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

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Abstract

\textit{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\textsuperscript{-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\textsuperscript{-1}(N\textsubscript{3}). Comparing to variable nitrogen scheduling these yield attributing characters were significantly higher when N was applied in 4 splits (1/4 basal + 1/4 at active tillering+ 1/4 panicle initiation +1/4 at flowering) under Tarai conditions recorded the maximum growth and yield attributes as well as grain yield (4778 kg ha\textsuperscript{-1}). The nutrient NPK uptake were also higher under treatment receiving 150 kg N ha\textsuperscript{-1} and nitrogen scheduling N in 4 splits (1/4 basal + 1/4 at active tillering+ 1/4 panicle initiation +1/4 at flowering. Net return (Rs.38848), and B:C ratio (1.59) were recorded higher with 150 kg N ha\textsuperscript{-1}applied whereas, nitrogen scheduling N in 4 splits(1/4 basal + 1/4 at active tillering+ 1/4 panicle initiation +1/4 at flowering) gave the highest net return (Rs.40878), and B:C ratio (1.69) followed by N in 3 splits (1/4 basal + 1/2 active tillering + 1/4 panicle initiation).}

\textit{Key words:} Nitrogen scheduling, Nutrient supply, Direct seeded aerobic rice

I. INTRODUCTION

Rice (\textit{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 Aulichapludoll (Desphande 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 (N1), 120 (N2) and 150 kg ha−1 (N3) in main-plots with the seven sets of nitrogen scheduling in sub-plots viz. 2 splits (¼ basal + ½ at Panicle Initiation), 2 splits (¼ 10-12 Days after emergence + ½ at Panicle Initiation), 3 splits (¼ basal + ½ at active tillering + ¼ at Panicle Initiation), 3 splits (¼ 10-12 Days after emergence + ¼ at active tillering + ¼ at Panicle Initiation), 4 splits (¼ basal + ¼ at active tillering + ¼ at Panicle Initiation + ¼ at flowering), 4 splits (¼ 10-12 days after emergence + ¼ at active tillering + ¼ at Panicle Initiation + ¼ at flowering) and 4 splits (¼ basal + ¼ at active tillering + ¼ at Panicle Initiation) represented as F1, F2, F3, F4, F5, F6 and F7 respectively. The levels of nitrogen i.e. 90, 120, 150 kg ha−1 were applied as per the treatments, phosphorus @ 60 kg P2O5 ha−1 was applied through single super phosphate (SSP) and potassium @ 40 kg K2O 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 weedicings 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, FeSO4 was applied @ 0.5% a.i /ha. There was no serious problem of insect-pest except mild incidence of stem borer. These insects

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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 with 150 kg 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 627 gm\(^{-2}\) respectively) was more with 150 kg N ha\(^{-1}\) and at maturity, nitrogen @ 150 kg N ha\(^{-1}\) produced the highest plant dry matter (771 gm\(^{-2}\)) 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 \textit{i.e.} one-third at basal, at one-third at active tillering and remaining one-third at panicle initiation stage produced highest dry matter (625 g m\(^{-2}\)) which was statistically \textit{at par} to all other nitrogen scheduling except \(F_2\) when nitrogen was applied in two splits \textit{i.e.} half at 10-12 day after emergence rest half at panicle initiation (536 g m\(^{-2}\)). At maturity, where nitrogen was applied in four splits \textit{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 (760 g m\(^{-2}\)) and it was significantly higher over all other treatments and was statistically \textit{at par} with \(F_7\) when nitrogen was applied in three splits \textit{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 split 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\(_{3}\) (231) while at par with remaining treatment i.e. F\(_{3}\) (251), F\(_{4}\) (257), F\(_{5}\) (251) and F\(_{6}\) (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 with similar 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 with 150 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)
Lampayan et al. (2010) reported that increasing nitrogen rate from N₀ to N₁₅₀ kg/ha increased biomass and yield. However, biomass and yields were statistically the same for N₁₂₀ and N₁₅₀ 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)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Plant height (cm)</th>
<th>Plant dry matter accumulation (g m⁻²)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>30 days</td>
<td>60 days</td>
</tr>
<tr>
<td>Levels of Nitrogen</td>
<td></td>
<td></td>
</tr>
<tr>
<td>N₁:90 kg ha⁻¹</td>
<td>30.7</td>
<td>68.2</td>
</tr>
<tr>
<td>N₂:120 kg ha⁻¹</td>
<td>32.9</td>
<td>70.5</td>
</tr>
<tr>
<td>N₃:150 kg ha⁻¹</td>
<td>32.0</td>
<td>73.9</td>
</tr>
<tr>
<td>S.Em±</td>
<td>0.8</td>
<td>1.6</td>
</tr>
<tr>
<td>CD(%)</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Nitrogen scheduling</td>
<td></td>
<td></td>
</tr>
<tr>
<td>F₁ :N-2 splits (3/₄ basal + ½ PI)</td>
<td>31.6</td>
<td>70.3</td>
</tr>
<tr>
<td>F₂ :N-2 splits (2 10-12 DAE + ½ PI )</td>
<td>31.4</td>
<td>72.7</td>
</tr>
<tr>
<td>F₃ :N-3 splits (3/₄ basal + ⅓ AT + ¼ PI )</td>
<td>31.2</td>
<td>71.8</td>
</tr>
<tr>
<td>F₄ :N-3 splits (3 10-12 DAE + ⅓ AT + ¼ PI )</td>
<td>31.0</td>
<td>71.2</td>
</tr>
<tr>
<td>F₅ :N-4 splits(2/₄ basal + ⅓ AT+ ½ PI + ⅛ at FL)</td>
<td>31.5</td>
<td>69.3</td>
</tr>
<tr>
<td>F₆ :N-4 splits(⅔ 10-12 DAE + ⅓ AT + ⅛ PI + ⅛ at FL)</td>
<td>31.9</td>
<td>68.9</td>
</tr>
<tr>
<td>F₇ :N-3 splits(⅔ basal + ⅓ AT + ⅛ PI)</td>
<td>30.9</td>
<td>71.9</td>
</tr>
<tr>
<td>S.E.m±</td>
<td>0.7</td>
<td>1.1</td>
</tr>
<tr>
<td>CD (%)</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>CV(%)</td>
<td>6.7</td>
<td>4.8</td>
</tr>
<tr>
<td>Interaction</td>
<td>NS</td>
<td>NS</td>
</tr>
</tbody>
</table>

