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Nitrogen management strategies for direct seeded aerobic rice (*Oryza sativa* L.) grown in mollisols of Uttarakhand (India)

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Abstract

A field experiment was conducted during the rainy (Kharif) season in 2013 and 2014 at N.E. Borlaug Crop Research Centre of G.B. Pant University of Agriculture & Technology, Pantnagar (Uttarakhand) India to study nitrogen management in direct seeded aerobic rice(cv. Pant Dhan 16). The experiment consisted of three nitrogen level (90,120 and 150 kg ha^{-1}) in main-plots with the seven set of nitrogen scheduling in sub-plots in a split plot design with three replications. The result on the basis of pooled analysis revealed that growth and yield attributes viz. number of shoots, 1000 grain weight, number of grain / panicle, grain and straw yield were higher in the treatment receiving 150 kg N ha^{-1}(N_3). Comparing to variable nitrogen scheduling these yield attributing characters were significantly higher when N was applied in 4 splits ($\frac{1}{4}$ basal + $\frac{1}{4}$ at active tillering+ $\frac{1}{4}$ panicle initiation +$\frac{1}{4}$ at flowering) under Tarai conditions recorded the maximum growth and yield attributes as well as grain yield (4778 kg ha^{-1}). The nutrient NPK uptake were also higher under treatment receiving 150 kg N ha^{-1} and nitrogen scheduling N in 4 splits ($\frac{1}{4}$ basal + $\frac{1}{4}$ at active tillering+ $\frac{1}{4}$ panicle initiation +$\frac{1}{4}$ at flowering. Net return (Rs.38848), and B:C ratio (1.59) were recorded higher with 150 kg N ha^{-1}applied whereas, nitrogen scheduling N in 4 splits($\frac{1}{4}$ basal + $\frac{1}{4}$ at active tillering+ $\frac{1}{4}$ panicle initiation +$\frac{1}{4}$ at flowering) gave the highest net return (Rs.40878), and B:C ratio (1.69) followed by N in 3 splits ($\frac{1}{4}$ basal + $\frac{1}{2}$ active tillering + $\frac{1}{4}$ panicle initiation).

Key words: Nitrogen scheduling, Nutrient supply, Direct seeded aerobic rice

I. INTRODUCTION

Rice (*Oryza sativa* L.) is the most important and widely cultivated crop in the world. Asia is the home of rice as more than two billion people get 60-70% of their energy requirement from rice alone as about 90 % of the total rice is grown and consumed in Asia. India has to produce about 125 MT of rice by 2025 to feed the ever growing population **(UNESCO, 2007).** Rice crop is grown by many ways depending upon resource availability. Due to resource constraints, especially water and labours, direct seeding under dry condition is now emerging as a new trend in rice cultivation. India is having substantial area under rainfed/ semi-dry rice and has a vast scope of growing rice under aerobic conditions. Aerobic rice, the term recently introduced in rice cultivation is a practice of direct drilling of seeds in rows and maintaining aerobic conditions of the field under limited water availability. According to IRRI scientists, aerobic rice is a production system of rice in which especially developed “aerobic rice” varieties are grown in well-drained, non-puddled, and frequently saturated soils (Bouman and Lampayan, 2009).

The new concept of aerobic rice entails the use of nutrient responsive cultivars that are adapted to aerobic culture aiming at yields of 70-80% of high input flooded rice (Prasad, 2011). Nitrogen is the key nutrient that most frequently limits the rice production. In low land rice ecosystems, the nitrogen use efficiency is approximately 30% whereas in upland rice, whether irrigated or rainfed, nitrogen use efficiency would be in the range of 40 to 60%. Split application is one of strategies for efficient use of N fertilizers throughout the growing season by synchronizing with plant demand, reducing denitrification losses and improved N uptake for maximum straw and grain yield, and harvest index in DSR (Bufogle *et al.*, 1997). As aerobic rice is a new method of rice cultivation and the form and availability of nitrogen is entirely differing from traditional transplanted paddy field. Nitrogen requirement of aerobic rice at different stages is also differ from transplanted one. Very meager information also available that the total nitrogen requirements for aerobic rice is equal to transplanted rice or somehow differ. Nitrogen application should coincide with crop growth and its requirement. However, there is a need to quantify the nitrogen doses at different growth stages of aerobic rice with particular reference to the cultivars, location and management conditions. In addition, altering the split doses according to the crop requirement is also needed to be analyzed under aerobic rice cultivation. Therefore, optimization of nitrogen level as well as split doses to different crop growth stages is more important to produce higher grain yield of rice under aerobic conditions.

