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Effect of different doses and method of application on nitrogen use efficiency (NUE) in rice (*Oryza Sativa* L.)

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Abstract
In India, rice is grown during *kharif* season and losses of applied N through leaching may be decreased through proper rate and timing of N application. However, appropriate source of N fertilizer, rate and time of application may improve N fertilizer use efficiency of the crop. Furthermore, effective rate of application for slow N releasing fertilizer like polymer coated urea (PCU) for increasing rice productivity at Varanasi districts has not been established. Therefore, A field experiment was conducted with 12 treatments and 3 replications of control, 100% of RDN through normal urea as a single basal dose and as in 3 split, and 100%, 85%, 70% and 55% RDN through PCU as single basal doses and as in 3 split under randomized block design (RBD) on rice variety HUR-105 during *kharif* season 2016. The last treatment (T_{12}) was comprising with 55% of RDN through PCU as basal dressing + 2 tons FYM ha^{-1} + PGPR (mixture of *Azotobactorchroococcum, Pseudomonas aeruginosa, Pseudomonas flurescens, Pseudomonas putida, Bacillus subtilis, Azospirillumbrasilense, Trichodermaharzianum*).

Keywords: Nitrogen Use Efficiency (NUE), Polymer Coated Urea (PCU), rice, Normal Urea

Introduction

Nitrogen (N) plays a central role in modern agriculture. It is an essential nutrient and also the major limiting factor in most agricultural soils under all agro-ecological condition. Poor nutrient utilization and nitrogen losses from urea applications have been reported for many years (Khalil *et al*., 2009). The N losses from applied urea have been estimated to be 30 to 40 per cent in tropical soil (Freney *et al*., 1981). Low recovery of N in annual crop is associated with its loss by volatilization, leaching, surface runoff, and denitrification. However, worldwide recovery of N in cereal crops is usually 30-50 per cent (Ladha *et al*., 2005).

Availability of nitrogen applied as fertilizer to crop depends not only on the rate but also on the nature of the N fertilizer, soil types and conditions, cropping system, management as well as on temperature and precipitation during the growing season (Przulj and Momcilovic, 2001) [16]. Highly soluble N fertilizers like urea may be lost from the soil plant system through leaching, NH_3 volatilization, denitrification and immobilization or may be fixed on the soil colloids as NH_4-N form (Bock, 1984) [3]. Such losses raise concerns about water contamination and greenhouse gas emissions. Low use efficiency of fertilizer N also reduces economic returns from fertilizer inputs. NUE of crop can be increase by reduce the N loss. Increased efficiency can also increase yield and quality of crops and economic return for growers. Consequently, it has been the challenge of the fertilizer industry to develop special types of fertilizers avoiding or at least reducing such losses.Urea has disadvantage; considerable amounts of N can be lost through volatilization which might be resulted in very low N fertilizer use efficiency (Chen *et al.* 2008) [5], if not incorporated into soil soon after application. The N recovery by crops from the soluble N fertilizers such as urea is often as low as 30–40% which is low use efficiency, with a potentially high environmental cost associated with N losses via NH_3 volatilization, NO_3 - leaching and N_2O emission to the atmosphere (Zhou *et al.*, 2009) [21]. Then, nitrogen fertilizer use efficiency of crops becomes low.

For improving N use efficiency (NUE) proper N application timing and rates are critical for meeting crop needs (Dhugga and Waines, 1989; Blankenau *et al.*, 2002) [7, 2]. Growth stage of plants at the time of application also determines NUE. For attaining the high N uptake the N fertilizer application in split dose in later stage of crop growth (Ashraf and Azam, 1998) [1]. NUE, grain yield produced per unit of N supply, is a complex trait comprising N uptake efficiency (NUPE) and N utilization efficiency (NUTE) (Moll *et al.*, 1982; Ortiz-Monastero *et al.*, 1997) [12, 14].

NUPE reflects the ability of the plants in obtaining N, while NUTE reflects the efficiency with which the crop utilizes N in the plant for the synthesis of grain yield.

Coated urea fertilizers are a group of controlled release fertilizers consisting of prills of urea coated in less-soluble chemicals such as sulfur, polymers, other products or a combination. These fertilizers have advantage over Normal Urea in aspects of fertilizer burning. The coatings release the urea either when penetrated by water, as with sulfur, or when broken down, as with polymers. It is possible to predict and control the nutrient release rate from these products are more accurately than for Normal Urea (Trenkel, 2010) [19].

