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Effect of nutrient management on quality, NPK content and uptake in rice (*Oryza sativa* L.) under rice-wheat cropping system

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Abstract
In the present experiment rice variety HUR-105 (P9) was grown under irrigated conditions during *Kharif* 2012 at the Agricultural Research Farm, Institute of Agricultural Sciences, B.H.U., Varanasi, India under RBD replicated thrice with 7 treatments to evaluate the quality parameter, nutrient content and nutrient uptake. Application of 75% RDF and 25% N through vermicompost or sesbania registered maximum protein content and were significant. The maximum protein yield obtained with 100% RDF + $S_{40}Zn_5B_{1.5}$ kg ha^{-1} and lowest in control (N, P, K: 00,00,00). The highest nitrogen and potassium content by rice grain and straw were recorded with the application of 75% RDF + 25% N through vermicompost. The phosphorus content in grain was highest with 100% RDF + $S_{40}Zn_5B_{1.5}$ kg ha^{-1} while in straw it was maximum with customized fertilizer. The higher K content in grain and straw were noticed in 75% RDF + 25% N through sewage sludge.

Keywords: Nutrient management, nutrient content, nutrient uptake, protein yield, RDF, rice

Introduction
Rice-Wheat cropping system is the most dominant cropping system of the world which plays a critical role in food security particularly in South Asia. In recent years, the rice-wheat system has started suffering production fatigue, over nutrient mining, declining factor productivity, decreasing soil profitability, lowering of groundwater table build-up of pests including weeds, diseases and insects causing concern of sustainability (Yadav *et al.* 2005) [10]. This stagnation of rice-wheat system productivity is attributed to the monotony of system, deterioration of soil physical properties, development of hardpan beneath the plough layer, exhaustive nature of the cereal-cereal system, similar foraging, etc. The combination of poor soil fertility and inadequate, unbalanced, and inefficient use of fertilizers contribute much to this problem (Yadav *et al*., 2013) [11]. It has also been established that cereal-cereal crop sequences are more elaborate and place a greater demand on soil resources than grain-legumes and grain-oilseed sequences. Continuous practice of the same system has an adverse effect on soil conditions (Kumar and Yadav, 2002) [4].

Current generalized recommendations regarding NPK fertilizers point to soil exhaustion, which proves their decreased efficiency and thus requires upward refining and proper balance between essential nutrients. The concept of balanced fertilization cannot be limited to N, P and K only. Balanced fertilization includes all plant nutrients necessary for high agricultural productivity and soil health. Preventing degradation of soil-organic carbon is considered to be the most powerful weapon in combating soil quality degradation and sustenance of soil quality. The soil has starved for both primary and secondary nutrients as well as some micronutrients *viz*. Zn, Fe, Cu, and Mn. The primary reason for secondary and micronutrient deficiency is almost no application of organic fertilizers. While chemical fertilizers are being used by farmers who are devoid of secondary and micronutrients. Therefore, if there is a need to pay attention to the use of key nutrients as well as secondary and micronutrients as needed in balanced proportions, then chemical fertilizers are the only dependency. Indian farms have a huge potential for organic resources, which can effectively be used as an organic component of INM, around 7.5 million tonnes of NPK. This will ensure stability in agricultural production. Vermicompost is a major component of the environment-friendly agricultural system. In recent years, it has been favoured due to its high analysis and improved mineralization. It is a rich source of plant nutrients, such as N, P and K, as well as micronutrients and vitamins or enzymes. On the other hand, the huge production of sewage sludge, which contains good amounts of organic matter and plant nutrients and significant additions of nutrients to the green manure, is a good replacement for the chemical fertilizers cultivated in the rice-wheat system. Recently some customized fertilizers containing major and micronutrients have come to the market to enable balanced nutrition and to check for micronutrient deficiencies. Balanced nutrition can also be taken care of by applying major, secondary and micronutrients through fertilizers.