II. MATERIALS AND METHOD

The experiment was conducted during the *kharif* (Rainy) season 2013 and 2014 at N.E. Borlaug Crop Research Centre of G.B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand (India). Pantnagar falls in sub-humid and subtropical climatic zone and situated in *Tarai* belt of Shivalik range of foot hills of Himalayas. Soil of experimental field was silt loam in texture, alluvial origin and classified as Auichapludoll (Deshpande *et al*., 1971). The chemical analysis of upper 20 cm soil showed slightly alkaline in reaction (ph 7.8), high in organic carbon (0.98%), low in available N (236 kg/ha), medium in available phosphorus (22 kg/ha) and potassium (215 kg/ha). The experiment consisted of 3 nitrogen level *viz.* 90 (N_1),120 (N_2) and 150 kg ha^{-1} (N_3) in main-plots with the seven sets of nitrogen scheduling in sub-plots *viz.* 2 splits ($\frac{1}{2}$ basal + $\frac{1}{2}$ at Panicle Initiation), 2 splits ($\frac{1}{2}$ 10-12 Days after emergence + $\frac{1}{2}$ at Panicle Initiation), 3 splits ($\frac{1}{3}$ basal + $\frac{1}{3}$ at active tillering + $\frac{1}{3}$ at Panicle Initiation), 3 splits ($\frac{1}{3}$ 10-12 Days after emergence + $\frac{1}{3}$ at active tillering + $\frac{1}{3}$ at Panicle Initiation), 4 splits ($\frac{1}{4}$ basal + $\frac{1}{4}$ at active tillering + $\frac{1}{4}$ at Panicle Initiation +$\frac{1}{4}$ at flowering), 4 splits ($\frac{1}{4}$ 10-12 days after emergence + $\frac{1}{4}$ at active tillering + $\frac{1}{4}$ at Panicle Initiation +$\frac{1}{4}$ at flowering) and 4 splits ($\frac{1}{4}$ basal + $\frac{1}{2}$ at active tillering + $\frac{1}{4}$ at Panicle Initiation) represented as F_1, F_2, F_3, F_4, F_5, F_6 and F_7 respectively. The levels of nitrogen i.e. 90, 120, 150 kg ha^{-1} were applied as per the treatments, phosphorus @ 60 kg P_2O_5 ha^{-1} was applied through single super phosphate (SSP) and potassium @ 40 kg K_2O ha^{-1} applied through muriate of potash. Full dose of phosphorus and potassium fertilizer were incorporated into the soil at the time of sowing. Rice variety 'Pant Dhan-16' was used as test crop variety. The sowing of direct seeded aerobic rice was done on 16 June, 2013 during the first year and on 15 June, 2014 during the second year in dry moist soil. Before sowing seeds were treated with Carbendazim @ 2 g kg^{-1} seed. Pre-emergence herbicides Pendimethalin @ 1.0 kg a.i. ha^{-1} was applied using 800 liters of water. Fallowed by post emergence Bispiyribac sodium @ 0.025 kg a.i. ha^{-1} amount of water and herbicides to be sprayed were computed on the basis of gross area of each plot. Hand weedings were done at 20 and 40 days after sowing by removing weeds manually using "*Khurpi*". Under plant protection measure controlling *Khaira* (Zn deficiency), two sprays of zinc (5 kg zinc sulphate with 2.5 kg slaked lime dissolved in 1000 liter water per ha) were done at 15 and 25 days after emergence, for Fe deficiency, $FeSo_4$ was applied @ 0.5% a.i /ha. There was no serious problem of insect-pest except mild incidence of stem borer. These insects were controlled timely by applying Cartap hydrochloride 4G @ 20 kg ha^{-1}.Matured straw had turned yellow and data on grain and straw yield were recorded. Partial factor productivity (PFP) as per the prescribed formula. The cost of cultivation and returns were calculated by taking into account the prevailing cost of inputs and prices of output. The number of panicle-bearing tillers were counted with the help of scale from 1 m row length for effective tillers m^{-2}, 10 panicles were selected at random from each plot to compute panicle weight and grains $panicle^{-1}$. For test weight, 1000 grains were counted from each treatment and their weight was recorded. The crop was harvested manually with the help of sickle grain at optimum moisture content. The observations on important characters *viz.* plant height, number of tillers, number of panicles per m^2, 1000 –grain weight, dry weight and grain yield were recorded Nutrient estimation of grain and straw samples were done as per the prescribed methods.

