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Research Paper

Productivity and profitability of rice (*Oryza sativa*) varieties as influenced by age of seedlings in north-eastern Himalayan region

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ABSTRACT

An experiment was conducted during *boro* (*rabi*) season of 2012–13 and 2013–14, at Gerua, Kamrup, Asom, India, to study the effect of different age of seedlings on growth and yield of rice (*Oryza sativa* L.) varieties. Ten treatment combinations of 2 different duration rice varieties, i.e. 'Chandrama' (175 days) and 'Naveen' (155 days), and 5 ages of seedlings (40, 50, 60, 70 and 80 days) were tested. 'Chandrama' rice recorded significantly higher grains/panicle and 1,000-seed weight as well as grain yield (5.93 and 6.50 t/ha) over 'Naveen' rice. Days to 50% flowering decreased with the increment in age of seedling by 2–10 days, whereas total maturity duration increased by 6–28 days. In case of age of seedlings, 40 and 50 days old seedlings showed higher values of growth and yield attributes that reflected in grain yield. There was gradual yield decrease with increment in the age of seedling due to reduced values of tillers/m^2, filled grains/panicle. The yield penalty was non-significant in case of long-duration rice variety 'Chandrama', while in case of 'Naveen', there was significant reduction in grain yield when seedling age exceeded beyond 60 days. 'Naveen' rice with 40 and 50 days old seedlings recorded significantly higher grain yield over 70 and 80 days seedlings respectively. Earlier farmers using their own local rice landraces which were long duration and less affected by age of seedling but with development of new semi-dwarf, medium-duration rice varieties need to be transplanted at optimum age of seedling. Thus, the age of seedling can be extended up to 60 days for those rice varieties having long duration (>175 days) while for short duration (<155 days), it should not be extended beyond 50 days.

Key words **:** North-eastern Himalayan region, Production efficiency, Productivity, Profitability, Rice, Seedling age

The net demand of rice is increasing to over 481.9 million tonnes by 2025 and 525 million tonnes by 2050 (Alias *et al*., 2016). Globally food security, livelihood improvement, cultural heritage and sustainable development for global peace are directly or indirectly depend on rice and rice-based cropping systems (FAO, 2001). India's food security largely depends on rice, as it contributes 41.5% to the total foodgrain production with 104.8 million tonnes production from 43.9 million ha (GoI 2016). In India, rice is traditionally grown throughout the year as 3 crops, viz. autumn rice/*ahu* (March–April to June–July), winter rice/*sali* (June–July to November–December) and summer/*boro* rice (November–December to May–June). Though *sali* is considered as the main rice crop but owing to higher productivity and expansion of irrigation facilities, *boro* rice cultivation has taken place in recent years in West Bengal, Bihar and Asom. The implementation of bringing Green Revolution to Eastern India (BGREI) and national food security mission (NFSM) programmes encouraged expansion of *boro* rice in these states. It is likely to expand further to more areas in West Bengal, Asom, parts of Eastern Uttar Pradesh, coastal areas of Odisha and Andhra Pradesh.

The farmers are habituated to transplant aged seedling ranging from 70 to 90 days during *boro* season in the region which might be due to their long-duration local varieties. However, modern semi-dwarf and medium-duration rice varieties with same age of seedling restricting them to harvest higher yield. As *Boro* rice is known for higher productivity (5–6 t/ha) in shallow lowland areas of Asom, where productivity has traditionally been very poor (< 1 t/ha) during the rainy (*kharif*) season (Singh, 2002). The

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productivity of *boro* rice under shallow lowland is very low (2.1 t/ha) in north-eastern states, being comparatively lower than that of the national average productivity of 3.2 t/ha (GoI, 2011). Khatun *et al*. (2002) identified the reasons for low yield of rice which include aged seedlings is one of the most important cause to reduce plant growth and yield attributes resulting low productivity. Bassi *et al*. (1994) also found that, seedlings age at transplanting was an important factor for uniform stand of rice and regulating its growth and yield. Tiller dynamics of the rice plant greatly depends on the age of seedlings at transplanting (Pasuquin *et al*., 2008). Generally, young seedlings are transplanted when they attain 2 to 3 phyllochrons of growth, as they start photosynthesis in light even at the age of 2-leaf stage (Jeyaraj and Anbumani, 2005). A significant decline in productive tillers/hill was recorded with delayed transplanting resulting in reduced grain yield (Prema, 2007). Crop establishment is an important issue with regard to changing climatic as well as genotype characteristics of improved lines, hybrids, varieties and new plant types, which might be required distinct management practices in the field. Keeping above points in view, a study was initiated with objectives to evaluate age of seedling for transplanting under north-eastern Himalayan conditions.