Nitrogen, an integral part of various enzymes, proteins, and chlorophylls, etc., has been reported to increase cell size and cell numbers (Novoa and Loomis, 1981) [6]. Similarly, phosphorus is an integral part of many plant constituents, such as nucleoprotein, phosphopyridine, NAD, NADP, ADP and ATP. Phosphorus is also associated with cell division, transfer of hereditary characters, transport of ions to the cell membranes, and transfer of free energy during respiration (Mengel and Kirkby, 2001) [5]. Phosphorus plays an important role in transporting sugars and converting light energy into physiologically useful chemical energy. Therefore, phosphorus clearly affects the characters of growth and development of almost all plants. K enhances the action of photosynthesis through photophosphorylation. In total, K is an activator of more than 60 enzymes. As a result, growth, development and finally yield is a function of the availability of these nutrients in the soil.

Materials and Methods

In the present experiment, a field trial was conducted at Agricultural Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, India during *Kharif*, 2012. The laboratory analyses of the plant grain, straw as well as soil samples were conducted during 2013. The present experiment is the part of long-term experiment on nutrient management of rice – wheat cropping system at fixed site, sponsored by USAID –AIP program of USA (Table 1). In *kharif* 2012, study was under taken for the investigation of NPK content and uptake in rice. The experimental area had uniform well-drained topography with a sufficient source of water supply. There were seven treatments which include control, three inorganic sources of nutrients and three integrated nutrient management (INM) treatments. The INM treatments comprised of 75% RDF and 25% N either through sewage sludge, vermicompost or green leaves manuring by sesbania. The present experiment was conducted on the rice variety HUR-105 (P9). This is a mutant of variety MPR 7-2, developed from Banaras Hindu University, Varanasi, UP in the year 2009. This is semi-dwarf in nature (100-102 cm), takes 130-135 days for maturity and yielding 50-55 q/ha. The soil of experimental site was Gangetic alluvial having sandy clay loam texture with pH 7.95. The spacing during transplanting was maintained at 20 x 10 cm. The field was flooded at the time of transplanting and further irrigations were given as and when required by the crop. In all, irrigation was given to the experimental crop mainly in the month of September due to insufficient rainfall.

Nutrient application

The nutrient application was done as per treatment. Half of the total amount of nitrogen with a full dose of phosphorus, potassium was applied to the puddled surface just before transplanting and manually added to the top 15 cm of soil. Zinc, Sulphur, and boron were also applied as basal dose as per treatments. In treatment T4, the entire quantity of customized fertilizer was applied as basal along with the supplemental dose of urea to meet the recommended dose of Nitrogen i.e. 60 kg N ha^{-1}. The remaining half quantity of N through urea fertilizer was top-dressed in two equal instalments.

Application of sesbania, sludge, and vermicompost

It was manually incorporated plot-wise as per the treatment. The application of these organic sources was done based on their nitrogen content, ignoring the other nutrients. Organic manures were included in the plots 10 days before the transplanting of rice. Based on the nitrogen present in them, the amount of organic fertilizers was calculated. Sewage sludge was air-dried and grounded before applied in the field. Vermicompost was applied as fresh and Sesbania plants were chopped and applied in the plots. The moisture content of all three manures was calculated and all were applied on a dry weight basis.

Observations recorded: Various quality parameters, NPK content, and uptake were recorded at different growth stages. These observations are discussed below.

Quality parameters: Crude protein content (%) and protein yield (kg ha^{-1}) Protein content in grain was worked out by multiplying the nitrogen content in grain with the factor 6.25, as suggested by A.O.A.C. (1970). Protein yield was determined by multiplying the protein content in grain with their respective yields.

$$\text{Protein yield (kg/ha)} = \frac{\text{Protein content (\%) x Grain yield (kg/ha)}}{100}$$

Chemical analysis

(a) N, P and K content (%) in plants: Plant material for this study was drawn at harvest of rice and the grain and straw were dried at 70 ^{0}C for 48 hours, the plant material thus obtained was ground with the help of grinder and passed through 40 mesh sieve and then used for determination of N, P and K content. The analysis of Total 'N' was done by Micro Kjeldahl method while the analysis of Total 'P' was done by Vanado Molybado phosphoric acid yellow colour method. The analysis of Total 'K' was done by the Flame photometer method (Jackson 1973).

