N plot was evident by Marahatta (2017). This increment might be attributed to the real N management by sufficient application of N fertilizer at split-based.

It is evident from the findings that the number of panicles per square meter was significantly influenced by various SSNM treatments; the highest number of panicles per m^{-2} was recorded under the SSNM based on Nutrient expert followed by SSNM based on LCC (Mannade et al 2017).

The 1000 grain weight of rice remained unaffected due to nutrient management practices and the finding was also supported by the result of Mannade et al (2017) who reported similar test weight on different fertilizer dose. In contrast to these findings, Biradar et al (2006) found that SSNM practice resulted in significantly higher test weight over farmer's fertilizer practice and recommended dose of fertilizer in rice.

Table 7. Yield attributes and yield-associated traits of rice as influenced by nutrient management practices at Fulbari, Chitwan, Nepal, 2017

Treatments	Effective tillers m^{-2}	Grains per panicle	Panicle length (cm)	Thousand grain weight (g)	Sterility (%)
Varieties					
Radha 4	196.66	103.05^{b}	23.28^{b}	22.86^{a}	20.72
Arize Tej Gold	206.98	139.21^{a}	27.94^{a}	21.52^{b}	22.46
SEm (±)	5.16	18.08	2.33	0.67	0.87
LSD (<0.05)	ns	13.30	1.38	1.15	ns
CV (%)	7.2	14	6.8	6.6	13.2
Nutrient management practices					
FAD	185.55^{d}	111.12^{c}	25.07^{b}	21.40	24.24
GRD	194.27^{c}	116.34^{bc}	25.44^{b}	21.65	22.43
NRD	206.53^{b}	113.66^{c}	24.73^{b}	22.71	21.80
LCC-N+NE-P,K	215.62^{a}	132.52^{a}	27.02^{a}	22.84	20.35
NED	207.13^{b}	132.02^{ab}	25.76^{ab}	22.35	19.14
SEm (±)	5.30	4.62	0.39	0.29	0.88
LSD (<0.05)	8.11	14.53	1.41	ns	ns
CV (%)	4.4	13.2	6.1	7.3	18
Grand mean	**201.82**	**121.13**	**25.61**	**22.19**	**21.59**

Note: FAD, Farmer applied dose (0-20:0-15:0-18 NPK kg ha^{-1}); GRD, Government recommended dose (100: 30: 30 NPK kg ha^{-1}); NRD, NARC recommended dose (120: 60: 40 NPK kg ha^{-1}); LCC-N+NE-P,K, LCC-based N , NE® based P and K dose (90-115:5-22:17-50 NPK kg ha^{-1} for Radha-4 and 90-140:5-36:38-73 NPK kg ha^{-1} for Arize Tej Gold); NED, Nutrient Expert® based NPK dose (93-109:5-22:17-50 NPK kg ha^{-1} for Radha-4 and 118-125:5-36:38-73 NPK kg ha^{-1} for Arize Tej Gold); DAS, Days after sowing; ns, non-significant; treatments means followed by common letter (s) are not significantly different among each other based on DMRT at 5 % level of significance.

Grain, straw yield and harvest index

The mean grain yield and straw yield in the experiment was 4.62 Mt ha^{-1} and 5.79 Mt ha^{-1} respectively. The grain yield and straw yield was significantly influenced by varieties as well as nutrient management (Table 8). The grain yield of hybrid variety Arize Tej Gold (5.41 Mt ha^{-1}) was significantly higher than the improved variety Radha-4 (3.82 Mt ha^{-1}). Similarly, the straw yield of hybrid variety Arize Tej Gold (6.40 Mt ha-1) was also significantly higher than the improved variety Radha-4 (5.19 Mt ha^{-1}).