MATERIALS AND METHODS

The field experiment was carried out in *boro* season of rice during 2012–13 and 2013–14 at the Regional Rainfed Lowland Rice Research Station, ICAR-National Rice Research Institute, Gerua, Kamrup (26° 14' 59" N, 91° 33' 44" E, 49 m above mean sea-level), Asom. The experimental area is located under the subtropical monsoon climate, which is specialized by moderately high temperature and heavy rainfall during the rainy (*kharif*) season (April–September) and low rainfall with moderately low temperature during the winter (*rabi*) season (October–March). Soil of the experimental site was slightly acidic winter (*p*H 5.8), high in organic carbon (1.22%), available nitrogen (265 kg/ha), phosphorus (15.5 kg/ha) and potassium (245 kg/ha). Crop received 531.9 and 563.4 mm rainfall during both the years respectively.

The experiment was laid out in a split-plot design with 3 replications, having plot size 30 m^2. Two different maturity duration, high-yielding rice varieties 'Chandrama' (175 days) and 'Naveen' (150–155) were taken as main plot treatments and 5 seedling ages (40, 50, 60, 70, 80 days) considered as subplots treatments. Seedlings were transplanted at a spacing of 20 cm × 15 cm. Recommended dose of fertilizers i.e. 80 : 40 : 40 kg/ha of N : P_2O_5 : K_2O was applied as urea, diammonium phosphate and muriate of potash. Full dose of P_2O_5, one-third N and three-fourths of K_2O were applied basal at the time of transplanting. Remaining N was applied in 2 equal splits–at maximum tillering and panicle-initiation stage, one-fourth K_2O top-dressed at panicle initiation. All other agronomic practices were kept normal and uniform for all the treatments. The crop was harvested the second fortnights of May and the first fortnight of July during both the years.

A unit area (1 m^2) was selected and harvested to record effective tillers/m^2, panicle length, grains/panicle and 1,000-grain weight. Grain yield was recorded on the basis of net plot 5 m × 4 m and expressed in t/ha at 14% moisture. Production efficiency (kg/day/ha) was calculated by grain yield divided by total maturity duration. Economics and profitability of the treatments were derived by considering the minimum support price fixed by the government for paddy grain, and cost of cultivation was calculated with prevailing inputs cost in the region. Experimental data were analysed statistically using the F-test as per the standard procedure. LSD values at P = 0.05 were used to determine the significance of difference between treatment means.

RESULTS AND DISCUSSION

Growth and yield attributes

Younger seedlings took more days to come in 50% flowering than older ones; however, total duration to maturity was the highest with aged seedlings because aged seedlings remained for longer duration in the nursery (Table 1). Both varieties showed difference with respect to plant height; however, the age of seedling influenced the plant height significantly in 2013–14. It might be owing to better micro-climate and higher sunshine hours during 2013–14 where younger seedling performed better and produced taller plants than the aged seedlings. On the other hand, younger seedlings recorded more plant height than older seedlings. It might be because aged seedlings remained in the nursery for longer duration till it attained maximum tillering stage and transplanting at that, stage heavier root damage made plants unable to establish vigorously to absorbed sufficient nutrients for vegetative growth. Singh and Singh (1999) also reported similar findings that, transplanting of 30–40 days seedlings resulted in taller plants than that of 60 days seedlings at the time of maturity.

'Naveen' rice had significantly higher tillers during 2012–13, being at par to 'Chandrama' in 2013–14. However, age of seedlings, made significant differences in number of tillers. The maximum number of tillers was recorded with 40 days seedlings followed by 50 and 60 days seedlings. Seedlings of 40, 50, 60 days had significantly more productive tillers than that of 70 and 80 days seed-

lings during 2012–13; though only 40 days old seedling showed significantly more productive tillers in 2013–14. It is reported that transplanting of young seedlings had the potential to provide more productive tillers owing to better root growth (Veeramani, 2007).

'Chandrama' variety showed significantly higher values of grains/panicle and 1,000-grain weight than 'Naveen' variety during both the years (Table 2). Age of seedlings had significant impact on grains/panicle. Seedlings of 40 days produced significantly more grains/panicle than 80 days seedlings. Transplanting of younger seedlings exhibited higher values of yield attributes which might be owing to early and quick establishment and better root growth (Sahoo and Rout, 2004).