(b) Estimation of nitrogen in plant and grain sample: Nitrogen content in plant and grain samples was determined by the Modified Kjeldahl Method. In a digestion tube, 0.5 g of powdered plant straw was taken and 10 ml of diacid solution (9:1, H_2SO_4: $HClO_4$) was added and kept for overnight then 10g of sulphate mixture [(20 parts K_2SO_4) + 1 part catalyst mixture (20 parts $CuSO_4$ + 1 part selenium powder)] was added and heating was done in a digestion chamber till a clear colourless solution appears, then cooled and filtered through Whatman No. 42 filter paper in a 50 ml volumetric flask and made up to the volume with distilled water. The outlet of the distillation apparatus was immersed in a ten ml boric acid solution containing 4% boric acid solution containing bromocresol green and methyl red indicator in a conical flask. Ten ml of the aliquot was taken and transferred to the distillation tube of Kjeltec Semi-Auto Nitrogen Analyzer and 10 ml of 40% NaOH was sucked and added to the distillation tube. Then the instrument was put on distillation for 9 min. After completion of distillation, the boric acid was titrated against 0.005 N H_2SO_4. Blank was also run, and N content was calculated by the formula.

$$\text{Percent N in Plant material} = \frac{T \times 0.005 \times 0.014 \times 50 \times 100}{10 \times 0.5}$$

Where

T = Sample reading - Blank reading

(c) Digestion for P, K, S, B, Zn in rice straw and grain

Sample (20 mesh) of 0.5 g dry and powdered plant was taken in 50 ml digestion tube and 10 ml di-acid mixture (4: 1 v / v HNO_3: $HClO_4$) and kept overnight. It was digested on a block digester until a colourless solution was obtained. The acid content was reduced until there was only moist residue in the flask. The flask was cooled, and 25 ml distilled water was added. The solution was filtered in a 50 ml volumetric flask and diluted to the mark. The digestion of grain was also done in a similar manner.

(d) Phosphorus content in grain and straw

Five ml of the digest was taken in a 25 ml volumetric flask and 2 drops of 2, 4 di-nitrophenol indicators were added. Ammonium solution was added till yellow colour appeared and then 6 N HCl was added (dropwise) till it becomes colourless. Then 5 ml of Vanadate molybdate solution was added and diluted to 25 ml with distilled water, mixed well and the intensity of yellow colour was read on spectrophotometer by using a blue filter at 440 nm wavelength. A blank was also run without P solution simultaneously. First standard reading and then sample reading was taken. Phosphorus content in straw and grain was calculated using a standard curve and expressed as total P (%). The same procedure was followed to the determination of P content in grain. Standard solutions of 1, 2,3,4,5 and 10 ppm were prepared.

$$\text{Total P \%} = \frac{\text{Abs. x dilution factor}}{\text{The slope of the Std curve x 10000}}$$

(e) Potassium content in straw and grain

The potassium content of plant and grain was determined by Flame Photometer method (Jackson, 1973). In the case of potassium, the digested extract was used directly for flame photometer determination of potassium. The potassium content of digested straw and grain was determined by Flame Photometer. K content was calculated as under.

$$\text{Total K \%} = \frac{\text{R x dilution factor}}{10000}$$

Where

R = Flame photometer reading, Dilution factor = 50/0.5 = 100 times

Statistical Analysis and Interpretation of Data

The raw data observed during the whole experiment was put for statistical analysis by following the Randomized Block Design (RBD) to draw the valid differences among the treatments using SPSS software.

Result and Discussion

Effect on quality

Protein content was recorded maximum in treatments receiving 75% RDF and 25% N either through Vermicompost or Sesbania green manuring and being comparable to T2, T3, T4, and T5, all recorded significantly higher protein content than control (Table 2). This could be attributed to the availability of the nutrients under INM treatments and the better availability of Zn in T4 and that of S and Zn in T3 that is known to promote the nitrogen uptake and protein content in plants. Further, due to better protein content and higher grain yield, 100% RDF + $S_{40}Zn_5B_{1.5}$ kg ha^{-1} (T3) recorded significantly high protein yield than T5 and T1, however, it does not differ statistically with T2, T4, T6, and T7. Dixit and Gupta (2000) [1] observed that grain protein content of rice was increased due to application of NPK fertilizer which ranged from 5.35 to 7.20 per cent and 5.20 to 7.09 per cent during second and first year, respectively. Similarly, Hattab *et al.* (1998) [2] reported that application of 25 per cent organic sources as basal and 75 per cent N through inorganic N as the top dressing was superior in respect of various quality parameter.

