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Full Research Article

Response of Hybrid Rice to Transplanting Date and Nitrogen Fertilization under System of Rice Intensification in Rainfed Lowland Ecosystem

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Abstract

A field experiment was conducted during *kharif* seasons of 2011 and 2012 at Imphal, Manipur to study the performance of hybrid rice PAC-801 to transplanting dates (6th July, 21st July and 5th August) and nitrogen levels (0, 60, 120 and 180 kg N ha^{-1}) on productivity, profitability and nitrogen use efficiency under system of rice intensification in rainfed lowland condition. 21st July transplanted hybrid rice significantly increased panicles m^{-2} (17.9%), panicle length (4.6%), spikelets panicle^{-1} (13.7%), filled grains panicle^{-1} (17.7%), 1000-grain weight (2.17%), grain yield (12.4%) and straw yield (8.6%) over 5th August transplanting. Transplanting either on 6th July or 21st July produced significantly higher grain and straw NPK uptakes, agronomic efficiency and partial factor productivity of nitrogen than late transplanting on 5th August. Hybrid rice PAC 801 showed significant response to application of N up to 180 kg N ha^{-1} which improved the yield attributes (panicles m^{-2}, panicle length, spikelets panicle^{-1}, filled grains panicle^{-1}), grain and straw yields and NPK uptakes of grain and straw. Maximum grain yield (7,169 kg ha^{-1}) was with 180 kg N ha^{-1}. This was 32.8, 13.3 and 2.2% higher over 0 (control), 60 and 120 kg N ha^{-1}, respectively. Nitrogen fertilization beyond 60 kg ha^{-1} level significantly reduced agronomic efficiency, partial factor productivity and apparent recovery of applied nitrogen. Transplanting hybrid rice on 21st July along with nitrogen fertilization of 120 kg ha^{-1} resulted higher economical grain yield under rainfed lowland ecosystem as compared to rest of the treatments.

1. 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. Rice provides 35%–60% of the dietary calories and 50%–80% of the energy intake of the people in developing countries (Fageria and Baligar, 2003). In India rice is the most important food crop having an average area of 43.95 mha and 106.54 mt of average production during 2013−14 (G.O.I., 2014). India will need to produce more rice if it has to meet the growing demand which is, likely to be 121.2 mt by the year 2030, 129.6 mt by the year 2040 and by the year 2050, the demand will be 137.3 mt (CRRI, 2013). In general, India needs to produce 1.7 mt of additional rice every year to ensure national food security (Dass and Chandra, 2013).

Green revolution by passed lowland rice eco-systems. Traditionally rice mono-cropped with photo period-sensitive, medium to long duration and low yielding varieties has dominated the lowland rice ecosystem. Moreover, rice cultivation in India is predominantly practiced by transplanting method that involves raising, up rooting and transplanting of seedlings. This is rather a resource and cost intensive method since preparation of seedbed, raisings of seedling and transplanting are labour and time intensive operations. To avoid these difficulties and fulfil the demand of increasing population of India, there is an urgent need to adopt some innovative techniques to break the yield ceiling in rice. The introduction of system of rice intensification (SRI) is gaining attention among the rice growers. The most obvious advantage from SRI appears to be the yield increases in farmers' field without addition of extra seeds or chemical and mechanical inputs (Stoop et al., 2002). Beside the SRI, most important criterion is selection of hybrids for particular climatic conditions that performed well and produce significantly higher yield. It is one of the viable and proven technologies available at present to enhance the rice productivity and production in the country (Yuan, 2002).

Advantage of heterosis can be achieved to the fullest extent, when it is supported by favourable weather condition, especially of temperature and sunshine hrs. 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 determine 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. Soils under these conditions are saturated, flooded, and anaerobic and N use efficiency is low. Under these situations, increasing rice yield unit^{-1} area through use of appropriate N management practices has become an essential component of modern rice production technology. Nitrogen requirement of hybrid rice cultivars is expected to be different from that of inbred rice cultivars. However, limited information is available on the N requirement of hybrid rice especially under rainfed lowland condition. The balanced use of N fertilizer and optimum transplanting date are crucial factors for enhancing the productivity of rice. A comprehensive study is thus crucially important to optimize N fertilizer requirements of hybrid rice for enhancing N use efficiency under lowland rice ecosystem. Therefore, experiment was undertaken to study the effect of transplanting dates and N levels on production potential and nitrogen use efficiency of hybrid rice.