The LCC-N+NE-P,K produced the highest grain yield (5.19 Mt ha^{-1}) and straw yield (6.43 Mt ha^{-1}) followed by NE based application where 5.00 Mt ha^{-1} grain and 6.29 Mt ha^{-1} straw yield was obtained. These two treatments were statistically similar but significantly superior to GRD, NRD, and FAD treatments. Farmer applied dose (FAD) produced the lowest grain yield and straw yield (4.00 Mt ha^{-1} and 4.93 Mt ha^{-1} respectively) and was statistically similar to the government recommended dose (4.32 Mt ha^{-1} and 5.33 Mt ha^{-1} respectively). These findings were similar to the results of Mannade et al (2017), Mishra et al (2007), and Islam et al (2012), Acharya et al (2019). The increased grain yield might be attributed to the greater number of effective tillers coupled with more filled grains in the LCC-N+NE-P,K plots than others. Higher yield in LCC-N+NE-P,K might be due to the split application of nitrogen that may help in the continuous supply of nitrogen to the plant to retain leaf greenness for a longer period. Increased N level and their split application show a positive effect on morphological and yield contributing characters of rice (Kumar et al 2017). Nitrogen use efficiency, solar radiation utilization and assimilates production can be increased through the split application of nitrogen, which ultimately leads to increased biomass and grain production (Sathiya et al 2009). The right dose of split N during critical periods of crop growth increases nutrient uptake, reduces the N losses and increases N use efficiency (Kamruzzaman et al 2013).

Harvest index was not statistically influenced by nutrient management practice which was found greater in GRD (41.23) and least in NRD (39.56) (Table 8). Similar insignificant effect of nitrogen levels on harvest index was reported by Lone (2014). Studies also reported that percentage of productive tillers decreases with an increase of N fertilizer. Further, the indifference of N splitting on harvest index was observed by Kamruzzaman et al (2013) and Kumar et al (2015).

Table 8. Grain yield (Mt ha^{-1}), straw yield (Mt ha^{-1}) and harvest index as influenced by nutrient management practices at Fulbari, Chitwan, Nepal, 2017

Treatments	Grain yield (Mt ha^{-1})	Straw yield (Mt ha^{-1})	Harvest Index
Varieties			
Radha 4	3.82^{b}	5.19^{b}	38.86^{b}
Arize Tej Gold	5.41^{a}	6.40^{a}	42.37^{a}
SEm (±)	0.80	0.60	1.75
LSD (<0.05)	0.31	0.29	2.54
CV (%)	8.6	6.4	8
Nutrient management practices			
FAD	4.00^{c}	4.93^{c}	40.82
GRD	4.32^{bc}	5.33^{bc}	41.23
NRD	4.57^{b}	5.99^{ab}	39.56
LCC-N+NE-P,K	5.19^{a}	6.43^{a}	41.03
NED	5.00^{a}	6.29^{a}	40.44
SEm (±)	0.22	0.29	0.30
LSD (<0.05)	0.40	0.73	ns
CV (%)	9.4	13.9	8.3
Grand mean	**4.62**	**5.79**	**40.62**

Note: FAD, Farmer applied dose (0-20:0-15:0-18 NPK kg ha^{-1}); GRD, Government recommended dose (100: 30: 30 NPK kg ha^{-1}); NRD, NARC recommended dose (120: 60: 40 NPK kg ha^{-1}); LCC-N+NE-P,K, LCC-based N , NE® based P and K dose (90-115:5-22:17-50 NPK kg ha^{-1} for Radha-4 and 90-140:5-36:38-73 NPK kg ha^{-1} for Arize Tej Gold); NED, Nutrient Expert® based NPK dose (93-109:5-22:17-50 NPK kg ha^{-1} for Radha-4 and 118-125:5-36:38-73 NPK kg ha^{-1} for Arize Tej Gold); DAS, Days after sowing; ns, non-significant; treatments means followed by common letter (s) are not significantly different among each other based on DMRT at 5 % level of significance.