Effect on nutrient content and uptake

The maximum nitrogen content was recorded in treatment T6 and being at par with T7 both recorded significantly higher grain N content than other treatments. However, control (T1) recorded significantly lower grain N content than other treatments. The maximum content (0.856%) was recorded in treatment T6 (75% RDF + 25% N through vermicompost) followed by T7 (75% RDF + 25% N through Sesbania) and both recorded significantly higher straw N content than rest of the treatments (Table 3). Maximum P content in grain was noticed in T3 (100% RDF + $S_{40}Zn_5B_{1.5}$ kg ha^{-1}) and being at par with the rest of the fertility treatments it recorded significantly grain protein content than control and T5 (75% RDF + 25% N through sewage sludge). With respect to P content in straw, the maximum value was noticed in T4 (312 kg customized fertilizer + 85.7kg N through urea) and is comparable to other treatments produced significantly higher P content of straw than control (T1). The potassium content in grain ranged between 0.307 to .417%. Maximum (.417%) being in treatment T5. The K content in rice straw ranged between 0.915% to 1.172%. Maximum (1.172%) being in treatment T5 followed by T3 (1.160%). Control registered significantly lowest K content in straw than the rest of the treatment.

The maximum nitrogen uptake by straw (57.75 kg ha^{-1}) was recorded with T5 (75% RDF + 25% N through sewage sludge) followed by T3 (100% RDF + $S_{40}Zn_5B_{1.5}$ kg ha^{-1}) which was about 59 and 55% higher than control (Table 4). The lowest value (23.31 kg ha^{-1}) was observed in control. The maximum value of nitrogen uptake by grain (51.35 kg ha^{-1}) was recorded with T3 followed by T2 (49.04 kg ha^{-1}). Treatment T3 and T2 increased N uptake by 47 and 42% over control, respectively. Maximum 51.53 kg ha^{-1} N uptake was recorded in T3 (RDF + S, Zn, B; 40-05-1.5) followed by 49.04 kg ha^{-1} in treatment T2 which were 46 and 44% higher over control. The total N uptake was recorded highest in treatment T3 (100% RDF + $S_{40}Zn_5B_{1.5}$ kg ha^{-1}). The maximum P uptake by rice grain (31.21 kg ha^{-1}) was recorded with treatment T3 and being at par with T2, T4, T5, and T7 it registered significantly higher P uptake by grain than control(T1) and 75% RDF + 25% through vermicompost (T6). The highest phosphorus uptake (10.69 kg ha^{-1}) was recorded in treatment T5 (75% RDF + 25% N through sewage sludge). Potassium uptake by grain varied from 9.5to 20.0 kg ha^{-1}. The maximum uptake of potassium by rice grain (20.0 kg ha^{-1}) was recorded with T3 followed by T2, T4, T6, T7, and T5 respectively, all remained comparable to each other but proved significantly superior to T1(control). The maximum potassium uptake by straw was recorded with T5 (84.2 kg ha^{-1}) and being at par with T3, T4, and T2. It established INM treatments recorded significant higher K uptake by straw than control (T1). The highest total potassium uptake was recorded with the application of 75% RDF+25% N through sewage sludge (T5) and it was closely followed by T3 (100% RDF + $S_{40}Zn_5B_{1.5}$ kg ha^{-1}).

The content of NP and K in grain and straw were appreciably enhanced with application 100% RDF + S40 Zn5 B1.5 kg ha^{-1}, customized fertilizer + urea as well as INM treatments where 25% of recommended N was substituted through sewage sludge/vermicompost/ Sesbania green manuring. This accompanied with higher yields of grain and straw, T3 (100% RDF + $S_{40}Zn_5B_{1.5}$ kg ha^{-1}) resulted in maximum uptake of nitrogen and phosphorus by grain and straw as well as total uptake. Nevertheless, the highest total uptake of potassium was recorded in T4 (customized fertilizer + urea), closely followed by T3 (100% RDF + $S_{40}Zn_5B_{1.5}$ kg ha^{-1}). These findings support the findings of Rahman *et al.* (2008) and Vidyavathi *et al.* (2012) [9]. Vennila *et al.* (2007) [8] reported that the application of 75 per cent N through inorganic source along with 25 per cent N as organic manure and 100% RDF N to the preceding wet seeded rice recorded higher nutrient uptake.