There are different mechanisms to improve the nitrogen fertilizer use efficiency. Cropping system, soil and water management, use of appropriate N fertilizer and application rate are among the main management options to increase N fertilizer use efficiency. In addition to these, use of slow N releasing fertilizers, nitrification inhibitor, efficient species or genotypes, and disease, insects and weeds control are also important for improvement of N fertilizer use efficiency (Fageria, 2009) [8]. However, some of the management options listed above is not being practiced in India in general and Varanasi region in particular. For instant, slow N releasing fertilizers and nitrification inhibitors are not being practiced at Varanasi district.

In India, rice is grown during *kharif* season and losses of applied N through leaching may be decreased through proper rate and timing of N application. Limited research has been done on the effects of N rate and time of application in different dose in relation to slow releasing fertilizer like PCU for NUE. Such studies may give a clue for enhancing grain yield and protein content and production and productivity. This study the on variations in NUE, and their association with grain yield and productivity, morphological characteristic, chlorophyll content of local and improved rice varieties under different N rates and time of applications of PCU and Normal Urea. Therefore, appropriate source of N fertilizer, rate and time of application may improve N fertilizer use efficiency of the crop. Furthermore, effective rate of application for slow N releasing fertilizer like polymer coated urea (PCU) for increasing rice productivity at Varanasi districts has not been established. Therefore, keeping the above facts in view, the present research work has been under taken during *kharif* 2016 at the agricultural research farm, Banaras Hindu University, Varanasi.

Materials and Methods

Experimental Site

The Agricultural Research Farm is situated at a distance about 10 km from Varanasi railway station in south eastern part of Varanasi city, which lies in the northeast plane zone of eastern Uttar Pradesh. Physiographical location of the farm at $25^0$18’ N, $83^0$03’ E and altitude of 75.7 meters above the mean sea level in the Northern Gangetic alluvial plains. The experimental trial was conducted in field number A/14 of Agricultural Research Farm, B.H.U. The field was homogeneously fertile with even topography and uniform textural make up as well as adjoining the main irrigation channel connecting the farm tube well for quick regular and timely irrigation. Proper drainage is also provided for removal of excess water which is harmful for crop.Varanasi is located in north-east plane zone in the eastern part of Uttar Pradesh. Varanasi (India) at $25^0$18’ N latitude, $83^0$03’ longitude and at altitude of 75.7 m above the mean sea level. It has subtropical climate with extremes of hot in summer and cold in winter. June is the hottest months with mean temperature ranging from 28.9 ^{0}C to 41.0 ^{0}C.

Soil sampling and processing

A composite soil sample from the experimental field was collected before sowing of rice to know the initial status of soil in the field. Final samples from each plot were collected after harvesting of the crop. Soil samples were collected from 5 different places of the plot and then mixed to collect the final representative sample. Soil samples were brought to the laboratory, air dried and ground and then passed through 2-mm sieve and representative samples (about half kg) were collected in polythene bags. Physio-chemical and biological properties were then analyzed.

Soil analysis

Mechanical analysis of the initial soil was done by Bouyoucos hydrometer method (Bouyoucos, 1962) [4]. 50 g soil was weighed into a beaker, 60 mL 6% H_2O_2 was added to it followed by 400 ml distilled water. It was stirred for 10 minutes. Suspension was transferred into settling cylinder up to 1L mark and was shaken vigorously for 5 minutes. The hydrometer was placed in suspension and readings were taken exactly after 4 minutes and 2 hours. Percentage sand, silt and clay were calculated and textural class was determined with the help of Textural Triangle. A soil-water suspension was prepared in the ratio of 1:2.5 (10 g soil with 25 mL of distilled water) and pH was measured with the help of pH meter (Chopra and Kanwar, 1982) [6]. Soil water suspension prepared for determination of pH was used to estimate the electrical conductivity of soil. Soil suspension was allowed to settle till supernatant became clear. Electrical conductivity was measured with the help of EC meter and expressed as dsm^{-1} (Jackson, 1973). Soil organic carbon content was determined by Rapid Titration Method (Walkley and Black, 1934) [20]. In this method two gram of soil was oxidized with a mixture of potassium dichromate and concentrated sulphuric acid utilizing the heat of dilution of sulphuric acid. 200 mL of distilled water and 10 mL of orthophosphoric acid were added to the conical flask. Unconsumed potassium dichromate was back-titrated with ferrous ammonium sulphate in presence of diphenylamine indicator. Available nitrogen was determined using alkaline potassium permanganate method (Subbiah and Asija, 1956) [18]. The procedure involves distilling the soil with alkaline potassium permanganate solution and determining the ammonia liberated by titrating against sulphuric acid (0.02 N). The Olsen's method (Olsen *et al*., 1954) was used for determination of available-P in soil. In this method soil was extracted with 0.5 M $NaHCO_3$ (pH 8.5). 5 mL of extract was taken and colour was developed by ascorbic acid solution. After waiting for 10 minutes, the intensity of blue colour was measured on spectrophotometer at 760 nm. Five gram soil was extracted with neutral normal ammonium acetate solution (pH 7.0) by shaking for 30 minutes. Potassium content in the extract was determined flame-photometrically as given by Muhr *et al*. (1965) [13].

