

Original Research Article

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## Effect of Planting Time and Nitrogen Fertilization on Yield, Nutrient Uptake and Nitrogen Use Efficiency of Hybrid Rice under Rainfed Shallow Land Condition of North East India

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### ABSTRACT

A field experiment was conducted during the rainy (*kharif*) seasons of 2011 and 2012 at Imphal, Manipur to study the performance of hybrid rice (*Oryza sativa* L.) "PAC 801" to planting times and nitrogen levels on the production potential, nutrient uptake and nitrogen use efficiency under rainfed shallow land condition in a split plot design with three replications, consisting of 12 treatments, namely, main plots: three dates of transplanting (July 6, July 21 and August 5) and sub-plots: four levels of nitrogen (0, 60, 120 and 180 kg N ha<sup>-1</sup>). The research results indicated that 21 July transplanted hybrid rice produced significantly higher yield, yield attributes and N, P and K uptake of grain and straw. The delayed planting on 5 August significantly reduced these crop parameters. The reduction in grain yield to extent of 12 per cent and a loss of 28 kg grain/ha/day was observed under 5 August planting. Planting either on 6 July or 21 July recorded significantly higher Agronomic Efficiency of Nitrogen (AE<sub>N</sub>) and Partial Factor Productivity (PFP<sub>N</sub>) than late planting on 5 August. On the contrary, the lowest Nitrogen Harvest Index (NHI) was recorded from crop planted on 21 July. Nitrogen fertilization resulted in significant increase in yield, yield attributes *viz.* number of panicles m<sup>-2</sup>, panicle length, number of spikelets panicle<sup>-1</sup>, number of filled grains panicle<sup>-1</sup>, percentage of filled grains and test weight and grain and straw N, P and K uptake of hybrid rice with every increase in dose of nitrogen upto 180 kg N ha<sup>-1</sup>. Application of 180 kg ha<sup>-1</sup> increased the grain yield of hybrid rice to the extent of 2.20, 13.30 and 32.78 per cent over 120, 60 and 0 (control) kg ha<sup>-1</sup> nitrogen levels respectively while the nitrogen fertilization beyond 60 kg N ha<sup>-1</sup> level significantly reduced the agronomic efficiency, partial factor productivity and apparent recovery of nitrogen on hybrid rice. Nitrogen application also significantly decreased the nitrogen harvest index with increasing levels. Transplanting hybrid rice on 21<sup>st</sup> July along with nitrogen fertilization of 120 kg ha<sup>-1</sup> resulted to the maximization of net return and B: C ratio.

### Keywords

Planting time,  
Nitrogen fertilization,  
Hybrid rice and N use  
efficiency.

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### Introduction

Rice (*Oryza sativa* L.) is the staple food providing about two-thirds of the calories for

more than two billion people in humid and sub-humid Asia and one-third of the calorie

intake of nearly one billion people in Africa and Latin America. India will need to produce 130 million tonnes of rice by 2030 compared with the present production of 106.3 million tonnes. In north-eastern region of India rice is also the principal food crop occupying an area of about 3.5 m ha with an average productivity of 1.78 t ha<sup>-1</sup>, which is much below the national average (2.42 t ha<sup>-1</sup>). The region is still deficit of about 1.77 million tonnes of rice. Rice productivity has reached a plateau and hence there is an urgent need to adopt some innovative technologies to break the yield ceiling in rice.

Among the available technological options to enhance rice production and productivity, hybrid rice is the most practically feasible and readily adoptable technology. Hybrid vigour in rice is profitably used to increase its productivity by 14-28 per cent over the available best varieties in India (Siddiq, 1993). The yield improvement associated with hybrid rice necessitates for development of appropriate cultural management practices to achieve the potential yield. The Chinese hybrid rice experience has shown that the yield potential of hybrid rice can only be achieved, if each eco region develops its own hybrids or screens hybrids developed in other regions to meet specific local conditions (Justin *et al.*, 1994).

However, climatic factors i.e. temperature and solar radiation influences grain yield of rice hybrids. The amount of stem reserves allocated to the grain, the rate of dry matter production in the grain filling period, and the length of the grain filling period mainly determines the potential of a rice hybrid (Kropff *et al.*, 1994). But it can only be attained if favourable temperature, solar radiation and N supply are maintained by planting the crop in appropriate time and maintaining favourable N supply environments in soil system.