Benefit-cost ratio

The B:C ratio was higher in hybrid variety Arize Tej Gold (2.30) than in improved variety Radha 4 (2.11) (Table 9). B:C ratio was statistically similar in FAD, LCC-N+NE-P,K, and NED but was highest in LCC-N+NE-P,K (2.41) followed by FAD (2.38) and NED (2.29). Highest B:C in LCC-N+NE-P,K was also reported by Thapa et al (2020). Need based nitrogen application reduced the fertilizer cost without yield reduction revealing more profitability of the practice. In contrast to our finding Thapa et al (2020) reported low B:C in FAD. Further, Jahan et al (2014) found no extra benefit on the extra dose of nitrogen application in aromatic rice. Similar B:C ratio was mainly due to the significant reduction in the nitrogen fertilizer cost and satisfactory crop performance.

Table 9. Total variable cost, gross return, net return and benefit-cost ratio of rice as influenced by the nutrient management practices at Fulbari, Chitwan, Nepal, 2017

Treatments	Total Variable cost (NRs ha^{-1})	Gross return (NRs ha^{-1})	Net return (NRs ha^{-1})	B: C Ratio
Varieties				
Radha 4	46975.14[b]	98409.90[b]	51434.77[b]	2.11[b]
Arize Tej Gold	66335.31[a]	152256.36[a]	85921.05[a]	2.30[a]
SEm (±)	9680.09	26923.23	17243.14	0.09
LSD (<0.05)	1023.07	8031.85	7455.70	0.13
CV (%)	2.30	8.20	13.80	7.80
Nutrient management practices				
FAD	45447.75[c]	108395.76[c]	62948.01[b]	2.38[a]
GRD	57972.57[b]	117052.36[bc]	59079.80[b]	1.99[b]
NRD	62648.28[a]	124941.91[b]	62293.64[b]	1.98[b]
LCC-N+NE-P,K	58538.55[b]	140220.76[a]	81682.21[a]	2.41[a]
NED	58668.99[b]	136054.87[a]	77385.89[a]	2.29[a]
SEm (±)	2922.86	5883.01	4531.30	0.09
LSD (<0.05)	1293.94	10390.36	10580.48	0.20
CV (%)	2.50	9.10	16.90	10.00
Grand mean	**56655.23**	**125333.13**	**68677.90**	**2.21**

Note: FAD, Farmer applied dose (0-20:0-15:0-18 NPK kg ha^{-1}); GRD, Government recommended dose (100: 30: 30 NPK kg ha^{-1}); NRD, NARC recommended dose (120: 60: 40 NPK kg ha^{-1}); LCC-N+NE-P,K, LCC-based N , NE® based P and K dose (90-115:5-22:17-50 NPK kg ha^{-1} for Radha-4 and 90-140:5-36:38-73 NPK kg ha^{-1} for Arize Tej Gold); NED, Nutrient Expert® based NPK dose (93-109:5-22:17-50 NPK kg ha^{-1} for Radha-4 and 118-125:5-36:38-73 NPK kg ha^{-1} for Arize Tej Gold); DAS, Days after sowing; ns, non-significant; treatments means followed by common letter (s) are not significantly different among each other based on DMRT at 5 % level of significance.

CONCLUSIONS

In this experiment, the nutrient management practice of LCC-N+NE-P,K was found profitable in rice in Fulbari, Chitwan, Nepal. Comparatively higher level of fertilizers on research-based recommendation (NRD) and lower level of fertilizers on the farmers' fertility management practice (FAD) was found crucial for achieving higher productivity of rice. SSNM-based nutrient management decision support tool, Nutrient Expert® may be the appropriate option for nutrient management in rice. Nutrient Expert tool used in the experiment was specially designed for Indian conditions. So, more precise recommendation can be made through repeated trials and validation in the various agro-ecological condition of Nepal.

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AUTHORS' CONTRIBUTION

Milan Acharya designed, carried out the field experiment and prepared the manuscript and the respective coauthors guided him while experimentation and manuscript preparation.

CONFLICTS OF INTEREST

The authors have no any conflict of interest to disclose.

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