Productivity

'Chandrama' rice gave significantly higher grain and straw yields than 'Naveen' during both the years (Table 3). The maximum grain yield (5.75 and 6.39 t/ha) was recorded with 40 days old seedlings, followed by 50 days old ones (5.67 and 6.15 t/ha); whereas 80 days old seedlings had the lowest yield. Seedlings of 40 days resulted in 28.6% and 29.1% higher grain yield over the 80 days aged seedling during both the years. Transplanting of 40 days old seedlings recorded significantly higher straw yield over 80 days seedlings in 2013-–14. There was non-significant difference with respect to harvest index. Thus, the younger seedlings were better in terms of grain yield than that of aged seedlings. Transplanting of 30 days seedlings resulted significantly higher grain yield over 60 days seed-

Table 1. Effect of age of seedling on maturity duration and plant height of rice varieties

Treatment	Days to 50% flowering		Days to maturity		Plant height (cm)	
	2012–13	2013–14	2012–13	2013–14	2012–13	2013–14
Variety						
'Chandrama'	82	80	171	170	102.4	99.2
'Naveen'	67	65	157	156	100.7	100.0
SEm±	–	–	–	–	0.7	0.6
CD (P=0.05)	–	–	–	–	NS	NS
Age of seedling (days)						
40	80	78	150	148	98.6	101.4
50	78	76	158	156	101.6	100.0
60	74	73	165	162	103.0	100.3
70	71	71	171	172	104.3	98.4
80	70	68	178	176	100.2	97.8
SEm±	–	–	–	–	1.6	0.8
CD (P=0.05)	–	–	–	–	NS	2.4

NS, non-significant

Table 2. Effect of age of seedling on yield attributes of rice varieties

Treatment	Tillers (m^2)		Grains/panicle		Panicle length (cm)		1,000-grain weight (g)		Fertility (%)	
	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014
Variety										
'Chandrama'	310.0	320.2	162.1	171.1	22.7	24.4	21.2	21.7	78.2	75.4
'Naveen'	403.9	330.3	104.2	145.9	22.4	25.3	20.4	20.7	75.8	85.4
SEm±	6.7	8.6	1.4	1.7	0.19	0.3	0.08	0.10	0.4	0.49
CD (P=0.05)	40.5	NS	8.4	10.5	NS	NS	0.56	0.6	2.8	3.0
Age of seedling (days)										
40	394.4	346.0	140.3	177.9	23.5	25.9	20.9	21.1	81.8	79.3
50	390.0	341.8	133.8	166.6	22.9	24.9	20.9	21.0	78.8	80.3
60	366.6	321.5	135.5	158.3	22.7	24.8	20.7	21.3	76.1	80.4
70	317.8	314.0	130.5	149.0	22.1	24.5	20.7	21.5	72.3	81.2
80	315.3	303.0	125.7	140.7	21.5	24.2	20.7	21.0	76.0	80.5
SEm±	11.0	7.3	7.6	6.9	0.42	0.5	0.18	0.15	1.36	3.39
CD (P=0.05)	32.5	21.6	22.8	20.4	1.28	NS	NS	NS	4.09	NS

NS, non-significant

lings (Brar *et al*., 2012), whereas 45 days seedlings recorded the maximum yield (6.73 t/ha) and minimum (3.33 t/ha) with 75 days old seedlings during *boro* season (Khatun *et al*., 2002). Singh *et al*. (2012) also reported gradual reduction grain and biological yields with increasing the seedling age.

The negative linear correlation and determination coefcients between age of seedling and grain yield were recorded for both the varieties (Fig. 1). The short-duration 'Naveen' variety recorded higher negative linear correlation and determination coefcients which was statistically signicant (P = 0.05) and equal to R^2 = 0.839 during 2012–13. However, long-duration 'Chandrama' recorded lower negative linear correlation and determination coeffcients than 'Naveen' during both the years. The interaction between varieties and age of seedlings was found significant for grain yield during 2012–13 (Table 4). 'Naveen' variety with 40, 50, and 60 days seedlings showed significantly higher grain yield than of 80 days old seedlings. The interactive results of both varieties with age of seedling showed that age of seedling is more important for short-duration varieties than that of longer-duration ones. It was found that there was more penalty on grain yield with increasing age of seedling for short-duration variety 'Naveen' as compared to 'Chandrama'.