Nitrogen is normally a key factor in achieving optimum lowland rice grain yields (Fageria *et al.*, 1997). It is, however, one of the most expensive inputs and if used improperly, can pollute the ground water. Although rice is grown in different ecosystems, 78% of the world's rice is grown under irrigated or rainfed lowland conditions (IRRI, 1997). Soils under these conditions are saturated, flooded, and anaerobic and N use efficiency is low. Under these situations, increasing rice yield per unit area through use of appropriate N management practices has become an essential component of modern rice production technology (Fageria and Baligar, 2001). In short, reasonable management of nitrogen (N) and the development of N fertilizers with higher use efficiency are the two main methods to increase rice yield. The balanced use of N fertilizer and optimum transplanting date are crucial factors for the productivity of rice. Therefore, experiment was undertaken to study the effect of planting date and N levels on production potential and nitrogen use efficiency of hybrid rice.

## **Materials and Methods**

The field experiment was conducted at the Experimental Farm, College of Agriculture, Central Agricultural University, Iroisemba, Imphal during *kharif* 2011 and 2012. The soil of the experimental field was clayey in texture, strongly acidic in reaction (pH 5.4), high in organic matter (1.78 %), medium in available nitrogen (424 kg ha<sup>-1</sup>), phosphorus (22.4 kg ha<sup>-1</sup>) and potassium (238.2 kg ha<sup>-1</sup>). The experiment was laid out in two factors split plot design with three replications having twelve treatment combinations. Treatments consisted of three dates of planting (6 July, 21 July and 5 August) in the main plots and four levels of nitrogen (0, 60, 120 and 180 kg N ha<sup>-1</sup>) in the sub plots. A uniform dose of phosphorus and potassium each @ 60 kg ha<sup>-1</sup> was uniformly applied to all the treatments

through single super phosphate and muriate of potash, respectively. The whole amount of phosphorus and half of potash were applied as basal while the remaining half of the potash was applied at heading stage. Nitrogen was top dressed as per treatments in the form of urea in three splits, namely, (i) 1/2 dose N at basal (ii) 1/3 dose N at maximum tillering and (iii) 1/6 dose N at heading stage of the crop. Fourteen days old seedlings of hybrid rice cultivar PAC-801 were transplanted in a square pattern (25 cm x 25 cm) in plots of 5m x 4 m. Crop was raised under rainfed condition without giving any additional irrigation throughout the growth stages. The crop was harvested when most of the panicles turned light yellow. Observation on yield parameters like number of effective panicles  $m^{-2}$ , number of spikelets and filled grains panicle<sup>-1</sup>, test weight along with grain yield, straw yield and harvest index were recorded at maturity. Grain and straw samples were analyzed for total N content by a micro Kjeldahl method (Yoshida *et al.*, 1976). N uptake was calculated by multiplying grain yield and straw yield by N content.

## Results and Discussion

### Yield attributes and yield

Yield attributes as well as grain and straw yields of hybrid rice were significantly influenced by transplanting times and nitrogen levels (Table 1). The hybrid rice planted on 21 July produced the maximum value of yield-attributing characters followed by crops transplanted on 6 July and 5 August. All the planting times differed significantly among themselves, except for test weight. The significant reduction in effective panicle  $m^{-2}$ , panicle length, spikelets panicle<sup>-1</sup>, filled grains panicle<sup>-1</sup> and decreased percentage of fertility was noticed at 5 August planting. The higher grain yield was produced significantly when crop was planted on 21 July than either

of earlier planting on 6 July or delayed planting on 5 August during the study. The reduction in grain yield under 5 August planting was to the magnitude of 12 per cent which was calculated as loss of 28 kg grain/ha/day (pooled mean of two years). Late planting on 5 August might have exposed the crop to relatively more adverse environmental condition in terms of water stagnation at the tillering phase, low temperature at the reproductive phase and more infestation of insect pests and disease which might have pulled down the yield as compared to planting on 21 July. The higher yield for early planting was mainly due to favourable climatic conditions especially at the time of tillering, flowering, and grain filling stages. Early transplanted crops received more favourable temperature and longer sunshine duration especially at the tillering stage as compared to later transplanted crops. This led to more number of panicles  $m^{-2}$  and resulted in higher yield. Also earlier planting on 21 July also favours better rooting density and better uptake of N, P and K and thereby increase the growth and yield attributing characters and ultimately yield than delayed planting on 5 August. Om *et al.*, (1997) and Verma *et al.*, (2009) also reported that grain yield decreased as sowing was delayed.

