Oryza Vol. 51 No.3, 2014 (213-218)

Seeding density, seedling age and nutrient management for wet season rice production

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ABSTRACT

In Eastern India delayed onset and weak start of monsoon often mismatch the accumulated rainfall for puddling and optimum seedling age of rice. A field experiment comprising of recommended practice (seeding density - 50 g m^{-2} i.e. 50 kg ha^{-1} seed rate) of rice cultivation alongwith twelve other treatments of improved seedlings (seeding density - 10 g m^{-2} i.e. 10 kg ha^{-1} seed rate, high organic matter, high phosphate along with Zn and B application in nursery) transplanted at 25, 35, 45 and 55 days after sowing alongwith 100%, 75% and 50% recommended dose of fertilizer (RDF i.e. $N:P_2O_5:K_2O$ @ 80:40:40 kg ha^{-1}) was conducted during season of 2009 and 2010. Higher plant height, tillers $plant^{-1}$ and seedling dry weight were observed by the use of improved seedlings. Twenty five days old improved seedlings along with 100% RDF recorded maximum grain yield (6.00 t ha^{-1}) and net return (Rs.38,925 ha^{-1}). 25, 35 and 45 days old improved seedlings alongwith 100% RDF recorded 18%, 10% and 2% higher rice grain yield respectively than recommended practice (5.07 t ha^{-1}). Whereas 55 days old improved seedlings alongwith 75% and 100% RDF did not show significant difference with recommended practice. Thus improved seedlings provide an additional one moth time for transplanting without significant yield reduction and this practice may be termed as system of assured rice production (SARP).

Key words: *delayed monsoon, rice production, nursery, seeding density, age*

The wet season rice cultivation in Eastern India primarily depends on monsoon rainfall and face serious challenges due to monsoon vagaries (Anonymous, 2011). During the recent past monsoon rainfall has become uncertain and erratic, frequently delayed, followed by prolonged mid season break and shifted towards October (Guhathakurata and Rajeevan, 2008; Attri and Tyagi, 2010 and Samanta *et al.*, 2012). Rice transplanting requires a minimum 200 mm accumulated rainfall for puddling operation (De Datta, 1981). Very often farmers are compelled to retain their seedlings in the nursery, even after optimum age, until good amount of water is available. Older seedlings record very poor production and sometimes cultivation is abandoned due to damage of very old seedlings. Although a number of rice production technologies available to farmers, none of them can give assurance for successful rice cultivation under delayed monsoon condition. So, the development of a new rice production technology or refinement of the existing technologies to meet the challenges of delayed onset of monsoon is urgently needed.

In majority of rice cultivated area in India, the production system involves two distinct phases *viz.* nursery and main-field, which demand different inputs and management options. The nursery area is far less (around $1/10^{th}$) than the main-field. Under deficit rainfall condition with the help of limited irrigation water, farmers prepare rice nursery and maintain it till sufficient rainfall for transplanting is received. So, adequate nursery management is prerequisite, which can provide a great deal of flexibility with respect to seedling age and rainfall without any significant yield loss to meet the challenges of monsoon uncertainties. This makes the nursery management even more critical than main-field operations for assured wet season rice cultivation. This paper highlights how one month extension of nursery life of rice can be achieved by modifying nursery seeding density and nutrient management without any significant yield loss so that farmers can wait for an additional one month in case monsoon rainfall is delayed. Thus, this modified rice production technology will address the issues of delayed and uncertain monsoon. So it may be termed old as system for assured rice production (SARP).

In the traditional practice 50-60 kg seed of is sown in 1000 m^2 nursery area and 20-30 days seedlings are transplanted in 1 ha main-field, where 3-4 seedlings are transplanted in one hill. Due to higher seeding density, intra-seedling competition increases resulting in tall, lanky, seedlings with poor vigour without any tiller (Nayak and Patra, 2000 and Singh *et al.*, 2013). Better seedling vigour can be achieved with low nursery seeding density along with better nutrient management. Vigorous seedlings recorded significantly higher yield (Hari Om, 1996 and Naeem *et al.*, 2011). In single seedling transplanting 8-10 kg healthy seeds are required to cover one hectare of main-field (Balasubramanian *et al.*, 2005). Low nursery seeding density provides more space and nutrients, where seedlings are maintained with less competition for longer period even after tillering. Phosphorus plays a vital role for rice root development and higher P nutrition increases root dry weight and ultimate yield (Rose *et al.*, 2010). The present investigation was carried out with the objective to develop a system for assured rice production (SARP) with the modification of nursery seeding density, nursery management, seedling age and fertilizer management in main field.

