ISA/2016(12)/208

Indian Journal of Agronomy **63** (1): 55–59 (March 2018)

Research Paper

Influence of seeding density on seedling growth, productivity and profitability of rice (*Oryza sativa*) under rainfed lowland

TEEKAM SINGH[1], B.S. SATAPATHY[2] AND K.B. PUN[3]

Regional Rainfed Lowland Rice Research Station, ICAR-National Rice Research Institute, Gerua, Kamrup, Asom 781 102

Received : December 2016; Revised accepted : January 2018

ABSTRACT

A field experiment was conducted during the rainy seasons of 2012 and 2013 at Gerua, Asom, to evaluate the effect of seeding density on growth parameters, productivity and profitability of rice (*Oryza sativa* L.). The lowest seeding density (40 g/m^2) proved superior the higher density in respect of seedling height, number of leaves, dry-matter accumulation, crop growth rate (CGR), and relative growth rate (RGR). However, there was gradual reduction in growth and yield parameters and yield with increasing density from 40 to 160 g/m^2. The maximum values of effective tillers/m^2, filled grains/panicle and grain yield were recorded with 40 g/m^2 followed by 60 g/m^2, which were found significantly superior to 140 and 160 g/m^2 density. Seeding density of 40, 60 and 80 g/m^2 resulted in 32.5, 27.4 and 20.5% higher grain yield than 160 g/m^2 seeding density. Among the densities, the highest net returns and benefit: cost ratio were recorded with 40 g/m^2, which was closely followed by 60 g/m^2 density.

Key words : Growth indices, Rice, Rainfed lowland, Seeding density, Yield

Rice is the major foodgrain crop of India, and to meet the demand of increasing population, by 2050 India will need 137.3 million tonnes (mt) of rice annually (CRRI, 2013) as against a production of 106.3 mt in 2013–14 (GoI, 2014). Thus, an additional of 31 mt of rice is required and to be produced from the same or even less cultivated area with decreasing availability of inputs like fertilizers, pesticides, water etc., and shortage of land and water for rice cultivation (Khush, 2005). Keeping growth rate of rice production, India will be able to produce sufficient rice but a plateauing or even a negative yield trend has been reported in rice–wheat cropping system (Prasad, 2005). More than 50% of the rice cultivated in India is under rainfed conditions, of which 65, 27 and 8% is under lowland, upland and flood-prone conditions, respectively. The productivity of rice under rainfed lowland and upland situations is very low (less than 2 t/ha) which is comparatively lower than that of the national average. There are several factors responsible for low productivity of rice including poor crop management practices under rainfed conditions.

Rice production technology has variability in performance at farmer's field due to poor crop management practices. Farmers have been seen to raise rice nursery with very high seed rate in flat seed beds without any application of fertilizers. This variation is often exhibited by the failure to establish a good crop stand with uniform growth of seedlings. The success of transplanted rice cultivation depends on the seedling. Among the different components of nursery management, adequate nutrition, better seeding densities and transplanting seedlings at the appropriate age are important factors to obtain vigorous plant stand (Lal and Roy, 1996; Kewat *et al*., 2002). Healthy seedlings provide rapid and uniform crop establishment and reduce mortality rate after transplanting. Yield and yield components of rice crop are negatively affected by using a higher seeding density at the nursery level, while yield increased when a lower seeding density rate is used in nursery (Bond *et al*., 2005; Sarwar *et al*., 2011; Adhikari *et al.* 2013). Since information is meager on the influence of seeding density in nursery bed on vigourness of seedlings and consequent impact on plant growth and productivity of rice, the present study was carried out to study these aspects under rainfed lowland situations.

[1]**Corresponding author's Email**: tiku_agron@yahoo.co.in
*Senior Scientist, Division of Agronomy, ICAR-IARI, New Delhi, [2]Scientist, ICAR-National Rice Research Institute, Cuttack, [3]Principal Scientist, Division of Plant Pathology, ICAR-IARI, New Delhi

MATERIALS AND METHODS

A field experiment was carried out during the rainy seasons of 2012 and 2013 at Regional Rainfed Lowland Rice Research Station, ICAR-National Rice Research Institute, Gerua, (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). Thus, rice crop is naturally adapted suitable crop during rainy (*kharif*) season. Soil of the experimental site was slightly acidic (*p*H 6.1), high in organic carbon (1.22%), available nitrogen (272 kg/ha), phosphorus (16.5 kg/ha) and potassium (236 kg/ha). The weather data showed that rainfall distribution was more erratic and higher during 2012 than that of in 2013 (Fig. 1). Crop received 1,329 and 537 mm rainfall during both the years respectively. Average bright sunshine hours were 5.1 and 5.8 hours, and monthly evaporation was 115.5 and 112.1 mm during 2012 and 2013, respectively.