Plant analysis

The plant and grain samples collected at harvesting were dried at 60$\pm$2 °C for 48 hrs in a hot air oven and ground to powder. Nitrogen content in plant and grain samples was determined by Modified Kjeldahl Method as per procedure outlined by Gupta (2007). In a digestion tube, 0.5 g of powdered plant straw was taken and 10 mL of diacid solution (9:1, H_2SO_4:$HClO_4$) was added and kept overnight, 10g of sulphate mixture (20 parts K_2SO_4 + 1 part catalyst mixture containing 20 parts $CuSO_4$ + 1 part selenium powder) was added and heating was done in a digestion chamber till a clear colourless solution was obtained. The suspension was cooled and filtered through Whatman No. 42 filter paper in a 50 ml volumetric flask and volume was made up with distilled water. 10 mL of 4% boric acid solution containing bromocresol green and methyl red indicator was taken in a conical flask, outlet of distillation apparatus was dipped into boric acid solution. 5 mL of the aliquot was taken and transferred to distillation flask of micro-kjeldahl distillation apparatus and 10 mL of 40% NaOH solution was added. After completion of distillation, boric acid was titrated against 0.02 N H_2SO_4. Blank was also run. N content was calculated by using the formula given below:

$$N = \frac{0.02 \times T \times 0.014 \times 50 \times 50}{5 \times 0.5}$$

(Where, T = Sample reading - Blank reading)

One gram dried and powdered plant sample was taken in a 50 ml digestion tube and 10 ml di-acid mixture (4:1 v/v HNO_3: $HClO_4$) was added to it and was kept overnight. It was then digested on a block digester till a colourless solution was obtained. The volume of acid was reduced till the flask contained only moist residue. The flask was cooled and 25 mL of distilled water was added to it. The solution was filtered into a 50 mL volumetric flask and diluted up to mark. 2 ml of digest was taken in a 25 ml volumetric flask and 2 drops of 2, 4 di-nitrophenol indicator was added followed by ammonium solution till appearance of yellow colour. Now 6 N HCl was added dropwise till it became colourless. 5 mL of Vanadate molybdate solution was then added to it and diluted to 25 mL with distilled water, mixed well and the intensity of yellow colour was read on spectrophotometer by using blue filter at 440 nm wave length. A blank was also run without P solution simultaneously. Phosphorus content in straw and grain was calculated using standard curve and expressed as total P (%). Same procedure was followed in determination of P content in grain except the weight of sample in case of grain was only 0.2g (Jackson 1967).

$$\text{Total P\%} = \frac{\text{Abs.} \times \text{dilution factor}}{\text{Slope of std. curve} \times 10000}$$

Potassium content in plant and grain was determined by Flame Photometer Method (Jackson, 1973). Digested extract was used directly for flame photometric determination of potassium. K content was calculated using the standard curve and expressed as.

$$K = \frac{R \times \text{dilution factor}}{10000}$$

(Where, R = Flame photometer reading)

Nitrogen use efficiency parameters were calculated using the relationship:

Reference Moll *et al.* (1982) [12].

$$\text{AE (\%)} = \frac{\text{Grain Yield Fertilizer-Grain Yield Control}}{\text{Fertilizer N Applied}} \times 100$$

$$\text{PE (\%)} = \frac{\text{Grain Yield Fertilizer-Grain Yield Control}}{\text{N Uptake Fertilizer-N Uptake Control}} \times 100$$

$$\text{ANR (\%)} = \frac{\text{N Uptake Fertilizer-N Uptake Control}}{\text{Fertilizer N Applied}} \times 100$$

Statistical Analysis and Interpretation of Data

The data recorded during the course of investigation were subjected to statistical analysis as described by Panse and Sukhatme (1985) [15]. The significant effect of treatments was judged with the help of 'F' (variance ratio) table. The significant differences between of the means were tested against critical differences at 5% probability level.

Analysis of variance for all treatment in Randomized Block Design (RBD) was carried out. For testing the hypothesis the following ANOVA table was used. The significance and non-significant effect of the different treatments was tested with the help of 'F' variance ratio test. Calculated 'F' value was compared with table value of 'F' at 5% levels of significance. If calculated value of 'F' exceeds its table value, the effect was considered to be significant. The significant difference between treatment means was tested using critical difference at 5% level of significance.