MATERIALS AND METHODS

The experiment was conducted at Ranaghat, Nadia, West Bengal, India. Soil of the experimental site was characterized as sandy loam with pH 7.69, organic carbon 5.9 g kg^{-1}, total N 127.8 kg ha^{-1}, available P_2O_5 22.2 kg ha^{-1} , K_2O 145.0 kg ha^{-1} , Zn 0.005 kg ha^{-1} and B 0.03 kg ha^{-1}.

The experiment was conducted during wet season of 2009 and 2010 with altogether thirteen treatments. Twelve treatments comprised of modified seedlings (improved seedlings) produced with special nursery management and another one consisted of recommended seedlings (RS). Improved seedlings (IS) of four different ages *viz.* 25, 35, 45, 55 days after sowing (DAS) were transplanted in the main field in combination with three levels of fertilizers *viz.* 100%, 75% and 50% of recommended dose of fertilizers (RDF i.e. N:P_2O_5:K_2O @ 80:40:40 kg ha^{-1}), whereas 30 days recommended seedlings were supplied with 100% recommended dose of fertilizers in the main field. Thus the thirteen treatments were - T_1: IS transplanted 25 DAS with 100% RDF; T_2: IS transplanted 25 DAS with 75% RDF; T_3: IS transplanted 25 DAS with 50% RDF; T_4: IS transplanted 35 DAS with 100% RDF; T_5: IS transplanted 35 DAS with 75% RDF; T_6: IS transplanted 35 DAS with 50% RDF; T_7: IS transplanted 45 DAS with 100% RDF; T_8: IS transplanted 45 DAS with 75% RDF; T_9: IS transplanted 45 DAS with 50% RDF; T_{10}: IS transplanted 55 DAS with 100% RDF: T_{11}: IS transplanted 55 DAS with 75% RDF; T_{12}: IS transplanted 55 DAS with 50% RDF and T_{13}: RS transplanted with 100%RDF. The experiment was laid out in randomized block design with three replications. The rice variety MTU-7029 (145 days duration) was used for experimental purpose.

Basal dose of 2.5:10:5 g m^{-2} (N:P_2O_5:K_2O) alongwith 2.5 Kg m^{-2} organic matter, 0.5 g m^{-2} Zn and 0.11 g m^{-2} B was applied during preparation of improved wet nursery. Whereas, in recommended wet nursery a basal dose of 2.5:5:5 g m^{-2} (N:P_2O_5:K_2O) alongwith 0.5 g m^{-2} Zn and 0.11 g m^{-2} B were applied. Then sprouted healthy seeds @ 10 g m^{-2} and 50 g m^{-2} were spread over beds of improved and recommended nursery respectively. In both the cases (recommended and improved) the ratio of nursery area and main field remained same (1:10). Thus, 10 kg ha^{-1} and 50 kg ha^{-1} (state recommendation) seeds were allotted for improved and recommended practice respectively. In improved nursery N was top dressed @ 2.5 g m^{-2} at 15 days interval, whereas in recommended nursery one top dressing of N @ 2.5 g m^{-2} at 15 DAS was done. Both the types of nurseries were maintained totally weed free throughout the growth period by hand weeding alongwith a thin film of water.

The full dose of phosphorus and potash were applied as basal for all the treatments. In improved seedlings nitrogenous fertilizer was applied as 1/4 -1/2-1/4 as basal - 40 DAS - 80 DAS, basal - 50 DAS - 80

DAS, basal - 50 DAS - 80 DAS and basal - 60 DAS - 80 DAS respectively for 25, 35, 45 and 55 days seedlings. In case of recommended seedlings full dose of nitrogen was applied in similar way of 35 days improved seedlings. Seedlings raised in recommended nursery were transplanted 3-4 seedlings hill^{-1} with 20 cm X 15 cm spacing, whereas, seedlings from improved nursery were transplanted 1 seedling hill^{-1} alongwith its tillers with same spacing.