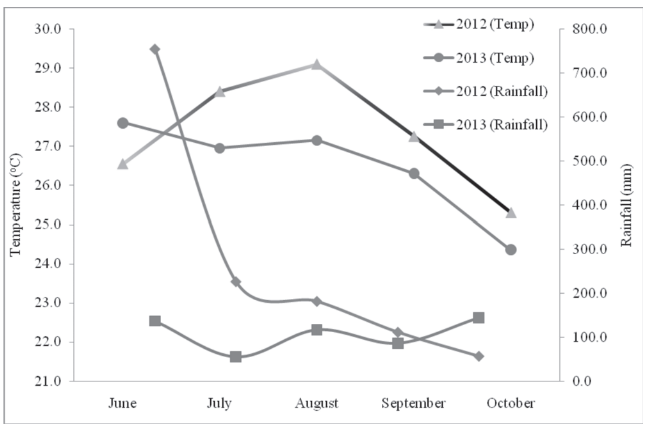

Fig. 1. Meteorological data recorded during crop growth period of 2012 and 2013

Seven seeding densities were evaluated, viz. 40, 60, 80, 100, 120, 140, 160 g/m^2. High-yielding rice variety 'Chandrama' (140 days duration) was used for nursery raising with the wet method. Land was prepared with 2 to 3 cross-ploughings, followed by 2 laddering before raising nursery. Seven nursery beds, one for each treatment, were raised and each seeding density replicated thrice. The seeds were uniformly sown in the wet nursery beds in the first week of June during both the years. Random sampling of 10 representative seedlings from each plot was taken at 10 days interval to evaluate seedling height, root length, number of leaves/seedling, seedlings and roots dry and fresh weight. The dry weight of seedlings and roots biomass were recorded after drying in an electric oven at 65 ± 2 ºC temperature till constant weight recorded. Crop growth rate (CGR), relative growth rate (RGR) and other seedling vigour indices were calculated on the basis of dry-matter accumulation by using following formulae.

$$\text{Crop growth rate (CGR)} = \frac{(W_2 - W_1)}{(t_2 - t_1)} = \text{g/seedling/day}$$

where W_1=weight of dry-matter/seedling at time t_1; W_2= weight of dry-matter/seedling at time t_2.

$$\text{Relative growth rate (RGR)} = \frac{(\text{In } W_2 - \text{In } W_1)}{(t_2 - t_1)} = \text{g/g/day}$$

where W_1= weight of dry-matter/seedling at time t_1; W_2= weight of dry-matter/seedling at time t_2 and I_n = Natural logarithm.

After measuring seedling length (shoot and root) and dry-matter accumulation, seedling vigour indices were calculated by using following formulas (Ashkan and Jalal, 2013).

Seedling length vigor index (SLVI)
= (mean shoot length + mean root length) × GP

Seedling weight vigor index (SWVI) = mean seedling weight × GP

where GP is germination percentage.

Experiment in main field was laid out in randomized complete block design with 3 replications, having plot size 30 m^2. Seedlings of 30 days were transplanted at a spacing of 20 cm × 15 cm in the first week of July during both the years. Recommended dose of fertilizers, i.e. 60: 30: 30 kg/ha of N: P_2O_5: K_2O was applied as urea, diammonium phosphate and muraite of potash respectively. Full dose of P_2O_5, one-third of N and three-fourths of K_2O were applied basal at the time of transplanting. Remaining N was applied in 2 equal splits–at the maximum tillering and panicle-initiation stage, one-fourth of K_2O was applied as top-dressing at panicle initiation. Rest agronomic practices were kept normal and uniform for all the treatments. The crop was harvested in the last week of October during both the years. A unit area (1 m^2) was selected and harvested to measure yield variables includes effective tillers/m^2, panicle length, grains/panicle, grain weight/panicle and 1,000-grain weight. Grain yield was recorded on the basis of net plot 5 m × 4 m harvested and threshed and expressed in t/ha at 14% moisture. The amount of seed required per hectare was calculated and the cost of seed was estimated based on their market price. The minimum support price of paddy (₹12,500 and ₹13,100/t in 2012–2013 and 2013–2014 respectively) was used to calculate economics and profitability of the treatments during the year of experimentation. Pooled means average data of 2 years were analyzed 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

Seedling characteristics

Seeding density significantly influenced the seedling fresh and dry weight, root length and root weight (Table 1). Seeding density of 40, 60, and 80 g/m^2 recorded significantly higher dry-matter accumulation over 140 and 160 g/m^2 seeding density at the time of transplanting. Similarly, root length and root dry-matter accumulation with the lowest seeding density (40 g/m^2) were significantly higher over the highest seeding density (160 g/m^2). The maximum values for seedling height, root and shoot dry matter, root length and number of leaves/seedling were recorded with the lowest seeding density. However, a decreasing trend in all the growth parameters was recorded with the increasing seeding density from. This might be owing to competition-free healthy and robust seedling from low seeding density. The maximum values of crop-growth rate (CGR), relative growth rate (RGR) and vigourness indices were recorded with 40g/m^2 seeding density (Table 2). A decreasing trend in CGR between 10 and 20 days was recorded with increasing seeding density but the differences remained non-significant. However, there was significant reduction in CGR between 20 and 30 days with increment in the seeding density. The maximum CGR between 20 and 30 days was recorded with 40 g/m^2 seeding density. The RGR remained statistically at par but decreasing trend was observed with increasing seeding density. Similarly, seedling vigourness indices (SLVI and SWVI) also exhibited a decreasing trend with the increasing seeding density. This might be due to more competition between seedlings for place, nutrient and light when grown at higher seeding rate during later seedling growth stages in the nursery. Seedlings raised from low seeding density in nursery produced robust and healthy seedlings with higher biomass, height, more leaves, long roots: high root to shoot ratio (Singh *et al*., 1997; Sarwa *et al.*, 2011; Gorgy, 2012). These results could be attributed to the fact that, the competition is less under low seeding rate in nursery which provides the adequate competition-free conditions to seedlings in nursery to grow well. In a study, Jayawardena *et al*. (2004) reported low inter-plant competition among the seedlings at 20 and 30 g/m^2 densities