The yield attributes, *viz.* effective panicle  $m^{-2}$ , panicle length, spikelets panicle<sup>-1</sup>, filled grains panicle<sup>-1</sup> were markedly influenced by nitrogen application to hybrid rice. Each additional application of N from 0 to 180 kg  $ha^{-1}$  brought about a corresponding increase in these yield contributing parameters. However, panicle length, filled grain percentage and test weight were found comparable under both the applications of nitrogen fertilizer at 120 kg  $ha^{-1}$  and 180 kg  $ha^{-1}$ . Nitrogen levels exerted significant effect on grain yield during the individual years and on pooled mean basis of both the years under study. The grain yield increased steadily and significantly with

increase in nitrogen levels during individual years as well as on pooled mean basis of both the years under study. The maximum grain yield of 7,169 kg ha<sup>-1</sup> was produced in crop receiving nitrogen at 180 kg ha<sup>-1</sup>, whereas, no nitrogen fertilization produced the minimum grain yield of 5,399 kg ha<sup>-1</sup> on pooled mean basis. The increase in grain yield owing to nitrogen at 180 kg ha<sup>-1</sup> over other lower levels of 120, 60 and 0 kg ha<sup>-1</sup> fertilization were 2.20, 13.30 and 32.78 per cent.

The higher grain yield was observed with application of nitrogen at 180 kg ha<sup>-1</sup> which might be due to higher growth and yield attributes along with efficient translocation of photosynthates from source to sink. This was in accordance with the findings of Sharma *et al.*, (2007), Murthy *et al.*, (2012), Uddin *et al.*, (2013) and Pradhan *et al.*, (2014).

Interaction effect between planting times and nitrogen levels was found to be significant with respect to the grain yield of hybrid rice. Hybrid rice planted on 21 July with N application at 180 kg ha<sup>-1</sup> gave significantly higher yield than all other combinations. Transplanting on 21 July at different N levels gave significantly higher yield than transplanting on 6 July and 5 August. On the other hand, the comparison of nitrogen levels at the same transplanting time showed that application of N at 180 kg ha<sup>-1</sup> at all the different planting times gave significantly more grain yield than other interactions but remained at par with application of N at 120 kg ha<sup>-1</sup>. Verma *et al.*, (2008) reported the similar findings.

### **Nutrient uptake**

Significant improvement in NPK uptake by grain and straw of hybrid rice was observed due to varied planting times (Table 1). The nutrient uptake pattern followed the trend of grain and straw yields. The maximum uptake

of NPK by grain and straw was recorded when the crop was transplanted on 21 July and it was found significantly superior to 6 July and 5 August planting times. This could be ascribed to the increase in the available N, P and K contents in soil resulting from the increased availability of nutrients which ultimately increased nutrient content in the plant tissues and also greater biomass production at early planting. The result confirms the findings of Pandey *et al.*, (2008) and Kabat and Satapathy (2011) and Kumar *et al.*, (2013). Uptake of NPK by grain and straw of hybrid rice was also positively influenced by N levels of 0, 60 and 120 and 180 kg N/ha. Application of increasing levels of nitrogen up to 180 kg N/ha significantly enhanced uptake of NPK by grain and straw. An increased uptake of nitrogen, phosphorus and potassium by rice might be due to constant release of nutrients that satisfied the demand of the hybrid rice at every phenophase. The increase in N uptake was mainly due to significant increase in grain and straw yield with every increase in nitrogen dose as also reported by Zaidi and Tripathi (2007).

The increase in phosphorus uptake with increase in nitrogen levels might be attributed to role of nitrogen to stimulate more vegetative growth and increased foraging capacity of roots that absorbs more phosphorus and potassium from the soil. These results are also in agreement with the findings obtained by Sharma *et al.*, (2007); Pasha *et al.*, (2011) and Singh *et al.*, (2013).