Observations like, seedling height, number of tillers plant^{-1}, 10 seedlings dry weight at 25, 30, 35, 40, 45, 50 and 55 DAS was taken from nursery. Grain yield, straw yield and yield attributing characters were recorded at harvest during both the years. Economics was computed using the prices of inputs and outputs as per prevailing market rate. The rate of paddy seed, urea, 10:26:26 (N:P:K) fertilizer were purchased at the rate Rs.15.00, 5.50, 9.00 per kg respectively. The farm gate price for paddy grain and straw were Rs.11.00 and 0.50 per kg respectively. The data generated for both the growing seasons were pooled together and analyzed statistically. Statistical analyses were performed using analysis of variance (ANOVA) for randomized block design (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Nursery management significantly influenced the growth of rice seedlings (Table 1). The improved seedlings recorded higher plant height at 25 DAS (27.65 cm) and 30 DAS (35.20 cm) than recommended seedlings (23.45 cm and 28.65 cm at 25 and 30 DAS respectively). Though the improved seedlings attained maximum height at 55 DAS (50.55 cm), but maximum rate of increase was observed during 30 DAS to 35 DAS (1.4 cm day^{-1}). The recommended seedlings recorded 1.05 and 1.15 number of tillers at 25 and 30 DAS respectively whereas the improved seedlings recorded 3.10 and 3.75 number of tillers at 25 and 30 DAS respectively. Increase in number of tillers in nursery continued with increase in age but the rate of increase was not uniform. Observed data indicates that tillering rate for improved seedlings at early stage (25-30 DAS) was 0.13 per day which was sharply declined after 45 DAS (0.03-0.04 per day). At 25 as well as 30 DAS improved seedlings recorded higher dry weight than recommended seedlings. These values were 100% and 136% respectively at 25 and 35 DAS. The highest seedling dry weight was observed at 55 DAS followed by 50, 45, 40, 35, 30 and 25 DAS. But, maximum rate of increase was recorded during 35 DAS to 40 DAS (1.11 g per day per 10 seedlings). The rate of increase in height, number tillers and also in dry weight were found to be declined sharply after 45 DAS. These may be due to the fact that with the increase in age in nursery the competition for space, water, nutrients etc. increases and the seedlings fail to maintain their normal growth. The seedlings in recommended nursery feel these completions more intensely than improved nursery. The higher competition in recommended nursery was primarily due to higher seeding density in recommended nursery than improved nursery. Rose *et al.* (2003) recorded higher plant height and increased shoot and root dry weight with nursery nutrient application. Our results confirm the findings of Sarwa *et al.* (2011), who reported higher seedling vigor with low seed rate.

Table 1. Effect of nursery management on seedling growth at different days after sowing (pooled of 2009 and 2010)

Treatments	Seedling height (cm)	Tillers plant^{-1}	10 seedlings dry weight (g)
25(IS)	27.65	3.10	3.10
25(RS)	23.45	1.05	1.55
30(IS)	35.20	3.75	4.85
30(RS)	28.65	1.15	2.05
35(IS)	42.20	4.20	6.10
40(IS)	43.35	4.90	11.65
45(IS)	49.20	5.35	14.75
50(IS)	50.00	5.55	15.50
55(IS)	50.55	5.70	16.00

DAS- days after sowing, IS- Improved seedling, RS- Recommended seedling

Nursery management, seedling age and fertilizer level significantly influenced the yield attributes of rice (Table 2). Significantly higher numbers of panicles were observed with improved seedlings transplanted at 25 DAS along with 100% RDF in main-field i.e. T_1 treatment which was found at par with T_2, T_4, T_5, T_6, T_7, T_8 and T_{10} treatment. In general seedlings transplanted at early stage produced higher number of panicles plant^{-1}. But seedlings experienced better environment in nursery can produce sufficient numbers of effective tillers even when transplanted late (may be of 55 days old) and received optimum nutrient (NPK). When seedlings are

Table 2. Effect of seeding density, nursery management, seedling age and fertilizer level on yield and yield attributes (pooled of 2009 and 2010)

Treatment	Panicles m^{-2}	Filled grains $panicles^{-1}$	Test wt(g)	Grain Yield t ha^{-1}
T_1	271.23[a]	132.50[a]	20.06	6.00[a]
T_2	250.36[abc]	131.50[a]	20.11	5.51[abc]
T_3	244.63[bcd]	129.00[a]	20.10	5.29[bcd]
T_4	267.11[ab]	125.00[abc]	20.10	5.59[ab]
T_5	270.23[a]	120.00[abc]	20.11	5.42[bc]
T_6	252.28[abc]	120.00[abc]	20.10	5.06[bcde]
T_7	254.77[abc]	122.00[abc]	20.00	5.19[bcd]
T_8	259.28[abc]	115.00[bc]	20.10	4.99[cde]
T_9	239.00[cd]	115.00[bc]	20.06	4.59[ef]
T_{10}	249.89[abc]	116.00[bc]	20.15	4.86[de]
T_{11}	238.78[cd]	115.00[bc]	20.00	4.59[ef]
T_{12}	222.88[d]	114.00[c]	20.06	4.25[f]
T_{13}	240.57[cd]	127.00[ab]	20.00	5.08[bcde]
CD (P=0.05)	25.34	12.4	NS	0.53