2. Materials and Methods

The field experiment was conducted during the rainy *(kharif)* seasons of 2011 and 2012, Imphal, Manipur (24°46′ N latitude and 93°54′ E longitude with an average altitude of 774.5 m above the mean sea level). A composite representative soil sample was collected from the experimental field prior to start of the experimentation and analysed for physico-chemical properties. 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^{-1}), phosphorus (22.4 kg ha^{-1}) and potassium (238.2 kg ha^{-1}). The experiment was laid out in split plot design assigning three dates of transplanting (6th July, 21st July and 5th August) in the main plots and four levels of nitrogen (0, 60, 120 and 180 kg N ha^{-1}) in the sub plots making 12 treatment combinations replicated thrice. A uniform dose of phosphorus and potassium each @ 60 kg ha^{-1} was 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 treatments^{-1} in the form of urea in three splits, namely, $^1/_2$ dose N at basal; $^1/_3$ dose N at maximum tillering and $^1/_6$ dose N at heading stage of the crop. Fourteen days old seedlings of hybrid rice cultivar PAC-801 were transplanted by using index finger and thumb and gently planted at the marked intersection of 25×25 cm^2 in puddled soil in plots of 6.0×4.0 m^2. Cono-weeder, being a part of SRI, was used two times during 15–20 and 30–35 DAT. The other crop management practices were followed as system^{-1} of rice intensification recommendations. The crop was harvested continuously to maturity as treatments^{-1}.

The LAI was measured by leaves of five plants taken from each penultimate rows and leaf area was recorded with a leaf area meter (Systronics 211). The LAI was worked out as: Leaf-area index=Total leaf-area (cm^2) Land^{-1} area. All the data pertaining to growth, yield attributes and yield were suitably recorded. Data on grain and straw yield were recorded from the net plot, whereas yield attributes from 5 randomly selected plants at harvesting. The dried crop samples at harvest stage were used for nitrogen, phosphorus and potassium analysis following the standard methods. The uptake of nutrients were obtained by multiplying the nutrient concentration with their dry weight and expressed as kg ha^{-1}. Economics was computed using the prices of inputs and outputs as prevailing^{-1} local market rates.

Agronomic Efficiency, Physiological Efficiency, Apparent Recovery Efficiency, Partial Factor Productivity and Nitrogen Harvest Index were calculated as

$$\text{Agronomic efficiency (kg N uptake kg}^{-1}\text{ N applied)} = \frac{(y_t\text{-}y_0)}{N_a}$$

$$\text{Apparent recovery efficiency (kg N uptake kg}^{-1}\text{ N applied)} = \frac{(N_t\text{-}N_0)}{N_a}$$

$$\text{Physiological efficiency (kg grain kg}^{-1}\text{ uptake)} = \frac{(y_t\text{-}y_0)}{N_t\text{-}N_0}$$

$$\text{Partial factor productivity (kg grain kg}^{-1}\text{ N applied)} = \frac{(y_t)}{N_a}$$

$$\text{Nitrogen harvest index (\%)} = \frac{Ng}{N_c} \times 100$$

Y_t=Grain yield under nitrogen treated plot (kg ha^{-1}), Y_0=Grain yield under control plot (kg ha^1) and N_a=Amount of fertilizer nitrogen applied (kg ha^{-1}), Nt=Total nitrogen uptake under nitrogen treated plot (kg ha^{-1}), N_0=Total nitrogen uptake under control plot (kg ha^{-1}) and Na=Amount of fertilizer nitrogen applied (kg ha^{-1}), Nt=Total nitrogen uptake under nitrogen treated plot (kg ha^{-1}) and N_0=Total nitrogen uptake under control plot (kg ha^{-1}) Ng=Nitrogen uptake by grain in each plot (kg ha^{-1}) and Nc=Nitrogen uptake by crop in each plot (kg ha^{-1}).

All the observations were analyzed statistically for their test of significance of the individual years, and pooled analysis was done over the years using the *F*-test (Gomez and Gomez, 1984). The significance of difference between treatments means were compared with critical differences at 5% level of probability.

