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Effect of different doses and method of application on nitrogen use efficiency (NUE) in wheat (*Triticum aestivum* L.)

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Abstract
In India, wheat is grown during *Rabi* 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 wheat 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 wheat variety Malviya-510 during *Rabi* season 2016-2017. The last treatment (T_{12}) was comprising with 55% of RDN through PCU as basal dressing + 2 tons FYM ha-1 + PGPR (mixture of *Azotobacter chroococcum, Pseudomonas aeruginosa, P. flurescens, P. putida, Bacillus subtilis, Azospirillum brasilense, Trichoderma harzianum*).

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

Introduction

Nitrogen (N) is often the most important and most limiting nutrient for crop yield in many regions of the world. Nitrogenous fertilizer is one of the main inputs for cereals production systems. Nitrogen is the plant nutrient that is often most limiting to efficient and profitable crop production. Inadequate supply of available N frequently results in plants that have slow growth, low protein levels, poor yield of low quality produce, and inefficient water use. Therefore, application of nitrogen fertilizer at the right rate and time is vital for the enhancement of soil fertility and crop productivity. High levels of N supply results in a higher protein content, but increased efficiency of utilization is realized when concentration in the kernels increases and grain yield remains stable (Ortiz Monasterio *et al.*, 1997) [14].

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 are 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, wheat is grown during *Rabi* 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 wheat 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 wheat productivity at Varanasi districts has not been established. Therefore, keeping the above facts in view, the present research work has been undertaken during *Rabi* 2016-2017 at the agricultural research farm, Banaras Hindu University, Varanasi.

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

Treatment		Yield (q ha^{-1})		
		Biological	**Grain**	**Straw**
T_1	Control	77.90	27.37	50.53
T_2	100% of RDN through Urea 3 Split	110.63	47.30	63.33
T_3	100% of RDN through PCU 3 Split	136.00	55.10	80.90
T_4	85% of RDN through PCU 3 Split	119.87	48.47	71.40
T_5	70% of RDN through PCU 3 Split	128.57	41.00	87.57
T_6	55% of RDN through PCU 3 Split	121.47	46.07	75.40
T_7	100% of RDN through Urea Single Basal	106.80	39.37	67.43
T_8	100% of RDN through PCU Single Basal	130.67	53.03	77.63
T_9	85% of RDN through PCU Single Basal	134.77	46.00	88.77
T_{10}	70% of RDN through PCU Single Basal	130.83	41.93	88.90
T_{11}	55% of RDN through PCU Single Basal	124.93	46.87	78.07
T_{12}	55% of RDN through PCU Single Basal + 40 Kg P + FYM @ 2 t ha^{-1} + PGPR	143.47	53.80	89.67
SEm±		0.141	0.043	0.124
CD at 5%		0.292	0.090	0.257

Table 2: Uptake of N, P and K by grain and straw of wheat 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	30.35	7.50	11.20	25.82	2.96	32.71
T_2	100% of RDN through Urea 3 Split	72.73	14.96	14.19	27.89	3.95	71.58
T_3	100% of RDN through PCU 3 Split	87.11	20.02	28.04	33.09	5.74	102.99
T_4	85% of RDN through PCU 3 Split	75.77	16.97	31.44	31.63	4.77	88.98
T_5	70% of RDN through PCU 3 Split	62.89	14.08	27.27	30.55	5.79	106.64
T_6	55% of RDN through PCU 3 Split	70.36	15.36	22.00	28.40	4.90	90.55
T_7	100% of RDN through Urea Single Basal	59.68	11.97	23.20	27.01	4.21	74.40
T_8	100% of RDN through PCU Single Basal	82.96	19.16	22.83	31.53	5.33	96.90
T_9	85% of RDN through PCU Single Basal	71.59	15.03	29.46	29.55	5.83	108.25
T_{10}	70% of RDN through PCU Single Basal	64.80	12.47	24.84	28.70	5.69	105.02
T_{11}	55% of RDN through PCU Single Basal	71.88	13.69	21.85	28.06	4.92	90.18
T_{12}	55% of RDN through PCU Single Basal + 40 Kg P + FYM @ 2 t ha^{-1} + PGPR	83.32	18.68	26.20	27.57	6.01	111.28
SEm±		6.864	1.515	2.515	0.437	0.850	15.949
CD at 5%		14.208	3.136	5.207	0.904	1.759	33.015