### **Economics**

The maximum net returns were obtained from 21 July planting either applied with 120 or 180 kg N ha<sup>-1</sup> (Table 2). Amongst the different combinations of planting times and nitrogen levels, the maximum benefit: cost ratio of 2.34 was recorded under 21 July planting with 120 kg N ha<sup>-1</sup> application.

**Table.1** Effect of date of planting and nitrogen level on yield attributes, yield and nutrient uptake by hybrid rice (Pooled data of 2 years)

Treatment	Yield attributes						Yield (kg ha <sup>-1</sup> )		HI (%)	Nutrient uptake (kg ha <sup>-1</sup> )						
	Effective panicle m <sup>-2</sup>	Panicle length (cm)	Spikelets panicle <sup>-1</sup>	Filled grains panicle <sup>-1</sup>	Fertility (%)	Test wt. (g)	Grain	Straw		Nitrogen (N)		Phosphorus (P)		Potassium (K)		
										Grain	Straw	Grain	Straw	Grain	Straw	
<b>Date of planting</b>																
July 6	296	24.0	165	134	81	23.1	6449	7859	45.2	84.79	24.56	17.95	16.77	25.47	144	
July 21	322	24.6	174	146	83	23.5	6870	8373	45.2	93.13	27.48	20.08	19.11	27.68	157	
August 5	273	23.5	153	124	81	23.0	6112	7707	44.3	78.69	22.37	16.72	16.00	23.84	136	
<b>SEm(±)</b>	<b>2.0</b>	<b>0.1</b>	<b>1.2</b>	<b>0.8</b>	<b>0.4</b>	<b>0.07</b>	<b>38</b>	<b>97</b>	<b>0.3</b>	<b>0.51</b>	<b>0.26</b>	<b>0.11</b>	<b>0.25</b>	<b>0.19</b>	<b>1.82</b>	
<b>CD (P=0.05)</b>	<b>6.4</b>	<b>0.3</b>	<b>3.7</b>	<b>2.6</b>	<b>1.4</b>	<b>NS</b>	<b>119</b>	<b>304</b>	<b>1.0</b>	<b>1.61</b>	<b>0.83</b>	<b>0.36</b>	<b>0.78</b>	<b>0.58</b>	<b>5.74</b>	
<b>Nitrogen Levels</b>																
N <sub>0</sub>	250	23.1	142	114	79	22.5	5399	7465	42.2	64.57	15.77	12.90	10.60	20.06	121	
N <sub>60</sub>	296	24.0	166	134	81	23.3	6327	7790	45.0	83.14	22.26	15.94	17.55	25.08	142	
N <sub>120</sub>	317	24.4	171	144	84	23.6	7014	8046	46.7	95.48	28.44	21.47	19.43	27.94	150	
N <sub>180</sub>	324	24.6	176	148	83	23.5	7169	8617	45.6	98.97	32.75	22.69	21.60	29.57	170	
<b>SEm(±)</b>	<b>2.0</b>	<b>0.1</b>	<b>1.0</b>	<b>0.8</b>	<b>0.7</b>	<b>0.07</b>	<b>41</b>	<b>106</b>	<b>0.3</b>	<b>0.60</b>	<b>0.40</b>	<b>0.14</b>	<b>0.25</b>	<b>0.20</b>	<b>2.12</b>	
<b>CD (P=0.05)</b>	<b>5.7</b>	<b>0.3</b>	<b>2.8</b>	<b>2.2</b>	<b>1.9</b>	<b>0.20</b>	<b>117</b>	<b>305</b>	<b>1.0</b>	<b>1.73</b>	<b>1.14</b>	<b>0.40</b>	<b>0.70</b>	<b>0.57</b>	<b>6.08</b>	

**Table.2** Interactive effect of planting time and nitrogen levels on grain and straw yields and economics of hybrid rice (Pooled data of 2 years)