3. Results and Discussion

3.1. Transplanting date

3.1.1. Growth, yield attributes and yield

Significant effect of transplanting date was observed on growth parameters of rice hybrid (Table 1). Transplanting either on 6th or 21st July significantly increased plant height at harvest, tillers m^{-2}, leaf-area index and dry matter accumulation at 60 DAT over late transplanting on 5th August. It might be due to the fact that late planting had shorter growing period due to photoperiodic response and the July transplanting provided favourable environmental condition which enabled the plant to improve its growth and development as compared to the August transplanting (Chaudhary et al., 2011). 21st July transplanting hybrid rice produced 17.9%, 4.7%, 13.7% and 17.7% significantly more panicle m^{-2}, panicle length (cm), spikelets $panicle^{-1}$ and grains $panicle^{-1}$ over 5th August transplanting (Table 1). Similarly, 21st July transplanting produced significantly the maximum grain yield (6,870 kg ha^{-1}) and straw yield (8,373 kg ha^{-1}) (Table 2). The per cent increase in grain and straw yield by 21st July over 5th August planting was 12.4 and 8.64, respectively. It might be due to longer growing period of the crop for better development of parts to allocate greater accumulation of photosynthates in early planted crop which may result in the better development of growth and yield attributing characters.

3.1.2. Nutrient uptake

Significant improvement in NPK uptake by grain and straw of hybrid rice was observed due to varied transplanting times (Table 2). 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 21st July and it was significantly superior to 6th July and 5th August transplanting 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 Kabat and Satapathy (2011); Kumar et al. (2013).

3.1.3. Nitrogen use efficiency and profitability

There were significant effects of transplanting date on nitrogen use efficiency indices like agronomic efficiency (AE) of nitrogen, partial factor productivity (PFP) of nitrogen and nitrogen harvest index (NHI) in hybrid rice production.

Table 1: Effect of date of transplanting and nitrogen fertilization on growth and yield attributing characters of hybrid rice (pooled data of 2 years)

Treatment	Plant height (cm) at harvest	Tillers m^{-2} at harvest	Dry matter accumulation (g m^{-2}) at 60 DAT	LAI at 60 DAT	Panicles m^{-2}	Panicle length (cm)	Spikelets $panicle^{-1}$	Filled grains $panicle^{-1}$	1000-grain weight (g)
Date of transplanting									
6th July	95.85	141	549	4.79	296	24.0	165	134	23.1
21st July	98.54	175	569	5.29	322	24.6	174	146	23.5
5th August	91.65	111	528	4.44	273	23.5	153	124	23.0
SEm±	0.79	4.2	4.8	0.07	2.0	0.1	1.2	0.8	0.07
CD (p=0.05)	2.50	13.3	15.1	0.21	6.4	0.3	3.7	2.6	NS
Nitrogen levels (kg ha^{-1})									
N_0	89.89	280	377	3.70	250	23.1	142	114	22.5
N_{60}	95.47	335	523	4.63	296	24.0	166	134	23.3
N_{120}	97.46	360	640	5.35	317	24.4	171	144	23.6
N_{180}	98.58	366	655	5.70	324	24.6	176	148	23.5
SEm±	0.64	4.1	3.5	0.05	2.0	0.1	1.0	0.8	0.07
CD (p=0.05)	1.84	11.8	10.1	0.13	5.7	0.3	2.8	2.2	0.20

Table 2: Effect of date of transplanting and nitrogen fertilization on yield (kg ha^{-1}), harvest index and nutrient uptake (kg ha^{-1}) of hybrid rice (pooled data of 2 years)

Treatment	Grain yield	Straw yield	Harvest index	N uptake		P uptake		P uptake	
				Seed	Straw	Seed	Straw	Seed	Straw
Date of transplanting									
6th July	6449	7859	45.2	84.79	24.56	17.95	16.77	25.47	144
21st July	6870	8373	45.2	93.13	27.48	20.08	19.11	27.68	157
5th August	6112	7707	44.3	78.69	22.37	16.72	16.00	23.84	136
SEm±	38	97	0.3	0.51	0.26	0.11	0.25	0.19	1.82
CD (p=0.05)	119	304	1.0	1.61	0.83	0.36	0.78	0.58	5.74
Nitrogen levels (kg ha^{-1})									
N_0	5399	7465	42.2	64.57	15.77	12.90	10.60	20.06	121
N_{60}	6327	7790	45.0	83.14	22.26	15.94	17.55	25.08	142
N_{120}	7014	8046	46.7	95.48	28.44	21.47	19.43	27.94	150
N_{180}	7169	8617	45.6	98.97	32.75	22.69	21.60	29.57	170
SEm±	41	106	0.3	0.60	` 0.40	0.14	0.25	0.20	2.12
CD (p=0.05)	117	305	1.0	1.73	1.14	0.40	0.70	0.57	6.08