Table 3: Total uptake of N, P and K by wheat 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	56.16	10.46	43.91
T_2	100% of RDN through Urea 3 Split	100.62	18.91	85.77
T_3	100% of RDN through PCU 3 Split	120.20	25.76	131.03
T_4	85% of RDN through PCU 3 Split	107.40	21.74	120.42
T_5	70% of RDN through PCU 3 Split	93.44	19.86	133.90
T_6	55% of RDN through PCU 3 Split	98.76	20.26	112.55
T_7	100% of RDN through Urea Single Basal	86.69	16.18	97.59
T_8	100% of RDN through PCU Single Basal	114.49	24.49	119.73
T_9	85% of RDN through PCU Single Basal	101.14	20.86	137.72
T_{10}	70% of RDN through PCU Single Basal	93.50	18.16	129.86
T_{11}	55% of RDN through PCU Single Basal	99.94	18.61	112.03
T_{12}	55% of RDN through PCU Single Basal + 40 Kg P + FYM @ 2 t ha^{-1} + PGPR	110.89	24.69	137.48
SEm±		6.851	1.731	16.751
CD at 5%		14.182	3.582	34.674

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

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	37.05	16.61	44.46
T_3	100% of RDN through PCU 3 Split	53.36	23.11	41.52
T_4	85% of RDN through PCU 3 Split	50.23	20.69	40.89
T_5	70% of RDN through PCU 3 Split	44.38	16.23	36.11
T_6	55% of RDN through PCU 3 Split	64.54	28.33	43.42
T_7	100% of RDN through Urea Single Basal	25.44	10.00	38.45
T_8	100% of RDN through PCU Single Basal	48.60	21.39	43.08
T_9	85% of RDN through PCU Single Basal	44.10	18.27	41.38
T_{10}	70% of RDN through PCU Single Basal	44.45	17.34	38.50
T_{11}	55% of RDN through PCU Single Basal	66.33	29.55	43.58
T_{12}	55% of RDN through PCU Single Basal + 40 Kg P + FYM @ 2 t ha^{-1} + PGPR	72.01	34.78	48.17
SEm±		6.694	4.320	3.192
CD at 5%		13.857	8.942	6.607

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

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, $83^0 31'$ 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, $83^0 31'$ 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. April are the hottest months with mean temperature ranging from 16.2^0C to 33.7^0C.

Soil sampling and processing

A composite soil sample from the experimental field was collected before sowing of wheat 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 400ml 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). 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}. 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). The procedure involves distilling the soil with alkaline potassium permanganate solution and determining the ammonia liberated by titrating against sulphuric acid (0.02N). 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).

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 (20 mesh) plant sample (20 mesh) 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.

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

Potassium content in plant and grain was determined by Flame Photometer Method. 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].

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

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

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

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). 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.

ANOVA

S. No	Source of variation	d. f.	Sum of squares	Mean sum of squares	‘F’ Value	
					F. cal	F. tab at 5%
1.	Replications	(r-1)	SSR	SSR/(r-1)	MSSR/MESS	F(r-1)
2.	Treatments	(t-1)	SST	SST/(t-1)	MSST/MESS	F(t-1)
3.	Error	(r-1) (t-1)	SSE	SSE/(r-1)(t-1)	MSSE	F(r-1)(t-1)
	Total	(rt-1)	TSS			

Where,
d. f. = Degree of freedom
r = Number of replications
t = Number of treatments
SSR = Sum of square due to replications
SSE = Sum of squares due to error
MSSR = Mean sum of squares due to replication
MSST = Mean sum of squares due to treatments
MSSE = Mean sum of squares due to error.
SE (m) ± = √Me/r
SE (d) ± = √2Me/r
C.D. (5%) = SE (d) × $t_{0.05}$ error d. f.

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 grain and straw yield of wheat at harvest

Effect on grain, straw and biological yield

A critical perusal of the data presented in table 1 revealed that the grain yield of wheat was ranging from 27.33 qha^{-1} to 55.10 qha^{-1} and it has increased significantly with the split application of PCU at different levels. The maximum grain yield (55.10 qha^{-1}) was recorded in the treatment T_3 (100% of RDN through PCU 3 Split). Among the split application treatment T_3 record the maximum yield which is significant 101.31% and 51.51% increase over control (T_1) and T_5(70% of RDN through PCU 3 Split). Compare to other split dose treatment T_3 are non-significant increase. But compare to the basal dose application the maximum grain yield in T_{12} (55% of RDN through PCU Single Basal + FYM + PGPR) is 53.40 q ha^{-1} which has been only 4.74% less than T_3.

A critical perusal of the data presented in table 1 revealed that the straw yield of wheat was ranging from 50.53 q ha^{-1} to 89.67 q ha^{-1}. The maximum straw yield (89.67 q ha^{-1}) was recorded in the treatment T_{12} (55% of RDN through PCU Single Basal + FYM + PGPR) and T12 was found significantly 77.45% higher over control. Among the split dose T_5 (70% of RDN through PCU 3 Split) record the maximum straw yield (87.57 q ha^{-1}) was found significant 73.30% higher over control treatment (T_1). In split dose treatment T_4 (100% of RDN through PCU 3 Split) and T_5 are significant over control (T_1). Whereas, in single basal doses the treatment T_{12} (55% 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), T_6 (55% of RDN through PCU 3 Split) were found statically at par to each other.