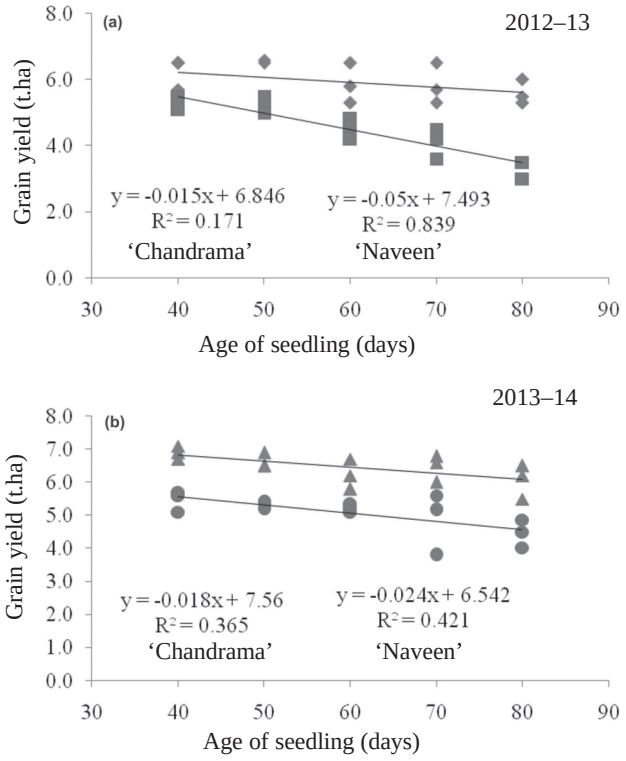

Fig. 1. Relationship between grain yield and age of seedling in rice varieties; ['Chandrama' (▲); 'Naveen' (•)]

Production efficiency and economics

Among the age of seedlings, transplanting at 40 days old seedling showed the maximum production efficiency, followed by 50 days old seedlings. There was a gradual reduction in production efficiency with increase in age of seedling, indicating that younger seedlings should be preferred over aged seedlings.

'Chandrama' rice with 40 days seedlings recorded the highest net returns and benefit: cost (B:C) ratio. Among the age of seedlings, the maximum net returns and B:C ratios were recorded with 40 days old ones, followed by 50 days old seedling. However, the minimum net returns and B:C ratios were obtained with traditionally 80 days old seedlings during both the years. Singh and Singh (1999) also reported recorded the maximum gross returns and

Table 3. Effect of age of seedling on productivity, production efficiency, net returns and benefit: cost (B:C) of rice varieties

Treatment	Grain yield (t/ha)		Straw yield (t/ha)		Harvest index		Production efficiency (kg/day/ha)		Net return (× 10^3₹/ha)		Benefit: cost ratio	
	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014
Variety												
'Chandrama'	5.93	6.43	6.60	6.92	0.47	0.48	34.7	36.79	34.2	47.3	1.74	2.00
'Naveen'	4.49	5.10	4.83	5.83	0.48	0.47	28.5	31.92	14.4	28.1	1.31	1.60
SEm±	0.12	0.11	0.15	0.10	0.003	0.002	–	–	–	–	–	–
CD (P=0.05)	0.72	0.68	0.88	0.64	NS	NS	–	–	–	–	–	–
Age of seedling (days)												
40	5.75	6.39	6.33	6.76	0.48	0.49	38.3	43.18	31.5	46.7	1.68	1.99
50	5.67	6.15	6.05	6.51	0.49	0.49	36.0	39.42	30.3	43.2	1.65	1.92
60	5.20	5.79	5.75	6.57	0.48	0.47	31.5	35.82	24.3	38.0	1.52	1.81
70	4.97	5.56	5.48	6.28	0.48	0.47	29.1	32.52	21.1	35.0	1.45	1.74
80	4.47	4.93	4.95	5.76	0.48	0.46	25.2	27.47	14.5	26.2	1.31	1.55
SEm±	0.16	0.18	0.31	0.19	0.01	0.01	–	–	–	–	–	–
CD (P=0.05)	0.49	0.52	NS	0.56	NS	NS	–	–	–	–	–	–

NS, non-significant

Table 4. Interactive effect of varieties and age of seedling on grain yield

Variety	Age of seedling (days)									
	40		50		60		70		80	
	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014
'Chandrama'	6.23	7.10	6.10	6.90	5.87	6.47	5.83	6.27	5.60	5.40
'Naveen'	5.27	5.68	5.23	5.40	4.53	5.11	4.10	4.86	3.33	4.46
			CD (P=0.05)					SEm±		
			2013	*2014*				*2013*	*2014*	
Variety			0.72	0.69				0.12	0.11	
Age of seedling			0.49	0.52				0.16	0.18	
Interaction			0.69	NS				0.23	0.25	

NS, non-significant.

B:C ratios with 45 days old seedlings and the minimum with 60 days old ones during the winter season.

Based on the 2 years study, it was found that semi-dwarf, high-yielding rice varieties with young seedlings of 40 to 50 days resulted in better plant growth, yield attributes, productivity and profitability. The results of present experiment also indicated that age of seedling for longer duration varieties like 'Chandrama' may be extended up to 60 days; however, for shorter duration like 'Naveen' it should not be extended beyond 50 days during *boro* season.

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