However, transplanting time had a very low impact on physiological efficiency and apparent recovery efficiency of hybrid rice as different transplanting times did not show any significant improvement on these parameters. The highest AE and PFP of nitrogen were reported with 21st July transplanting followed by 6th July transplanting. The AE of applied N varied from 9.63 to 15.34 kg kg^{-1} of N and PFP values for N were about 53.66–57.29 kg kg^{-1} of N (Table 3). The main reason of low N use-efficiency is N loss mechanism, especially through leaching, denitrification and ammonia volatilization. On the other hand, 21st July transplanting also being at par with 6thJuly transplanting recorded the minimum nitrogen harvest index (NHI) than late planting on 5th August. Crop planted on 21st July fetched significantly higher net return (₹ 53,191 ha^{-1}) and benefit: cost ratios (2.19) which might be due to higher grain yield registered under the treatment (Table 3). Similar findings were reported by Kumar et al. (2013).

3.2. Nitrogen fertilization

3.2.1. Growth, yield attributes and yield

Results revealed that hybrid rice responded well to nitrogen fertilization in terms of growth parameters. Nitrogen application of 180 kg ha^{-1} produced significantly higher plant height, tillers m^{-2}, LAI and dry matter accumulation than other lower levels of nitrogen application. Nitrogen due to having a role in production and translocation of cytokinin from the root to the shoots increases cell division rate and the growth of hybrid rice. The increase in leaf area index with increase in nitrogen levels might be due to increase in number of leaf and leaf development and also remaining functional over long period. Verma et al. (2008); Gautam et al. (2008) also observed that with increase in nitrogen fertilizer levels, LAI values of hybrid rice were raised. A strong positive correlation was observed between grain yield and growth parameters of hybrid rice. The yield attributes, viz., panicles m^{-2}, panicle length, spikelets $panicle^{-1}$, filled grains $panicle^{-1}$ were significantly influenced by nitrogen fertilization 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 increased the grain yield steadily and significantly with increase in nitrogen levels. The maximum grain yield of 7, 169 kg ha^{-1} was recorded in crop receiving nitrogen at 180 kg ha^{-1}, whereas, no nitrogen fertilization produced the minimum grain yield of 5,399 kg ha^{-1} on pooled mean basis (Table 2). The increase in grain yield owing to nitrogen at 180 kg ha^{-1} over other lower levels of 120, 60 and 0 kg ha^{-1} fertilization were 2.20, 13.30 and 32.78%, respectively. As grain yield is primarily a function of cumulative effect of yield attributing characters along with efficient translocation of photosynthates from source to sink, the higher values of these attributes can be assigned as the most probable reason for significantly higher grain yield. It is well evinced from the positive correlation between crop DMA and nutrient uptake by the crop. Murthy

Table 3: Profitability and nitrogen-use-efficiencies of hybrid rice as influenced by date of transplanting and nitrogen fertilization (pooled data of 2 years)

Treatment	Net return (₹ ha^{-1})	Benefit: cost ratio	Agronomic efficiency (kg grain kg^{-1} N)	Apparent recovery efficiency (%)	Physiological efficiency (kg grain kg^{-1} N uptake)	Partial factor productivity (kg grain kg^{-1} N applied)	Nitrogen harvest index (%)
Date of transplanting							
6th July	47211	2.06	13.79	37.34	48.65	54.02	77.88
21st July	53192	2.19	15.34	36.32	41.64	57.29	77.74
5th August	42679	1.96	9.63	29.98	31.07	53.66	78.01
SEm±	515	0.01	0.73	2.02	8.65	0.55	0.20
CD (p=0.05)	1622	0.04	2.30	NS	NS	1.72	0.64
Nitrogen levels (kg ha^{-1})							
N_0	35408	1.84					80.31
N_{60}	46298	2.06	15.47	41.75	36.06	89.98	78.92
N_{120}	53995	2.19	13.46	34.78	40.82	44.99	77.05
N_{180}	55075	2.18	9.83	27.11	44.49	29.99	75.23
SEm±	570	0.01	0.50	1.50	5.22	0.18	0.28
CD (p=0.05)	1635	0.04	1.46	4.38	NS	0.52	0.81

et al. (2012); Uddin et al. (2013); Pradhan et al. (2014) also reported significant positive influence of nitrogen application on yield attributes and yield of hybrid rice.Straw yield was also recorded higher with increasing rates of N application. It might be due to improved biomass plant^{-1} at successive growth stages and increase in various morphological parameters like plant height, number of tillers etc.