Treatment	Grain yield (kg ha <sup>-1</sup> )			Straw yield (kg ha <sup>-1</sup> )			Net return (K ha <sup>-1</sup> )			Benefit: cost ratio		
	6 July	21 July	5 August	6 July	21 July	5 August	6 July	21 July	5 August	6 July	21 July	5 August
N <sub>0</sub>	5304	5625	5268	7321	7393	7682	34023	38272	33928	1.81	1.91	1.80
N <sub>60</sub>	6301	6807	5872	7696	8246	7427	45872	52997	40025	2.05	2.21	1.92
N <sub>120</sub>	7036	7505	6502	7951	8406	7782	54184	60734	47067	2.20	2.34	2.04
N <sub>180</sub>	7156	7542	6807	8468	9448	7935	54764	60764	49696	2.17	2.30	2.06
<b>SEm (±)</b>	<b>71</b>			<b>184</b>			<b>986</b>			<b>0.02</b>		
<b>CD (P=0.05)</b>	<b>203</b>			<b>529</b>			<b>2832</b>			<b>0.06</b>		

**Table.3** Effect of date of planting and nitrogen level on nitrogen use efficiencies of hybrid rice

Treatment	Agronomic Efficiency (AE <sub>N</sub> ) (Δkg grain kg <sup>-1</sup> N applied)			Agro Physiological Efficiency (APE <sub>N</sub> ) (Δkg grain Δkg <sup>-1</sup> N uptake)			Apparent Recovery Efficiency (ARE <sub>N</sub> ) (%)			Partial Factor Productivity (PFP <sub>N</sub> ) (kg grain kg <sup>-1</sup> N applied)			Nitrogen Harvest Index (NHI) %		
	2011	2012	Pooled	2011	2012	Pooled	2011	2012	Pooled	2011	2012	Pooled	2011	2012	Pooled
	<b>Date of Planting</b>														
6 July	12.16	15.41	13.79	59.80	83.76	71.78	33.66	36.18	34.92	53.41	54.62	54.02	78.168	77.6	77.88
21 July	14.14	16.55	15.34	38.39	44.89	41.64	36.66	35.99	36.32	55.71	58.87	57.29	77.040	78.4	77.74
5 August	5.97	13.29	9.63	24.07	38.08	31.07	25.15	34.82	29.98	54.56	52.76	53.66	77.685	78.3	78.01
<b>SEm (±)</b>	<b>0.53</b>	<b>1.528</b>	<b>0.73</b>	<b>17.56</b>	<b>25.72</b>	<b>14.16</b>	<b>3.09</b>	<b>5.74</b>	<b>2.93</b>	<b>0.48</b>	<b>1.07</b>	<b>0.55</b>	<b>0.23</b>	<b>0.27</b>	<b>0.20</b>
<b>CD(P=0.05)</b>	<b>2.102</b>	<b>NS</b>	<b>2.30</b>	<b>NS</b>	<b>NS</b>	<b>NS</b>	<b>NS</b>	<b>NS</b>	<b>NS</b>	<b>NS</b>	<b>4.18</b>	<b>1.72</b>	<b>0.91</b>	<b>1.05</b>	<b>0.64</b>
<b>Nitrogen level (kg ha<sup>-1</sup>)</b>															
N <sub>0</sub>	-	-	-	-	-	-	-	-	-	-	-	-	81.29	79.3	80.31
N <sub>60</sub>	11.68	19.25	15.47	28.79	43.34	36.06	38.73	44.76	41.75	89.28	90.68	89.98	78.50	79.3	78.92
N <sub>120</sub>	11.75	15.18	13.46	42.23	43.23	42.73	31.22	36.36	33.79	44.64	45.34	44.99	76.92	77.2	77.05
N <sub>180</sub>	8.84	10.82	9.83	51.25	80.15	65.70	25.52	25.86	25.69	29.76	30.23	29.99	73.79	76.7	75.23
<b>SEm (±)</b>	<b>0.77</b>	<b>0.643</b>	<b>0.50</b>	<b>10.48</b>	<b>23.43</b>	<b>12.82</b>	<b>2.53</b>	<b>1.18</b>	<b>1.40</b>	<b>0.14</b>	<b>0.33</b>	<b>0.18</b>	<b>0.41</b>	<b>0.38</b>	<b>0.28</b>
<b>CD(P=0.05)</b>	<b>2.370</b>	<b>1.979</b>	<b>1.46</b>	<b>NS</b>	<b>NS</b>	<b>NS</b>	<b>7.80</b>	<b>3.65</b>	<b>4.08</b>	<b>0.44</b>	<b>1.01</b>	<b>0.52</b>	<b>1.23</b>	<b>1.14</b>	<b>0.81</b>

This might be owing to higher productivity of hybrid rice and relatively low production cost per unit of yield under the treatment. Owing to better response of rice to nitrogen, the net returns were greater at higher rates of application, i.e. 120 and 180 kg N/ha.