Results and Discussion

Effect of different levels of recommended dose of nitrogen (RDN) through PCU and NU on biological, grain and straw yield of rice at harvesting

Effect on grain, straw and biological yield

A critical perusal of the data presented in table 3 revealed that the grain yield of rice was ranging from 33.64 q ha^{-1} to 63.86 q ha^{-1} and it has increased significantly with the split application of PCU at different levels. The maximum grain yield (63.86 qha^{-1}) was recorded in the treatment T_3 (100% of RDN through PCU 3 Split) which was 9.66% higher than treatment T_2 (100% of RDN through Urea 3 Split) and 2.27% higher than T_8 (100% of RDN through PCU Single Basal). The treatment T_3 (100% of RDN through PCU 3 Split) was found 89.83% and 3.38% higher over the treatment T_1 (control) and T_{12} (55% of RDN through PCU Single Basal+ FYM +PGPR +SSP) respectively. The treatment T_{11} (55% of RDN through PCU Single Basal) gave 57.29 qha^{-1}grain yield which was 1.77% higher over the T_6 (55%of RDN through PCU 3 Split). Treatment T_4 (85% of RDN through PCU 3 Split) gave 77.34% and 6.04% higher grain yield over the T_1 (control) and T_9 (85% of RDN through PCU Single Basal) respectively. However, Treatment T_{10} (70% of RDN through PCU Single Basal) gave 53.32% and 1.39% higher grain yield over the T_1 (control) and T_5 (70% of RDN through PCU Single Basal) respectively. The total biological yield tent to slightly decrease with decrease the fertilizer level and found statistical significance over treatment control T_1 presented in table 3. It ranges from 96.01 q ha^{-1} and 164.59 q ha^{-1} from treatment (T_1) to treatment (T_{12}) respectively. The treatment (T_{10}) was found significantly 109.82% higher than the treatment control (T_1). However, among the all the maximum biological yield and straw yield was found in the treatment (T_{12}) and maximum yield value occurred in the treatment (T_1). These treatments are statistically significant over treatment control (T_1). Singh *et al*. (1995) reported that grain yield of lowland wheat from a single application of polymer coated urea (PCU) was equivalent to or better than 3-4 time split application of urea. Fertilizer recovery with PCU was 70-75% compared to 50% with prilled urea.

Effect of different levels of recommended dose of nitrogen (RDN) through PCU and NU on uptake of N, P and K by grain and straw of rice

Nitrogen uptake by grain and straw

The data pertaining to the effect of PCU, UREA, FYM and PGPR on nitrogen uptake by rice grain has been presented in Table 2 showed a significant variation in grain. The nitrogen uptake by rice grain varied from 29.91 to 78.82 kg ha^{-1} where maximum nitrogen uptake was recorded with T_3 (100% of RDN through PCU 3 Split). It was about 193.52% higher than T_1 (control). The lowest value (29.91kg ha^{-1}) was observed in control (T_1). There was a concomitant increase in nitrogen uptake with 3 split of 100% PCU found 45.80% higher over T_7 (100% of RDN through Urea Single Basal), 24.53% higher over T_6 (55% of RDN through PCU 3 Split), and 20.64% higher over T_2 (100% of RDN through Urea 3 Split) and 2.52% higher over T_8 (100% of RDN through PCU Single Basal). Furthermore, treatment T_{12} (55% of RDN through PCU Single Basal+ FYM + PGPR + SSP) showed increased N uptake of 74.56 kg ha^{-1}. Furthermore, lower rate of single basal in T_{12} (74.56 kg ha^{-1}) gave higher uptake than T_{11} (64 kg ha^{-1}), T_{10} (58.08 kg ha^{-1}) and T_5 (57.38 kg ha^{-1}). However, split application of PCU in T_4 (67.45 kg ha^{-1}) showed higher N uptake than T_9 (63.57 kg ha^{-1}). The nitrogen uptake by rice straw varied from 18.98to 42.16 kg ha^{-1}. Maximum nitrogen uptake (42.16kg ha^{-1}) recorded with T_{12} (55% of RDN through PCU Single Basal + FYM + PGPR + SSP) was about 122.12% higher over T_1 (control) and 0.33%,1.20%, 6.65% and 9.19% higher over T_3 (100% of RDN through PCU 3 Split), T_8 (100% of RDN through PCU Single Basal), T_9 (85% of RDN through PCU Single Basal) and T_{10} (70% of RDN through PCU single basal) respectively. The lowest value (18.98kg ha^{-1}) was observed in control (T_1). However, uptake in Split application of PCU in treatment T_7 (33.94 kg ha^{-1}), T_4 (33.33 kg ha^{-1}), T_6 (32.80 kg ha^{-1}), T_2 (32.71 kg ha^{-1}) and T_6 (31.73 kg ha^{-1}) was found at par from each other. Total uptake of N by grain and straw varied from 48.88 Kg ha^{-1} to 120.84 Kg ha^{-1}. Maximum total nitrogen uptake (Grain + Straw) 120.84kg ha^{-1} was recorded with T_3 (100% of RDN through PCU 3 Split), which was about 147.21% higher than T_1 (control). The lowest value (48.88 kg ha^{-1}) was observed in control (T_1). However, the treatments T_5 (70% of RDN through PCU 3 Split), T_6 (55% of RDN through PCU 3 Split), T_{11} (55% of RDN through PCU Single Basal), and T_{10} (70% of RDN through PCU Single Basal) were found statically at par to each other. Results demonstrate the potential of split application PCU to improve N input into agro ecosystem while pointing out the need for long-term field studies to better understand the effect of PCU on nitrogen availability.