3.2.2. Nutrient uptake

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^{-1}. Application of increasing levels of nitrogen up to 180 kg N ha^{-1} led to significant increase in uptake of NPK by grain and straw (Table 2). An increased uptake of nitrogen, phosphorus and potassium by crop 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 (Zaidi and Tripathi, 2007). The increase in phosphorus and potassium 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 Pasha et al. (2011) .

3.2.3. Nitrogen–use efficiency and profitability

Nitrogen fertilization beyond 60 kg N ha^{-1} level significantly reduced AE on hybrid rice on pooled mean basis (Table 3). Since grain yield response to applied N follows law of diminishing returns, a number of workers (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. Partial factor productivity of nitrogen (PFP) was markedly affected by nitrogen fertilization. There was strong negative relationship between PFP and nitrogen levels and a markedly successive reduction in PFP at higher levels of N application. The crop at the low nitrogen level (N_{60} kg ha^{-1}) recorded the highest value of PFP (89.98 kg grains kg^{-1} of nitrogen applied) and the crop at the high nitrogen level (N_{180} kg ha^{-1}) recorded the lowest value of PFP (29.99 grains kg^{-1} of nitrogen applied). The results noticed that though the crop fed with high nitrogen levels increased the grain yield but showed less efficient in recording PFP. These were in conformity with the findings of Sharma et al.(2007). Like AE, the ARE of applied N gradually decreased with increasing N rate with minimum values observed at 180 kg ha^{-1} and the maximum values were recorded at 60 kg N ha^{-1} (Table 3). 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^{-1}. Increase in N level from 0 to 180 kg ha^{-1} also fetched additional returns with a higher benefit: cost ratio over the control (Table 3), primarily owing to higher grain yield with comparatively lesser additional cost of N. The maximum net return (₹ 55,075 ha^{-1}) were obtained from the crop receiving nitrogen at 180 kg ha^{-1} while the highest benefit:cost ratio (2.19) was realized from crop receiving nitrogen fertilizer application of 120 kg ha^{-1} on pooled mean basis (Table 2). However, nitrogen fertilization applications of both 120 and 180 kg ha^{-1} were at par in realizing the maximum net return and benefit:cost ratio under study.

3.4. Interaction effect

Transplanting on 21st July along with 180 kg N ha^{-1} recorded significantly higher panicle m^{-2} over rest of the treatment combinations which was found at par with same date of transplanting along with 120 kg N ha^{-1} (Table 4a). It could be due to the fact that rice transplanted on 21st July with higher levels of N experienced more favourable temperature and high temperature coupled with more solar radiation interception as compared to late and early transplanted crops, i.e. more congenial thermo-periodism and photo-periodism and adequacy of nitrogen probably favoured the proper cellular activities during panicle formation and development, which led to increased number of effective panicle m^{-2}. Grain yield of rice was also significantly influenced by interaction effect of date of transplanting and nitrogen fertilization. The maximum grain yield ofrice was recorded from crop transplanted on 21st July along with 180 kg N ha^{-1} and but remained at par with 21st July transplanted crops along with 120 kg N ha^{-1} (Table 4b). This might be due to marked improvement in growth and yield attributes along with efficient translocation of photosynthates from source to sink.

Table 4a: Interaction effect between date of transplanting and nitrogen fertilization on panicles m^{-2} (pooled mean of 2 years)

	Nitrogen levels (kg ha^{-1})			
Date of transplanting	0	60	120	180
6th July	252	301	312	320
21st July	264	318	349	355
5th August	233	270	291	297
SEm±			3.4	
CD (p=0.05)			9.8	

Table 4b: Interaction effect between date of transplanting and nitrogen fertilization on grain yield (kg ha^{-1}) (pooled mean of 2 years)

	Nitrogen levels (kg ha^{-1})			
Date of Transplanting	0	60	120	180
6th July	5304	6301	7036	7156
21st July	5625	6807	7505	7542
5th August	5268	5872	6502	6807
SEm±			71	
CD (p=0.05)			203	

4. Conclusion

Planting of hybrid rice between 6th July and 21st along with 120 kg N ha^{-1} produced economically optimum growth and yield attributes, crop productivity, agronomic nitrogen use efficiency and return $rupee^{-1}$ investment on clay soils of shallow lowland rainfed conditions of Imphal Valley, Manipur, India.

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