III. RESULTS AND DISCUSSION

A. YIELD AND YIELD ATTRIBUTES OF DIRECT SEEDED AEROBIC RICE

Plant height increased continuously with advancement in crop age up to 90 days after sowing and thereafter decreased. No significant difference was observed in plant height by varying nitrogen doses and their nitrogen scheduling at different crop growth stages (Table 1). The plant height was increased with increased in nitrogen doses and maximum height was recorded with150kg N ha^{-1}at all the crop growth stage. Malik *et al.* (2014) reported that plant height is not a yield component but it indicates the influence of various nutrients on plant metabolism. The Plant height increased up to 120 kg N ha^{-1}, which was, comparable with 140 kg N ha^{-1} and shortest plant stature was recorded with 80 kg N ha^{-1} Murthy *et al.* (2012).Variable application of nitrogen scheduling did not significantly influenced plant height. The plant dry matter produced by the crop increased with the advancement of crop growth. The increased nitrogen doses from 90 to 150 kg N ha^{-1} increased the plant dry matter at all the stages of crop growth but this increase was significant only at maturity. At 30, 60 and 90 days after sowing, dry matter (45.0, 389 and 627gm^{-2}respectively) was more with 150 kg N $ha^{-1}$and at maturity, nitrogen @150 kg N ha^{-1} produced the highest plant dry matter (771gm^{-2}) which was significantly higher as compared to remaining treatment. Increases dry matter with increasing N doses might be to increases the photosynthetic efficiency of crop leading to sink (Table 2). Maheshwari *et al.* 2007 and Murthy *et al.* 2012 also reported that dry matter production and root volume increased progressively up to 120 kg N ha^{-1}, which was significantly superior to all the other nitrogen levels. Nitrogen application scheduling had significant effect on the plant dry matter production at 90 days after sowing and at maturity only. At 90 days after sowing, F_3 where nitrogen was applied in three splits *i.e.* one-third at basal, at one-third at active tillering and remaining one-third at panicle initiation stage produced highest dry matter (625g m^{-2}) which was statistically *at par* to all other nitrogen scheduling except F_2 when nitrogen was applied in two splits *i.e.* half at 10-12 day after emergence rest half at panicle initiation (536g m^{-2}). At maturity, where nitrogen was applied in four splits *i.e.* one-fourth as basal, one-fourth at active tillering, one-fourth at panicle initiation and remaining one-fourth at flowering (F_5) stages accumulated the highest plant dry matter (760g m^{-2}) and it was significantly higher over all other treatments and was statistically *at par* with F_7 when nitrogen was applied in three splits *i.e.* one-fourth as basal, half at active tillering and rest one-fourth at panicle initiation(746 g m-^{2}). Sathiya and Ramesh, 2009 also reported that spilt doses of nitrogen to different crop growth stage is more important to produce the dry matter production, as higher nitrogen to plant leading to its higher uptake and translocation from vegetative parts.