Phosphorus uptake by grain and straw

The phosphorus uptake by rice grain varied from 7.98to 20.18kg ha^{-1} where maximum phosphorus uptake was recorded with T_3 (100% of RDN through PCU 3 Split). It was about 152.88% higher than T_1 (control). The lowest value (7.98 kg ha^{-1}) was observed in control (T_1). There was a concomitant increase in phosphorus uptake with 3 split of 100% PCU found 69.57% higher over T_7 (100% of RDN through Urea Single Basal) and 39.17% higher over T_2 (100% of RDN through Urea 3 Split) and 3.27% higher over T_8 (100% of RDN through PCU Single Basal). Furthermore, treatment T_{12} (55% of RDN through PCU Single Basal+ FYM + PGPR + SSP) showed a increased N uptake of 18.65 kg ha^{-1}. However split application of PCU in T_4 (16.59 kg ha^{-1}), T_5(13.63 kg ha^{-1}), gave somewhat higher N uptake than single basal dose inT_9 (15.34 kg ha^{-1}) and T_{10} (13.51 kg ha^{-1})at same level of dose. Moreover, T_6 (14.69 kg ha^{-1}) and T_{11} (14.78 kg ha^{-1}) was found at par to each other. The phosphorus uptake by rice straw varied from 5.74to 13.98kg ha^{-1}. Maximum phosphorus uptake (13.98kg ha^{-1}) recorded with T_{12}(55% of RDN through PCU Single Basal + FYM + PGPR + SSP) was about 143.55% higher over T_1 (control) and 1.45%, 38.82%, 32.76%, 4.17% and 3.81% higher over T_3 (100% of RDN through PCU 3 Split), T_2 (100% of RDN through Urea 3 Split), T_7 (100% of RDN through Urea Single Basal) andT_8 (100% of RDN through PCU Single Basal) respectively. The lowest value (7.28kg ha^{-1}) was observed in control (T_1). Split application of PCU in treatment T_4 (11.58 kg ha^{-1}), T_5 (12.78 kg ha^{-1}) and T_6 (11.60 kg ha^{-1}) gave lower uptake over single basal dose in T_9 (13.60 kg ha^{-1}), T_{10} (13.78 kg ha^{-1}) and T_{11} (11.77 kg ha^{-1}). The phosphorus content in straw was greater than grain. Thus the uptake of phosphorus was high in straw as compared to grain. Total uptake of P by grain and straw varied from 13.71 Kg ha^{-1} to 33.97 Kg ha^{-1}. Maximum total phosphorus uptake (Grain + Straw) 33.97 kg ha^{-1} was recorded with T_3 (100% of RDN through PCU 3 Split), which was about147.77% higher than T_1 (control). The lowest value (13.71 kg ha^{-1}) was observed in control (T_1). However, the treatments T_2 (100% of RDN through Urea 3 Split), T_4 (85% of RDN through PCU 3 Split), T_5 (70% of RDN through PCU 3 Split), T_6 (55% of RDN through PCU 3 Split), T_9 (85% of RDN through PCU Single Basal), T_{10} (70% of RDN through PCU Single Basal) and T_{11} (55% of RDN through PCU Single Basal) were found statically at par to each other. Results demonstrate the potential of single basal application PCU to improve P input into agro ecosystem while pointing out the need for long-term field studies to better understand the effect of PCU on phosphorus availability.