The total biological yield tent to slightly decrease with decrease the fertilizer level and found statistical significance over treatment control T_1. It range from 77.46 q ha^{-1} and 143.47 q ha^{-1} from treatment (T_1) to treatment (T_{12}) respectively. The treatment (T_{12}) was found significantly 81.17% 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 treatment 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 wheat

Nitrogen uptake by grain and straw

The data pertaining to the effect of PCU, UREA, FYM and PGPR on nitrogen uptake by wheat grain has been presented in Table 2 showed a significant variation in grain. The nitrogen uptake by wheat grain varied from 30.35 to 87.11 kg ha^{-1} where maximum nitrogen uptake was recorded with T_3 (100% of RDN through PCU 3 Split). It was about 151.96% higher than T_1 (control). The lowest value (30.35 kg ha^{-1}) was observed in control (T_1). There was a concomitant increase in nitrogen uptake with 3 split of 100% PCU found 45.96% higher over T_7 (100% of RDN through Urea Single Basal) and only 5% higher over T_8 (100% of RDN through PCU Single Basal). Furthermore, treatment T_{12} (55% of RDN through PCU Single Basal + FYM + PGPR) showed significant increased N uptake of 55.38 kg ha^{-1} over control treatment (T_1). However, split application of PCU in T_4 (75.77 kg ha^{-1}) showed non significant higher N uptake than T_9 (71.59 kg ha^{-1}).

The nitrogen uptake by wheat straw varied from 25.82 to 33.09 kg ha^{-1}. Maximum nitrogen uptake (37.96 kg ha^{-1}) recorded with T_3 (100% of RDN through PCU 3 Split) was about 28.15% higher over T_1 (control). The lowest value (25.82 kg ha^{-1}) was observed in control (T_1). However, uptake in Split application of PCU in treatment T_6 (28.40 kg ha^{-1}) and single basal application in T_7 (27.01 kg ha^{-1}), T_9 (29.55 kg ha^{-1}), T_{10} (28.70 kg ha^{-1}), T_{11} (28.06 kg ha^{-1}) and T_{12} (27.57 kg ha^{-1}) was found at par from each other. The nitrogen content in grain was greater than straw. Thus the uptake of nitrogen was high in grain as compared to straw.

Total uptake of N by grain and straw has been presented in Table 3 varied from 56.16 Kg ha^{-1} to 120.20 Kg ha^{-1}. Maximum total nitrogen uptake (Grain + Straw) 120.20 kg ha^{-1} was recorded with T_3 (100% of RDN through PCU 3 Split), which was about 114.03% higher than T_1 (control). The lowest value (56.16 kg ha^{-1}) was observed in control (T_1). However, in case of basal application the treatments T_8 (100% of RDN through single basal) was found 114.49 kg ha^{-1}. 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

A critical observation of the data given in table 2 revealed that the effect of application of PCU, UREA, FYM and PGPR on P uptake by wheat grain showed a significant variation in grain. The phosphorus uptake by wheat grain varied from 7.50 to 20.02kg ha^{-1} where maximum phosphorus uptake was recorded with T_3 (100% of RDN through PCU 3 Split). It was about 166.93% higher than T_1 (control). The lowest value (7.50 kg ha^{-1}) was observed in control (T_1). There was a concomitant increase in phosphorus uptake with 3 split of 100% PCU found 67.25% significant higher over T_7 (100% of RDN through Urea Single Basal) and 33.82% higher over T_2 (100% of RDN through Urea 3 Split) and only 4.48% higher over T_8 (100% of RDN through PCU Single Basal) which found non significant. Furthermore, treatment T_{12} (55% of RDN through PCU Single Basal + FYM + PGPR) showed increased N uptake of 18.68 kg ha^{-1}. However split application of PCU in T_4 (16.97 kg ha^{-1}), T_5 (14.08 kg ha^{-1}), gave somewhat higher N uptake than single basal dose inT_9 (12.47 kg ha^{-1}) and T_{10} (13.69 kg ha^{-1}) at same level of dose. The phosphorus uptake by wheat straw varied from 2.96 to 6.01 kg ha^{-1}. Maximum phosphorus uptake (6.01kg ha^{-1}) recorded with T_{12} (55% of RDN through PCU Single Basal + FYM + PGPR) was about 103.04% higher over T_1 (control). The lowest value (2.96 kg ha^{-1}) was observed in control (T_1). Split application of PCU in treatment T_4 (4.77 kg ha^{-1}), T_5 (5.79 kg ha^{-1}) and T_6 (4.90 kg ha^{-1}) gave lower uptake over single basal dose in T_9 (5.83 kg ha^{-1}), T_{10} (5.69 kg ha^{-1}) and T_{11} (4.92 kg ha^{-1}). The phosphorus content in grain was greater than straw. Thus the uptake of phosphorus was high in grain as compared to straw. Total uptake of P by grain and straw varied from 10.46 Kg ha^{-1} to 25.76 Kg ha^{-1}. Maximum total phosphorus uptake (Grain + Straw) 25.76 kg ha^{-1} was recorded with T_3 (100% of RDN through PCU 3 Split), which was significant about 146.27% higher than T_1 (control). The lowest value (10.46 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. Prasad *et al.* (2010) reported that incorporation of FYM along with inorganic fertilizer increased the availability of P to crop and mineralization of organic P due to microbial action and enhance mobility of P.