The different nitrogen doses did not shows significant influence on number of panicle per m^2 of rice during 2013 and 2014 (Table 2). Though number of panicles per m^2 increased due to increased nitrogen doses from 90 kg N ha^{-1}(248) to 150 kg N ha^{-1} (253). Variable application of nitrogen scheduling, shows significant influence on the number of panicle per m^2.Number of panicle per m^2 was more (267) with F_1 when nitrogen was applied in two splits *i.e.* half as basal and rest half at panicle initiation stages treatment as compare to F_2 (244) and F_5 (231) while *at par* with remaining treatment *i.e.* F_3 (251), F_4 (257), F_6 (251) and F_7 (251). Sathiya and Ramesh, 2009 reported that splitting doses of nitrogen in different crop growth stage produced the more number of panicles. The interaction effect was non-significant. Nitrogen doses had non-significant effect on panicle weight. Maximum and similar panicle weight was observed under 120 and 150 kg N ha^{-1} (2.0 g). Nitrogen application from 90 to 120 kg ha^{-1}increased the panicle weight from 1.9 to 2.0 g, though the increase was non-significant. Pasha *et al.* (2011) reported that panicle number, length and weight were significantly at higher doses of N *viz.*150 N kg ha^{-1} as compared to 120 kg N kg ha^{-1}. Nitrogen scheduling had significant effect on panicle weight significantly higher panicle weight (2.2 g) was observed with $F_{5,}$ when nitrogen was applied in four splits *i.e.* one-fourth as basal, one-fourth at active tillering, one-fourth at panicle initiation and remaining one-fourth at flowering stages over F_1 (1.8g) and F_4 (1.9g) while, statistically *at par* with rest of the treatments. 1000-grain weight was obtained similar with application of 120 kg N ha^{-1} and 150 kg N ha^{-1} (23.2g) which was significantly higher over 90 kg N ha^{-1} (22.9g). Bahmanyar and Ranjbar (2007) also reported that nitrogen application increased the 1000-grain weight. Variable applications of nitrogen scheduling have significant influence on the 1000 grain weight. When nitrogen was applied in four splits *i.e.* one-fourth as basal, one-fourth at active tillering, one-fourth at panicle initiation remaining one-fourth at flowering (F_5) (23.5 g) recorded significantly higher 1000 grain weight over rest of the treatments. However, lowest 1000 grain weight was recorded with F_1 (22.8 g) where nitrogen was applied in two splits *i.e.* half as basal and rest half at panicle initiation stages. Variations in sterility percentage due to variable application of nitrogen doses and nitrogen scheduling did not differ significantly and its interaction was also non-significant. Application of N @ 90 kg ha^{-1} recorded slightly higher sterility percentage (6.07%) while lowest was with 120 kg N ha^{-1}(5.94%) treatment. Effect of variable application of nitrogen scheduling on sterility percent was also found non-significant.

Treatments under variable nitrogen doses and scheduling had significant effect on grain yield of rice. Grain yield increased with the increase of nitrogen doses (Table 2). Highest grain yield of rice (4652 kg ha^{-1}) was obtained with150 kg N ha^{-1} which was at par with 120 kg N ha^{-1} of (4533 kg ha^{-1}). The increase in grain yield with N @150 kg ha^{-1} was 2.63% over 120 kg ha^{-1} and 7.34% over 90 kg N ha^{-1} treatments. Application of variable nitrogen scheduling also significantly influenced the grain yield. Grain yield was significantly higher in F_5 (4778 kg ha^{-1}) when nitrogen was applied in four splits while *at par* with F_6 (4556 kg ha-^{1}) when nitrogen was applied in four splits and F_7 (4599 kg ha^{-1}). Manzoor *et al.* (2006) reported that plant height, number of productive tillers per hill, panicle length, number of grains per panicle, 1000 grain weight and paddy yield showed increasing trend from 0 kg N/ha up to 175 kg N/ha. Shaiful *et al.* (2009) observed that effect of split application of N fertilizer on grain yield $hill^{-1}$ was statistically significant. Like grain yield, both the treatment variable nitrogen levels and nitrogen-scheduling had significant effect on straw yield also. Significantly higher straw yield was obtained with application of 150 kg N ha^{-1}(4522 kg ha^{-1}) as compared to 90 kg N ha^{-1} (4014 kg ha^{-1}) and 120 kg N ha^{-1}(4109 kg ha^{-1}). Nitrogen scheduling significantly influenced the straw yield of rice. Significantly higher straw yield was obtained with F_5 (4591 kg ha^{-1}) which was statistically *at par* with F_7 (4410 kg ha^{-1}) (Table 2). This might be due to the application of nitrogen in splits according to crop requirement caused not only reduction in loss of nitrogen but also increased the nitrogen absorption, consequently better utilization of applied nitrogen leads to higher yield attributes and finally resulted in higher grain and straw yields. Pramanik and Bera (2013) reported that grain yield increased steadily with the increase in nitrogen level up to the 150 kg ha-1 and decreased with further increase of applied N fertilizer (200 kg N ha-1). Lampayan *et al.* (2010) reported that increasing nitrogen rate from N_0 to N_{150} kg/ha increased biomass and yield. However, biomass and yields were statistically the same for N_{120} and N_{150} in both years of aerobic rice.