Potassium uptake by grain and straw

The data pertaining to the effect of PCU, UREA, FYM and PGPR on uptake by rice grain has been presented in Table 2. The Potassium uptake by rice grain varied from 4.42 to 14.57kg ha^{-1}. Maximum Potassium uptake (14.57 kg ha^{-1}) recorded with T_3 (100% of RDN through PCU 3 Split) was about 229.63% higher over T_1 (control) and 33.79%, 63.15%, 34.53%, 24.42%, 35.78% and 25.92% higher over T_2 (100% of RDN through Urea 3 Split), T_7 (100% of RDN through Urea Single Basal), T_5 (70% of RDN through PCU 3 Split), T_6 (55% of RDN through PCU 3 Split), T_{10} (70% of RDN through PCU Single Basal), and T_{11} (55% of RDN through PCU Single Basal) respectively. The lowest value (4.42 kg ha^{-1}) was observed in control (T_1). However, Split application of PCU in treatment T_4 (13.05 kg ha^{-1}), T_8 (14.05 kg ha^{-1}) and T_9 (12.14 kg ha^{-1}) were found at par to each other. The potassium uptake by rice straw varied from 68.10 to 139.90 kg ha^{-1}. Maximum Potassium uptake (139.90 kg ha^{-1}) recorded with T_{10} (70% of RDN through PCU single basal) was about 105.43% higher over T_1 (control) and 12.96%, 17.86%, 11.07%, 3.23% and 13.96% higher over T_3 (100% of RDN through PCU 3 Split), T_2 (100% of RDN through Urea 3 Split), T_7 (100% of RDN through Urea Single Basal), T_{12} (55% of RDN through PCU Single Basal + FYM + PGPR + SSP) and T_8 (100% of RDN through PCU Single Basal) respectively. The lowest value (68.10 kg ha^{-1}) was observed in control (T_1). Basal application of PCU in treatment T_9 (136.61 kg ha^{-1}), T_{10} (139.90 kg ha^{-1}) and T_{11} (122.31 kg ha^{-1}) gave higher uptake over split application in T_4 (114.02 kg ha^{-1}), T_5 (129.83 kg ha^{-1}) and T_6 (119.39 kg ha^{-1}). The Potassium content in straw was greater than grain. Thus the uptake of phosphorus was high in straw as compared to grain. Total uptake of K by grain and straw varied from 72.52 Kg ha^{-1} to 150.63 Kg ha^{-1}. Maximum total potassium uptake (Grain + Straw) 150.63 kg ha^{-1} was recorded with T_{10} (70% of RDN through PCU Single Basal) which was about 107.7% higher than T_1 (control). Though treatment T_{12} (55% of RDN through PCU Single Basal + FYM + PGPR + SSP) gave total uptake of 149.16 kg ha^{-1}. The lowest value (72.52 kg ha^{-1}) was observed in control (T_1). However, basal application of PCU in treatment T_9 (148.75 kg ha^{-1}), T_{10} (150.63 kg ha^{-1}) and T_{11} (133.89 kg ha^{-1}) gave higher total K uptake over split application in T_4 (127.07 kg ha^{-1}), T_5 (140.66 kg ha^{-1}) and T_6 (131.10 kg ha^{-1}) at same level of application. Results demonstrate the potential of basal application PCU to improve P input into agro ecosystem while pointing out the need for long-term field studies to better understand the effect of PCU on potassium availability.

Nitrogen Use Efficiency Parameter

Various nitrogen use efficiency parameter *viz.* agronomic efficiency, physiological efficiency and apparent N recovery are presented in table 4.

Agronomic Efficiency (AE)

The agronomic efficiency (AE) of rice ranged from 12.35 (T_7) to 37.01 (T_{12}) kg grain per kg N uptake. Maximum AE with treatment T_{12} (55% of RDN through PCU Single Basal + 40 Kg P + FYM @ 2 t ha^{-1} + PGPR) and minimum with treatment T_7 (100% of RDN through Urea Single Basal). When split applications compared with the single basal applications it was found to be increase with split application. T_3 (100% of RDN through PCU 3 Split) gave 22.88%, 105.88% and 4.96% higher over T_2 (100% of RDN through urea 3 Split), T_7 (100% of RDN through Urea Single Basal) and T_8 (100% of RDN through PCU Single Basal) respectively. However, the treatment (T_{12}) was significant superior over rest of the treatment.