### **Fertilizer N- use efficiency**

The planting time showed significant effect on nitrogen use efficiency indices like agronomic efficiency of nitrogen, partial factor productivity of nitrogen as well as nitrogen harvest index in hybrid rice production. However no significant influence on agro physiological efficiency and apparent recovery efficiency were observed due to planting time. The highest agronomic efficiency of nitrogen and partial factor productivity of nitrogen were obtained from the crop having planted on July 21 as compared to rest of other planting times whereas planting on July 21 also being at par with July 6 planting recorded the minimum nitrogen harvest index than late planting on August 5.

Agronomic efficiency ( $AE_N$ ) was maximum at 120 kg N ha<sup>-1</sup> and it was at par with 60 kg N ha<sup>-1</sup>. Then, it decreased with increasing N level up to 180 kg N ha<sup>-1</sup> during 2011 (Table 3). During 2012, AE (kg grain kg<sup>-1</sup> applied N) was maximum at 60 kg N /ha and then gradually decreased with increasing N rate up to 180 kg N ha<sup>-1</sup>.

On the basis of pooled mean it can be concluded that nitrogen fertilization beyond 60 kg N ha<sup>-1</sup> level significantly reduced the Agronomic efficiency ( $AE_N$ ) on hybrid rice. Since grain yield response to applied N follows law of diminishing returns, a number of workers (Kour *et al.*, 2007 and Singh *et al.*, 2007) have reported a decreasing trend in AE with increasing N rate due to higher values of AE at lower N rates. The AE was higher in

2011 than in 2012 possibly due to better climatic conditions which helped to achieve high yields.

Partial factor productivity of nitrogen ( $PFP_N$ ) was markedly affected by nitrogen fertilization during the second year and on pooled mean basis. There was strong negative relationship between  $PFP_N$  and nitrogen levels and a markedly successive reduction in  $PFP_N$  at higher levels of N application. The crop at the low nitrogen level (N<sub>60</sub> kg ha<sup>-1</sup>) recorded the highest value of  $PFP_N$  (89.28 and 89.98 kg grains kg<sup>-1</sup> of nitrogen applied) and the crop at the high nitrogen level (N<sub>180</sub> kg ha<sup>-1</sup>) recorded the lowest value of  $PFP_N$  (29.76 and 52.00 kg grains kg<sup>-1</sup> of nitrogen applied) respectively, during both the years. The results noticed that though the crop fed with high nitrogen levels increased the grain yield but showed less efficient in recording  $PFP_N$ . These were in conformity with the findings of Sharma *et al.*, (2007).

Like  $AE_N$ , the ARE of applied N gradually decreased with increasing N rate with minimum values observed at 180 kg ha<sup>-1</sup> and the maximum values were recorded at 60 kg N ha<sup>-1</sup> (Table 3) during both the years and on pooled mean basis. However,  $ARE_N$  at 120 kg N ha<sup>-1</sup> was at par with 60 kg N ha<sup>-1</sup> during the first year. The lower values of ARE at high N rates are most likely due to greater N losses through leaching, denitrification and ammonia volatilization. Similar results have been reported by Gupta *et al.*, (2011).

Nitrogen harvest index (NHI) was significantly varied among nitrogen levels. There was negative relationship between nitrogen harvest index and nitrogen levels. Nitrogen application significantly decreased the nitrogen harvest index with increasing levels. The maximum value of nitrogen harvest index of hybrid rice was recorded

from crop receiving no nitrogen and the minimum was observed at the highest level of 180 kg N ha<sup>-1</sup>.

From the present investigations, it may be concluded that planting of hybrid rice between July 6 and 21 along with 120 N ha<sup>-1</sup> produced economically optimum crop yield, agronomic nitrogen use efficiency and return per rupee invested on clay soils of shallow lowland rainfed conditions of Imphal Valley, Manipur.

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