Table 1: Plant height and plant dry matter accumulations at different growth stages of rice as influenced by doses and scheduling of nitrogen in direct seeded aerobic rice (pooled data of 2013 and 2014)

Treatment	Plant height (cm)				Plant dry matter accumulation (g m^{-2})			
	30 days	60 days	90 days	Maturity	30 days	60 days	90 days	Maturity
Levels of Nitrogen								
N_1:90 kg ha^{-1}	30.7	68.2	106	97	42.6	375	569	699
N_2:120 kg ha^{-1}	32.9	70.5	107	99	42.6	374	581	723
N_3:150 kg ha^{-1}	32.0	73.9	109	98	45.0	389	627	771
S.Em.±	0.8	1.6	1.6	1.63	1.2	8.0	19.4	2
CD(%)	NS	NS	NS	NS	NS	NS	NS	8
Nitrogen scheduling								
F_1 :N-2 splits ($\frac{1}{2}$ basal + $\frac{1}{2}$PI)	31.6	70.3	108	98	43.1	386	596	702
F_2 :N-2 splits ($\frac{1}{2}$ 10-12 DAE + $\frac{1}{2}$ PI)	31.4	72.7	108	97	46.9	353	536	713
F_3 :N-3 splits ($\frac{1}{3}$ basal + $\frac{1}{3}$ AT + $\frac{1}{3}$ PI)	31.2	71.8	109	98	43.1	381	625	728
F_4 :N-3 splits ($\frac{1}{3}$ 10-12 DAE + $\frac{1}{3}$ AT + $\frac{1}{3}$ PI)	31.0	71.2	109	98	42.3	400	588	725
F_5 :N-4 splits($\frac{1}{4}$ basal + $\frac{1}{4}$ AT+ $\frac{1}{4}$ PI +$\frac{1}{4}$ at FL)	31.5	69.3	106	97	43.5	381	600	760
F_6 :N-4 splits($\frac{1}{4}$ 10-12 DAE + $\frac{1}{4}$ AT + $\frac{1}{4}$PI +$\frac{1}{4}$ FL)	31.9	68.9	107	98	42.5	341	608	741
F_7 :N-3 splits($\frac{1}{4}$ basal + $\frac{1}{2}$ AT + $\frac{1}{4}$ PI)	30.9	71.9	106	99	39.2	412	607	746
S.E.m±	0.7	1.1	1.4	0.10	1.5	17.0	26.7	6.0
CD (%)	NS	NS	NS	NS	NS	NS	76.6	17.0
CV(%)	6.7	4.8	3.8	3.0	11.2	13.08	8.06	2.4
Interaction	NS	NS	NS	NS	NS	NS	NS	NS

DAE= Days after emergence; AT=Active tillering; PI= Panicle initiation; FL= Flowering; NS=Non-significant

Table 2: Yield and yield contributing characters as influenced by doses and scheduling of nitrogen in direct seeded aerobic rice in *Kharif* 2013 and 2014 (pooled over two years)