Physiological Efficiency (PE)

The physiological efficiency (PE) of rice ranged from 37.51 (T_7) to 50.18 (T_4) kg grain per kg N uptake. When split applications compared with the single basal applications it was found to be increase with split application. Highest physiological efficiency with treatment T_4 (85% of RDN through PCU 3 Split) which was 20.04% higher over the T_9 (85% of RDN through PCU Single Basal). T_3 (100% of RDN through PCU 3 Split) gave 1.59% higher over T_8 (100% of RDN through PCU Single Basal). While T_5 (70% of RDN through PCU 3 Split) gave 2.10% higher PE than T_{10} (70% of RDN through PCU Single Basal). T_2 (100% of RDN through urea 3 Split) gave 33.40% higher over T_7 (100% of RDN through Urea Single Basal). However, minimum PE was obtained with treatment T_7 (100% of RDN through Urea Single Basal). Compare to treatment T_{12} other treatment the PE was found non-significant.

Apparent N Recovery (ANR)

The apparent N recovery (ANR) of rice ranged from 32.60% (T_7) to 89.25% (T_{12}). Maximum ANR with treatment T_{12} (55% of RDN through PCU Single Basal + 40 Kg P + FYM @ 2 t ha^{-1} + PGPR) and minimum with treatment T_7 (100% of RDN through Urea Single Basal). When split applications compared with the single basal applications it was found increased with single basal application. Single basal application in T_{11} (55% of RDN through PCU Single Basal), T_{10} (70% of RDN through PCU Single Basal) and T_9 (85% of RDN through PCU Single Basal) gave 3.86%, 6.37% and 4.46% higher ANR over split application in T_6 (55% of RDN through PCU 3 Split), T_5 (70% of RDN through PCU 3 Split) and T_4 (85% of RDN through PCU 3 Split) respectively. Furthermore, split application in T_3 (100% of RDN through PCU 3 Split) showed 83.92%, 46.35% and 3.29% increased over T_7 (100% of RDN through Urea Single Basal), T_2 (100% of RDN through urea 3 Split) and T_8 (100% of RDN through PCU Single Basal) respectively.

Table 1: Effect of different levels of RDN through PCU on yield of rice at harvesting

Treatment		Yield (q ha^{-1})		
		Biological	**Grain**	**Straw**
T_1	Control	96.01	33.64	62.36
T_2	100% of RDN through Urea 3 Split	154.12	58.23	95.89
T_3	100% of RDN through PCU 3 Split	157.12	63.86	93.26
T_4	85% of RDN through PCU 3 Split	147.17	59.66	87.50
T_5	70% of RDN through PCU 3 Split	150.90	50.87	100.03
T_6	55% of RDN through PCU 3 Split	149.06	56.29	92.77
T_7	100% of RDN through Urea Single Basal	150.55	48.31	102.23
T_8	100% of RDN through PCU Single Basal	155.22	62.44	92.79
T_9	85% of RDN through PCU Single Basal	161.67	56.26	105.41
T_{10}	70% of RDN through PCU Single Basal	160.96	51.58	109.38
T_{11}	55% of RDN through PCU Single Basal	153.75	57.29	96.46
T_{12}	55% of RDN through PCU Single Basal + 40 Kg P + FYM @ 2 t ha^{-1} + PGPR	164.59	61.77	102.82
SEm±		2.362	1.773	1.371
CD at 5%		4.889	3.671	2.837

Table 2: Uptake of N, P and K by grain and straw of rice at different levels of RDN and mode of application through PCU and NU

Treatment		Uptake in grain (kg ha^{-1})			uptake in straw (kg ha^{-1})		
		N	P	K	N	P	K
T_1	Control	29.91	7.98	4.42	18.98	5.74	68.10
T_2	100% of RDN through Urea 3 Split	65.33	14.50	10.89	32.71	10.07	118.70
T_3	100% of RDN through PCU 3 Split	78.82	20.18	14.57	42.02	13.78	123.84
T_4	85% of RDN through PCU 3 Split	67.45	16.59	13.05	33.33	11.58	114.02
T_5	70% of RDN through PCU 3 Split	57.38	13.63	10.83	36.44	12.78	129.83
T_6	55% of RDN through PCU 3 Split	63.29	14.69	11.71	31.73	11.60	119.39
T_7	100% of RDN through Urea Single Basal	54.06	11.90	8.93	33.94	10.53	125.95
T_8	100% of RDN through PCU Single Basal	76.88	19.54	14.05	41.66	13.42	122.76
T_9	85% of RDN through PCU Single Basal	63.57	15.34	12.14	39.53	13.60	136.61
T_{10}	70% of RDN through PCU Single Basal	58.08	13.51	10.73	38.61	13.78	139.90
T_{11}	55% of RDN through PCU Single Basal	64.00	14.78	11.57	32.80	11.77	122.31
T_{12}	55% of RDN through PCU Single Basal + 40 Kg P + FYM @ 2 t ha^{-1} + PGPR	74.56	18.65	13.63	42.16	13.98	135.52
SEm±		2.305	0.515	0.626	1.679	0.974	3.688
CD at 5%		4.772	1.065	1.297	3.475	2.017	7.634