N.B.Similar letters indicates no significant differences among the treatments

T_1: Improved seedling (IS) transplanted 25 DAS with 100% recommended dose of fertilizer (RDF); T_2: IS transplanted 25 DAS with 75% RDF; T_3: IS transplanted 25 DAS with 50% RDF; T_4: IS transplanted 35 DAS with 100% RDF; T_5: IS transplanted 35 DAS with 75% RDF; T_6: IS transplanted 35 DAS with 50% RDF; T_7: IS transplanted 45 DAS with 100% RDF; T_8: IS transplanted 45 DAS with 75% RDF; T_9: IS transplanted 45 DAS with 50% RDF; T_{10}: IS transplanted 55 DAS with 100% RDF: T_{11}: IS transplanted 55 DAS with 75% RDF; T_{12}: IS transplanted 55 DAS with 50% RDF and T_{13}: RS transplanted with 100%RDF.

transplanted at a younger age before entering reproductive stage produce higher phyllocrone and avoid transplanting shock. Mishra and Salokhe (2008) reported a higher number of productive tillers after transplanting of younger seedlings. Improved seedlings along with 100% RDF transplanted at 25 DAS, 35 DAS, 45 DAS and 55 DAS recorded 12.75%, 11.03%, 5.90% and 3.87% higher panicles respectively than recommended practice. Though the maximum number of grains per panicle was recorded in T_1 (132.50 grains per panicle) but this treatment was found at par with T_2, T_3, T_4, T_5, T_6, T_7 and T_{13}. Forty five days old improved seedlings with 100% RDF did not show any significant variation with recommended cultivation practice (T_{13}) and even with improved seedlings of 25 DAS received 100% RDF regarding number of grains per panicle. However, older seedlings (55 days old) produced significantly less number of grains per panicle under any fertilizer dose (even at 100% RDF). Observed data also shows that transplanting of improved seedlings upto 45 DAS receiveing any level of fertilizer found superior or at par with recommended method with regard to panicle number or filled grains $panicle^{-1}$. Even the 55 days old seedlings received 100% RDF in main field did not show any significant difference with recommended package of practice. This may be attributed to the fact that nursery management had a significant effect on the number of fertile tillers. Higher numbers of fertile tillers were recorded when improved seedlings are transplanted. Vigorous seedlings produced by better nursery management are more tolerant to the transplanting shock and showed a better stand with more profuse tillering. Panda *et al.* (1991) reported that application of N fertilizer in nursery produced more panicle and two to five-time higher grain yield. Sarwa *et al.* (2011) also reported that nursery management had a significant effect on the number of fertile tillers and maximum tillers were recorded by transplanting fertile seedlings grown with lower seed rate. The finding of this experiment is supported by Patra *et al.* 2013. No significant treatment difference was observed regarding test weight.

Seedling age and fertlizer level significantly influenced the grain yield (Table 2). The maximum grain yield was recorded by transplanting 25 days improved seedlings along with 100% RDF in main-field (6.00 t ha^{-1}), followed by 35 days improved seedlings along with 100% RDF (5.59 t ha^{-1}) and 25 days improved seedlings along with 75% RDF (5.51 t ha^{-1}). The lowest grain yield was recorded in 55 days improved seedlings along with 50% RDF in the main-field. Transplanting of younger seedlings caused early and higher tiller production which ultimately increased the rice grain yield (Pasoquin *et al.*, 2008). Observed data also indicated that except 55 days improved seedlings with 50% RDF in the main-field, all the treatments of improved seedlings recorded at par or significantly higher yield than the recommended practice. Less intra-seedling competition for space and nutrients in improved nursery due to low seeding density and higher supply of nutrients resulted in vigorous growth, which ultimately resulted in higher grain yield. Our results are in agreement with Mishra and Salokhe (2008) and Sarwa *et al.* (2011), who observed that the fertilizer application at the nursery stage and low seeding density is a crucial factor in increasing seedling vigor. Farooq *et al.* (2007) also observed an increasing trend in plant height after transplanting improved seedlings. Transplanting of improved seedlings up to 45 days along with 100% RDF in main-field showed 115 to 925 kg ha^{-1} higher yield than the recommended practice. Possibly a positive effect was exerted on the development of source and sink strength of the plants when optimum levels of nutrients were applied, which ultimately improves the yield attributing traits. Optimum nutrient dose might have influenced different metabolic process in positive direction. Nutrient particularly nitrogen is a very important constituent of cell and plays a major role in the production of protein. Higher dose of nitrogen lead to more shoot growth and chlorophyll synthesis, ultimately increasing the yield (Shangguan *et al.*, 2000). P is responsible for better root development and subsequent absorption of N, whereas K is involved in N metabolism in cereals as well as imparts resistance to pest and disease and helps to escape the plants from other abiotic stresses (Perrenoud, 1990). Prasad *et al.* (2004), Ghosh *et al.* (2004) and Jat *et al.* (2011) have also reported balanced NPK application is essential to achieve the target yield.