Treatment	No .of panicle/m^2	Panicle weight (g)	1000 grain weight (g)	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Cost of cultivation (Rs/ha)	Net return (Rs/ha)	B:C ratio
Levels of Nitrogen								
N_1:90 kg ha^{-1}	248	1.9	22.9	4334	4014	23662	35126	1.48
N_2:120kg ha^{-1}	251	2.0	23.2	4533	4109	23994	37377	1.54
N_3:150 kg ha^{-1}	253	2.0	23.2	4652	4522	24360	38848	1.59
S.Em.±	3.6	0.05	0.05	53	47	-	-	-
CD(%)	NS	NS	0.2	206	184	-	-	-
Nitrogen scheduling								
F_1 :N-2 splits $\frac{1}{2}$ basal + $\frac{1}{2}$PI stage	267	1.8	22.8	4340	4037	23625	35106	1.48
F_2 :N-2 splits ($\frac{1}{2}$ 10-12 DAE + $\frac{1}{2}$ PI)	244	2.0	23.1	4401	4083	23825	35741	1.50
F_3 :N-3 splits ($\frac{1}{3}$ basal + $\frac{1}{3}$ AT + $\frac{1}{3}$ PI)	251	2.0	22.9	4390	4038	23958	35578	1.48
F_4 :N-3 splits ($\frac{1}{3}$ 10-12 DAE + $\frac{1}{3}$ AT + $\frac{1}{3}$ PI)	257	1.9	23.2	4480	4129	24158	36590	1.52
F_5 :N-4 splits($\frac{1}{4}$ basal + $\frac{1}{4}$ A+ $\frac{1}{4}$ PI +$\frac{1}{4}$ at FL)	231	2.2	23.5	4778	4591	24158	40878	1.69
F_6 :N-4 splits($\frac{1}{4}$ 10-12 DAE + $\frac{1}{4}$ AT + $\frac{1}{4}$PI +$\frac{1}{4}$ at FL)	251	2.0	23.1	4556	4217	24358	37429	1.53
F_7 :N-3 splits $\frac{1}{4}$ basal + $\frac{1}{2}$ AT + $\frac{1}{4}$ PI	251	2.1	23.0	4599	4410	23958	38498	1.61
S.E.m±	7.0	0.07	0.10	79	102	-	-	-
CD	21	0.2	0.3	228	293	-	-	-
Interaction	NS	NS	NS	NS	NS	-	-	-

DAE= Day after emergence; AT= Active tillering; PI= Panicle initiation; FL=Flowering; NS=Non-significant