Table 3: Total uptake of N, P and K by rice at different levels of RDN and mode of application through PCU and NU

Treatment		Total uptake		
		N kg ha^{-1}	P kg ha^{-1}	K kg ha^{-1}
T_1	Control	48.88	13.71	72.52
T_2	100% of RDN through Urea 3 Split	98.04	24.57	129.59
T_3	100% of RDN through PCU 3 Split	120.84	33.97	138.41
T_4	85% of RDN through PCU 3 Split	100.78	28.17	127.07
T_5	70% of RDN through PCU 3 Split	93.83	26.42	140.66
T_6	55% of RDN through PCU 3 Split	95.01	26.29	131.10
T_7	100% of RDN through Urea Single Basal	88.00	22.43	134.88
T_8	100% of RDN through PCU Single Basal	118.54	32.97	136.81
T_9	85% of RDN through PCU Single Basal	103.10	28.93	148.75
T_{10}	70% of RDN through PCU Single Basal	96.69	27.30	150.63
T_{11}	55% of RDN through PCU Single Basal	96.79	26.55	133.89
T_{12}	55% of RDN through PCU Single Basal + 40 Kg P + FYM @ 2 t ha^{-1} + PGPR	116.72	32.64	149.16
SEm±		2.534	1.361	3.704
CD at 5%		5.246	2.817	7.668

Table 4: Effect of different levels of RDN through PCU and NU on different parameter of nitrogen use efficiency (ANR, AE and PE) in rice.

Treatment		N use efficiency parameter		
		ANR* (%)	AE* kg kg^{-1}	PE* kg kg^{-1}
T_1	Control	0.00	0.00	0.00
T_2	100% of RDN through Urea 3 Split	40.97	20.49	50.04
T_3	100% of RDN through PCU 3 Split	59.96	25.18	42.02
T_4	85% of RDN through PCU 3 Split	50.88	25.51	50.18
T_5	70% of RDN through PCU 3 Split	53.50	20.51	38.40
T_6	55% of RDN through PCU 3 Split	69.89	34.31	49.13
T_7	100% of RDN through Urea Single Basal	32.60	12.23	37.51
T_8	100% of RDN through PCU Single Basal	58.05	23.99	41.36
T_9	85% of RDN through PCU Single Basal	53.15	22.17	41.80
T_{10}	70% of RDN through PCU Single Basal	56.91	21.35	37.61
T_{11}	55% of RDN through PCU Single Basal	72.59	35.83	49.44
T_{12}	55% of RDN through PCU Single Basal + 40 Kg P + FYM @ 2 t ha^{-1} + PGPR	89.25	37.01	41.43
SEm±		3.059	1.892	2.484
CD at 5%		6.333	3.916	5.143

Where, ANR* = Apparent nitrogen recovery, AE* = Agronomic efficiency, PE* = Physiological efficiency

Conclusions

Application of PCU simultaneously by all modes, i.e. single basal and 3 split applications showed maximum uptake of N, P and K by grain and straw resulting higher total uptake. The maximum uptake of N and P was found with T_3 (100% of RDN through PCU 3 Split) in the grain and for K maximum uptake was found by T_4 (85% of RDN through PCU 3 Split). In straw the maximum uptake of N was found with T_3 (100% of RDN through PCU 3 split) and P and K uptake was higher in T_{12} (55% of RDN through PCU Single Basal + 40 Kg P + FYM @ 2 t ha^{-1} + PGPR). Although, uptake of N was found to affect the K uptake in a negative way in the straw. However, minimum straw uptake of N, P and K by straw was found with control. As regards to N, its uptake was significantly increased with T_3 (100% of RDN through PCU 3 Split) both in grain and straw.

Various nitrogen use efficiency parameter *viz.* agronomic efficiency, physiological efficiency and apparent N recovery are presented. The agronomic efficiency (AE) of rice ranged from 12.35 (T_7) to 37.01 (T_{12}) kg grain per kg N uptake. Maximum AE was with treatment T_{12} (55% of RDN through PCU Single Basal + 40 Kg P + FYM @ 2 t ha^{-1} + PGPR) and minimum was with treatment T_7 (100% of RDN through Urea Single Basal).

The physiological efficiency (PE) of rice ranged from 37.51 (T_7) to 50.18 (T_4) kg grain per kg N uptake. Maximum PE with treatment T_4 (85% of RDN through PCU 3 Split) and minimum was with treatment T_7 (100% of RDN through Urea Single Basal). The apparent N recovery (ANR) of rice ranged from 25.44% (T_7) to 72.01% (T_{12}).

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