Table 1: Cropping History

Year	*Kharif*	*Rabi*
2008-09	Rice	Wheat
2009-10	Rice	Wheat
2010-11	Rice	Wheat
2011-12	Rice	Wheat
2012-13	Rice*	Wheat

* Experimental crop

Table 2: Effect of nutrient management on quality (protein content and protein yield) of rice.

Treatments		Protein content (%)	Protein yield (kg ha^{-1})
T_1	Control N, P, K (00,00,00)	5.5	170
T_2	100% RDF-NPK (120-60-60)	6.5	308
T_3	RDF+S, Zn, B (40-05-1.5)	6.37	321
T_4	Customized fertilizer ($N:P_2O_5:K_2O$:Zn:B:11:32:13:0.9:0.24)	6.29	304
T_5	75% RDF+ 25% N through sewage sludge	6.45	270
T_6	75% RDF+ 25% N through vermicompost	6.78	303
T_7	75% RDF+ 25% N through *Sesbania*	6.75	308.7
SE m±		0.22	12.1
CD (P=0.05)		0.68	37.28

Table 3: Effect of nutrient management on N, P and K (%) content in grain and straw of rice.

Treatments		N (%)		P (%)		K (%)	
		Grain	Straw	Grain	Straw	Grain	Straw
T_1	Control N, P, K (00,00,00)	0.88	0.548	0.466	0.112	0.307	0.915
T_2	100% RDF-NPK (120-60-60)	0.996	0.763	0.577	0.151	0.384	1.155
T_3	RDF+S, Zn, B (40-05-1.5)	1.02	0.765	0.62	0.15	0.4	1.16
T_4	Customized fertilizer ($N:P_2O_5:K_2O$:Zn:B:11:32:13:0.9:0.24)	1.01	0.762	0.57	0.162	0.392	1.22
T_5	75% RDF+ 25% N through sewage sludge	1.028	0.804	0.529	0.149	0.417	1.172
T_6	75% RDF+ 25% N through vermicompost	1.08	0.856	0.61	0.154	0.413	1.122
T_7	75% RDF+ 25% N through *Sesbania*	1.08	0.838	0.579	0.157	0.404	1.117
S.Em±		0.01	0.012	0.025	0.008	0.02	0.033
CD (P=0.05)		0.03	0.04	0.051	0.023	0.06	0.1

Table 4: Effect of nutrient management on N, P and K (kg ha^{-1}) uptake in grain and straw of rice.

Treatment		N (kg ha^{-1})			P (kg ha^{-1})			K (kg ha^{-1})		
		Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total
T_1	Control N, P, K (00,00,00)	27.4	23.3	50.7	14.4	5.2	19	9.5	38.9	48.4
T_2	100% RDF-NPK (120-60-60)	49	49.3	98.3	28.4	9.7	38.1	18.9	74.4	93.3
T_3	RDF+S, Zn, B (40-05-1.5)	51.4	52.2	103.6	31.2	10.2	41	20	79.2	99.2
T_4	Customized fertilizer ($N:P_2O_5:K_2O$:Zn:B:11:32:13:0.9:0.24)	48	48.4	96.4	27.2	10.3	37	18.7	77.3	95.9
T_5	75% RDF+ 25% N through sewage sludge	43.1	57.7	100.8	25.2	10.7	32	17.5	84.2	107.7
T_6	75% RDF+ 25% N through vermicompost	48.9	49.9	98.7	25.8	9	34.9	18.6	65.4	84
T_7	75% RDF+ 25% N through *Sesbania*	48.9	47.9	96.8	26.2	9.1	35.5	18.4	64.6	85
SE m±		1.99	2.39	3.15	1.65	0.95	3.69	0.89	6.03	7.12
CD (P=0.05)		6.14	7.36	9.71	4.88	2.93	11.37	2.63	18.57	20.9

Conclusion

The grains showed higher nitrogen and phosphorus content as compared to straw. The balanced nutrients application resulted in maximum nitrogen, phosphorus, and potassium uptake by grain, straw and total uptake by the crop at harvest. The lowest nitrogen, phosphorus and potassium uptake by grain, straw, and total biomass were recorded in control.

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