TOTAL NPK UPTAKE AND PARTIAL FACTOR PRODUCTIVITY

Variable application of nitrogen scheduling had significant effect on total N uptake by rice, significantly higher N uptake by rice was recorded with F_7 (183 kg ha^{-1}) where nitrogen was applied in three splits *i.e.* one-fourth as basal, half at active tillering and remaining one-fourth at panicle initiation which was statistically *at par* with F_5(182 kg ha^{-1}) when nitrogen was applied in four splits *i.e.* one-fourth as basal, one-fourth at active tillering, one-fourth at panicle initiation and one-fourth at flowering stages (Table 3). Interaction effect was non-significant. Likewise N uptake by grain and straw, the total uptake of nitrogen by rice was also significantly higher with 150 kg N ha^{-1} (186 kg ha^{-1}) as compared to 90 and 120 kg N ha^{-1} treatments. Patel and Thakur (1997) also reported that additional nitrogen supply by fertilization during maximum growth period of crop plants, might have favored the higher nitrogen uptake by crop plants. The different fertilizer level and variable application of nitrogen scheduling had significant influence on total Phosphorus uptake by rice. Application of nitrogen @150 kg ha^{-1}in rice removed the higher total phosphorus (36.9 kg ha^{-1}) which was significantly higher than 90 kg N ha^{-1}(30.4 kg ha^{-1}) and 120 kg N ha^{-1}(33.0 kg ha^{-1}).Increasing N application stimulated more vegetative growth and increased foraging capacity of roots which in turn increased the uptake of phosphorus. Rammohan *et al.* (1999) observed that highest phosphorus uptake was recorded with the 150 kg N ha^{-1}. Variable nitrogen application scheduling resulted in significantly higher uptake of total phosphorus by rice treatment. F_5 where nitrogen was applied in four splits *i.e.* one-fourth as basal, one-fourth at active tillering, one-fourth at panicle initiation and remaining one-fourth at flowering recorded significantly higher total P uptake (36.8 kg ha-^{1}) over all other treatments. Interaction effect was non-significant. Naidu *et al.* (2013) also reported that split application of nitrogen to rice under SRI will maintain the constant nutrient content and nitrogen, phosphorus and potassium uptake by rice at harvest was the highest with the supply of nitrogen in three splits of one-third each at basal, active tillering and panicle initiation (T_1), followed by supply of nitrogen in four splits of *i.e.* one-fourth each at basal, active tillering, panicle initiation and flowering stages. Different nitrogen doses had significant effect on total potassium uptake by rice. Application of nitrogen 150 kg ha^{-1} recorded higher uptake of total potassium by rice (88.1 kg ha^{-1}) , which was significantly higher than 90 kg N ha^{-1} (77.9 kg ha^{-1}) and 120 kg ha^{-1} (79.4 kg ha^{-1}). Increasing N application stimulated more vegetative growth and increased foraging capacity of roots which in turn increased the uptake of potassium by rice. Rammohan *et al.* (1999) observed that the highest potassium uptake was recorded when nitrogen was applied @ 150 kg ha^{-1}. Among variable application of nitrogen scheduling treatment F_5 (87.2 kg ha^{-1}) where nitrogen was applied in four splits *i.e.* one-fourth as basal, one-fourth at active tillering, one-fourth at panicle initiation and remaining one-fourth at flowering recorded the significantly higher uptake of total potassium by rice. which was statistically *at par* with F_6 (84.2 kg ha^{-1}) where nitrogen was applied in four splits *i.e.* one-fourth at 10-12 day after emergence, one-fourth at active tillering, one-fourth at panicle initiation remaining one-fourth at flowering and F_7 (85.3 kg ha^{-1}) where nitrogen was applied in three splits *i.e.* one-fourth as basal, one-fourth at active tillering and remaining one-fourth at panicle initiation stage. Interaction effect was non-significant.

Different nitrogen doses show significant effect on partial factor productivity of nitrogen. By increasing from 90 to 150 kg ha^{-1}, partial factor productivity decreases from 48.2 to 31.0 kg grain per kg nitrogen applied. Significantly higher partial factor productivity of the order of 48.2 kg grain per kg N applied was obtained with application of 90 kg N ha^{-1} over 120 and 150 kg ha^{-1}(Table 3). Singh *et al.* (1998) reported that decreased nutrient response with enhanced N levels. The probable reason for lower N efficiency at higher N levels may be due to higher N losses with increased levels of N (Daftardar and Savant 1995). Variable application of nitrogen scheduling also significantly influenced the partial factor productivity of nitrogen and significantly higher partial factor productivity was observed with F_5 (41.1 kg grain/kg N) where nitrogen was applied in four splits *at par* with F_6 (39.3 Kg grain/kg N) when nitrogen was applied in four splits and F_7 (39.8 Kg grain/Kg N) where nitrogen was applied in three splits, lowest partial factor productivity was calculated in the F_1 (37.5 kg grain/kg N) when nitrogen was applied in two splits.

AVAILABLE N, P and K IN SOIL

Available nitrogen in soil after harvest of rice was increased with increased nitrogen doses from 90 to 150 kg ha^{-1} (Table 2). Significantly higher available nitrogen (236kg ha^{-1}) was obtained with 150 kg N ha^{-1} which was statistically *at par* with 120 kg N ha^{-1} (234 kg ha^{-1}) but it was significantly higher than 90 kg N ha^{-1}(231 kg ha^{-1}). Variable application of nitrogen scheduling did not significantly influence the available in soil after harvest of rice. However, apparently treatment F_1 reported highest