Early transplanting (25 days and 35 days) incurred higher cost of cultivation due to higher level of irrigation and weeding. The expenditure for fertilizer was less in the treatments where 75% and 50% RDF were used. However, maximum net return (` 38,925/-) was recorded in the 25 days improved seedling grown with 100% RDF, followed by 55 days improved seedling with 100% RDF (37,200/-) and 45 days improved seedling with 100% RDF (36,950/-) due to higher grain yield. Except 35 days old improved seedlings transplanting of improved seedling always recorded higher profit than recommended practice. It was also found that improved seedlings always recorded better B:C ratio than recommended practice (Table 3).

Table 3. Economics of rice cultivation under different management practices of seedling and nutrient management (pooled of 2009 and 2010)

Treatment	Cost of cultivation (`)	Net return (`)	B:C ratio
T_1	39825	38925	1.98
T_2	39825	33988	1.87
T_3	39263	32350	1.84
T_4	38700	35025	1.90
T_5	38775	33938	1.89
T_6	38213	30100	1.80
T_7	37650	36950	2.12
T_8	33000	35313	2.09
T_9	32438	31475	1.99
T_{10}	31875	37200	2.31
T_{11}	28350	35563	2.28
T_{12}	27788	31725	2.17
T_{13} (con)	27225	30125	1.79

Input prices of paddy seed-Rs.15.00 per kg, urea-Rs.5.50 per kg, 10:26:26 (N:P:K)-Rs.9.00 per kg, Mandays-Rs.80.00 per manday. Output prices- paddy grain Rs.11.00 per kg and straw Rs.0.50 per kg.

T_1: Improved seedling (IS) transplanted 25 DAS with 100% recommended dose of fertilizer (RDF); T_2: IS transplanted 25 DAS with 75% RDF; T_3: IS transplanted 25 DAS with 50% RDF; T_4: IS transplanted 35 DAS with 100% RDF; T_5: IS transplanted 35 DAS with 75% RDF; T_6: IS transplanted 35 DAS with 50% RDF; T_7: IS transplanted 45 DAS with 100% RDF; T_8: IS transplanted 45 DAS with 75% RDF; T_9: IS transplanted 45 DAS with 50% RDF; T_{10}: IS transplanted 55 DAS with 100% RDF: T_{11}: IS transplanted 55 DAS with 75% RDF; T_{12}: IS transplanted 55 DAS with 50% RDF and T_{13}: RS transplanted with 100%RDF.

The present study indicates that lower seed rate alongwith high phosphate and high organic matter in wet nursery produces vigorous seedlings. If limited irrigation is available to irrigate the nursery, the vigorous seedlings can be maintained for a longer period (55 DAS) till sufficient rainfall for puddling is available, which does not reduce the rice yield significantly. Production of this type of improved seedlings provide a unique flexibility for transplanting age of seedlings i.e. during favourable early monsoon transplanting of younger seedlings can produce significantly higher rice yield, whereas, under late onset of monsoon older seedlings which otherwise are not suitable for transplanting, can produce satisfactory yield. Thus the development of such improved seedlings may reduce the risk of crop failure due to delayed onset of monsoon, so it may be termed as 'System of Assured Rice Production' (SARP) during wet season under rainfed condition. Moreover, seed requirement can be brought down to $1/5^{th}$, which will ensure quality seed supply to all the farmers. Cost of irrigation and weeding can also be minimized by adopting this type of nursery management.

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