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)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>No. of panicle/m²</th>
<th>Panicle weight (g)</th>
<th>1000 grain weight (g)</th>
<th>Grain yield (kg ha⁻¹)</th>
<th>Straw yield (kg ha⁻¹)</th>
<th>Cost of cultivation (Rs/ha)</th>
<th>Net return (Rs/ha)</th>
<th>B:C ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Levels of Nitrogen</td>
<td></td>
<td></td>
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<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>N₁:90 kg ha⁻¹</td>
<td>248</td>
<td>1.9</td>
<td>22.9</td>
<td>4334</td>
<td>4014</td>
<td>23662</td>
<td>35126</td>
<td>1.48</td>
</tr>
<tr>
<td>N₂:120 kg ha⁻¹</td>
<td>251</td>
<td>2.0</td>
<td>23.2</td>
<td>4533</td>
<td>4109</td>
<td>23994</td>
<td>37377</td>
<td>1.54</td>
</tr>
<tr>
<td>N₃:150 kg ha⁻¹</td>
<td>253</td>
<td>2.0</td>
<td>23.2</td>
<td>4652</td>
<td>4522</td>
<td>24360</td>
<td>38848</td>
<td>1.59</td>
</tr>
<tr>
<td>S.Em±</td>
<td>3.6</td>
<td>0.05</td>
<td>0.05</td>
<td>53</td>
<td>47</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CD(%)</td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

| Nitrogen scheduling | | | | | | | | |
| F₁ : N-2 splits (⅓ basal + ⅔ PI stage) | 267 | 1.8 | 22.8 | 4340 | 4037 | 23625 | 35106 | 1.48 |
| F₂ : N-2 splits (⅓ 10-12 DAE + ⅔ PI) | 244 | 2.0 | 23.1 | 4401 | 4083 | 23825 | 35741 | 1.50 |
| F₃ : N-3 splits (⅓ basal + ⅓ AT + ⅔ PI) | 251 | 2.0 | 22.9 | 4390 | 4038 | 23958 | 35578 | 1.48 |
| F₄ : N-3 splits (⅓ 10-12 DAE + ⅔ AT + ⅓ PI) | 257 | 1.9 | 23.2 | 4480 | 4129 | 24158 | 36590 | 1.52 |
| F₅ : N-4 splits (⅓ basal + ⅔ A+ ⅔ PI + ⅔ at FL) | 231 | 2.2 | 23.5 | 4778 | 4591 | 24158 | 40878 | 1.69 |
| F₆ : N-4 splits (⅓ 10-12 DAE + ⅔ AT + ⅔ PI + ⅔ at FL) | 251 | 2.0 | 23.1 | 4556 | 4217 | 24358 | 37429 | 1.53 |
| F₇ : N-3 splits (⅓ basal + ⅓ AT + ⅔ PI) | 251 | 2.1 | 23.0 | 4599 | 4410 | 23958 | 38498 | 1.61 |
| S.E.m± | 7.0 | 0.07 | 0.10 | 79 | 102 | | | |
| CD | | | | | | | | |

| Interaction | | | | | | | | |

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 F₇ (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 F₅ (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 \textit{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\(^{-1}\) (215 kg ha\(^{-1}\)) and 150 kg ha\(^{-1}\) (210 kg ha\(^{-1}\)) \textit{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)

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

DAE = Day after emergence; AT = Active tillering; PI = Panicle initiation; FI = 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).

BIBLIOGRAPHY