(237 kg ha^{-1}) available nitrogen where nitrogen was applied in two splits *i.e.* half as basal and rest half at panicle initiation and lowest with F_4 (231 kg ha^{-1}) when nitrogen was applied in three splits. Different levels of nitrogen doses and variable application of nitrogen scheduling had non-significant effect on available phosphorus in soil after harvest of rice. Nitrogen dose @ 150 kg ha^{-1} resulted higher available phosphorus (22.7 kg ha^{-1})as compared to at 90 kg N ha^{-1} (21.0 kg ha^{-1}) and 120 kg N ha^{-1}(21.9 kg ha^{-1}). Different nitrogen doses had significant effect on available potassium in soil after harvest of rice. Nitrogen doses @ 90 kg ha^{-1} resulted significantly higher available potassium (219 kg ha^{-1}) over 120 kg ha^{-1} (215kg ha^{-1}) and 150 kg ha^{-1} (210 kg ha^{-1}) *i.e.* increasing nitrogen levels decreased the availability of potassium in soil. This might be due to more potassium uptake by rice crop. Variable application on nitrogen scheduling had non-significant effect on available potassium in soil after harvest of rice.

Table 3: Total uptake of nitrogen (N), phosphorus (P) and potassium (K) by rice, available NPK in soil and Partial factor productivity (PFP) of N as influenced by doses and scheduling of nitrogen in direct seeded aerobic rice (pooled data of 2013 and 2014)

Treatment	Total N uptake (kg ha^{-1})	Total P uptake (kg ha^{-1})	Total K uptake (kg ha^{-1})	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})	Partial factor productivity of N
Levels of Nitrogen							
N_1:90 kg ha^{-1}	162	30.4	77.9	231	21.0	219	48.2
N_2:120kg ha^{-1}	170	33.0	79.4	234	21.9	215	37.8
N_3:150 kg ha^{-1}	186	36.9	88.1	236	22.7	210	31.0
S.Em.±	0.6	0.2	1.3	0.7	0.4	00.7	00.3
CD(%)	2.4	0.6	4.9	2.8	NS	1.3	1.3
Nitrogen scheduling							
F_1 :N-2 splits ($\frac{1}{2}$ basal + $\frac{1}{2}$PI)	159	31.8	79.0	237	21.5	215	37.5
F_2 :N-2 splits ($\frac{1}{2}$ 10-12 DAE + $\frac{1}{2}$ PI)	163	31.4	75.3	236	21.9	215	38.1
F_3 :N-3 splits ($\frac{1}{3}$ basal + $\frac{1}{3}$ AT + $\frac{1}{3}$ PI)	173	32.4	81.1	232	22.0	214	38.1
F_4 :N-3 splits ($\frac{1}{3}$ 10-12 DAE + $\frac{1}{3}$ AT + $\frac{1}{3}$ PI)	173	32.7	80.4	231	21.4	214	38.8
F_5 :N-4 splits($\frac{1}{4}$ basal + $\frac{1}{4}$ AT+ $\frac{1}{4}$ PI +$\frac{1}{4}$ at Fl)	182	36.8	87.2	234	21.5	214	41.1
F_6 :N-4 splits($\frac{1}{4}$ 10-12 DAE + $\frac{1}{4}$ AT + $\frac{1}{4}$PI +$\frac{1}{4}$ Fl)	177	33.9	84.2	233	20.4	215	39.3
F_7 :N-3 splits($\frac{1}{4}$ basal + $\frac{1}{2}$ AT + $\frac{1}{4}$ PI)	183	35.2	85.3	236	21.7	215	39.8
S.E.m±	1.6	0.5	2.1	1.4	0.6	0.9	00.6
CD (%)	4.6	1.4	5.9	NS	NS	NS	1.8
CV(%)	3.0	4.5	7.6	1.8	8.16	1.29	4.9
Interaction	NS	NS	NS	NS	NS	NS	NS

DAE= Day after emergence; AT= Active tillering; PI= Panicle initiation; FL=Flowering; NS=Non-significant

ECONOMICS

Treatment with nitrogen dose 150 kg N ha^{-1} obtained the maximum B:C ratio (1.59) followed by 120 kg N ha^{-1}(1.54) and 90 kg N ha^{-1} (1.48). Benefit cost ratio was maximum with nitrogen scheduling F_5 (1.69) where nitrogen was applied in four splits and lowest with F_1 when nitrogen was applied in two splits *i.e*. half as basal and rest half at panicle initiation stages (1.48).

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