Potassium uptake by grain and straw

The data pertaining to the effect of PCU, UREA, FYM and PGPR on uptake by wheat grain has been presented in Table 2. The Potassium uptake by wheat grain varied from 11.20 to 31.44 kg ha^{-1}. Maximum Potassium uptake (31.44 kg ha^{-1}) recorded with T_3 (100% of RDN through PCU 3 Split) was significant higher about 180.71% higher over T_1 (control). Among the single basal maximum value of K uptake by grain (26.20) was recorded with combine application of 55% of RDN through PCU Single Basal + FYM + PGPR in treatment T_{12} which was significant over rest of treatments. The K uptake recorded under different treatment by wheat straw varied from 32.72 to 111.28 kg ha^{-1}. Maximum Potassium uptake (111.28 kg ha^{-1}) recorded with T_{12} (55% of RDN through PCU Single Basal + FYM + PGPR) was about 226.40% higher over T_1 (control). Potassium content was greater than grain. Thus the uptake of phosphorus was high in straw as compared to grain. The result pertaining the total uptake of K by grain and straw varied with a value of 43.91 Kg ha^{-1} to 137.72 Kg ha^{-1}. Data revealed that maximum total potassium uptake (Grain + Straw) 137.72 kg ha^{-1} was recorded with T_3 (100% of RDN through PCU 3 split) which was significant about 213.64% higher than T_1 (control). Though treatment T_{12} (55% of RDN through PCU Single Basal + FYM + PGPR) gave total uptake of 137.48 kg ha^{-1}. The lowest value (43.91 kg ha^{-1}) was observed in control (T_1). The treatment in split application T_3 (100% of RDN through PCU 3 Split) and T_5 (70% of RDN through PCU 3 Split) record the significant total uptake of K over the control (T_1). 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. The increase Potassium content in straw might be due to application of fertilizer with the FYM and PGPR result in high microbial activity in soil which solubilization of native K in soil. The result concur with the finding of Shivakumar and Ahlawat (2008).

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 result of present investigation clearly show that agronomic efficiency (AE) of wheat ranged from 16.61 (T_7) to 34.78 (T_{12}) kg grain per kg N uptake. Maximum AE with treatment T_{12} (55% of RDN through PCU Single Basal + FYM +PGPR +SSP) 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. Treatment (T_{12}) gave 109.31%, 247.8% and 45.55% 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}) were significant superior over rest of the treatment.

Physiological Efficiency (PE)

The physiological efficiency (PE) of wheat ranged from 36.11(T_5) to 48.17(T_{12}) 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_{12} (55% of RDN through PCU Single Basal + FYM +PGPR) which was significant 33.39%, 25.27%, and 25.11% higher over the T_5 (70% of RDN through PCU 3 split), T_6 (55% of RDN through PCU 3 Split) and T_{10} (70% of RDN through Urea Single Basal) respectively. However, minimum PE was obtained with treatment T_5 (70% of RDN through PCU 3 split). Compare to treatment T_{12} other treatment the PE was found non significant.

Apparent N Recovery (ANR)

The apparent N recovery (ANR) of wheat ranged from 25.44% (T_7) to 72.01% (T_{12}). Maximum ANR with treatment (55% of RDN through PCU Single Basal + FYM +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 treatment T_{12} was found significantly 94.35% and 183.05% higher over the treatment T_2 (100% of RDN through urea 3 Split and T_7 (100% of RDN through Urea Single Basal) respectively. Furthermore, split application in T_3 (100% of RDN through PCU 3 Split) and T_4 (85% of RDN through urea 3 Split) showed as per each other. In single basal treatment $T_{8,}$ T_9 and T_{10} were found the value of 48.60, 44.10 and 44.45% equally as per each other.

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 wheat ranged from 10 (T_7) to 34.78 (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 wheat ranged from 36.11 (T_5) to 48.17 (T_{12}) kg grain per kg N uptake. Maximum PE 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_5 (70% of RDN through PCU 3 split). The apparent N recovery (ANR) of wheat ranged from 25.44% (T_7) to 72.01% (T_{12}).

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