Table 1. Effect of seeding density on growth and root characteristics of rice seedlings at the time of transplanting (average data of 2 years)

Seeding density (g/m^2)	Seedling fresh weight (g)	Seedling dry weight (g)	Root length (cm)	Root fresh weight (g)	Root dry weight (g)
40	1.27	0.62	13.37	0.77	0.54
60	1.12	0.56	12.17	0.67	0.43
80	1.06	0.54	12.30	0.60	0.39
100	1.04	0.52	11.13	0.62	0.39
120	1.04	0.51	10.22	0.60	0.37
140	0.89	0.45	10.45	0.48	0.36
160	0.83	0.43	10.42	0.48	0.33
SEm±	0.07	0.04	0.91	0.07	0.05
CD (P=0.05)	0.15	0.09	1.99	0.16	0.10

Table 2. Effect of seeding density on growth indices of rice seedlings (average data of 2 years)

Seeding density (g/m^2)	CGR (10–20)	CGR (20–30)	RGR (10–20)	RGR (20–30)	SLVI	SWVI
40	0.007	0.055	0.043	0.072	29.610	0.530
60	0.006	0.044	0.036	0.069	29.968	0.482
80	0.005	0.044	0.033	0.067	28.738	0.462
100	0.005	0.039	0.035	0.066	27.795	0.450
120	0.005	0.034	0.036	0.064	27.990	0.437
140	0.004	0.034	0.035	0.054	27.615	0.387
160	0.004	0.033	0.041	0.048	28.274	0.374
SEm±	0.001	0.006	0.008	0.008	–	–
CD (P=0.05)	NS	0.001	NS	NS	–	–

RGR, Relative growth rate (g/g/day); CGR, crop-growth rate (g/seeling/day); SLVI, seedling length vigour index; SWVI, seedling weight vigour index could be the reason for producing multi-tillered seedling at low seeding densities in nurseries. In this study, the maximum values for seedling height, root and shoot dry matter, root length, number of leaves/seedling, CGR, RGR and seedling vigour indices (SLVI and SWVI) were recorded with lowest seeding density 40 g/m^2 and thereafter, a decreasing trend in all the growth parameters was recorded with increasing seeding density from 40 to 160 g/m^2.

Growth, yield attributes, productivity and profitability

All the seeding density treatments did not affect the plant height significantly; however, a decreasing trend in plant height was observed with increasing seeding density from 40 to 160 g/m^2. The maximum plant height (108.9 cm) was obtained with the lowest seeding density. Among the yield components, number of productive tillers/m^2, filled grains/panicle and panicle length were highly affected by seeding density (Table 3). Seeding density of 40 and 60 g/m^2 were recorded significantly higher productive tillers/m^2, filled grains/panicle and long panicles over 140 and 160 g/m^2. The maximum effective tillers (389.2/m^2), filled grains/panicle (133.1), panicle length (22.4 cm) and 1,000 grain weight (22.42 g) were recorded with the lowest seeding density (40 g/m^2) and thereafter, decreasing trend was observed with increasing seeding density up to 160 g/m^2. Overall the seedlings obtained from lower seeding density resulted in higher values of yield attributes than that of higher seeding rate which might be due to robust and healthy seedling and less root damage, as healthy seedlings easily establish themselves after transplanting in the main field. Vigorous seedlings of rice obtained from lower seeding rate provide rapid and uniform crop establishment in the field which may be due to the decreased mortality rate after transplanting and produced higher yield and yield-attributing characters (Jayawardena *et al*., 2004; Gorgy, 2012). Singh *et al*. (1997) also investigated the reduction in number of panicles/hill and grains/panicle while using rice seedlings grown in a nursery using seeding rate of 20, 40, 60 and 80 g/m^2 were transplanted in permanent field using 1-3 seedlings/hill. Subedi (2013) reported significantly higher filled grains/panicle with lower seeding rate (100 g/m^2).

Grain and straw yields were significantly influenced by seeding density; the highest grain (5.2 t/ha) and straw yield (5.8 t/ha) were obtained in the minimum seeding density (40 g/m^2) plots (Table 4). However, decreasing trend was obtained in grain and straw yields with increasing seeding density from 40 to 160 g/m^2. Seeding density of 40 and 60 g/m^2 resulted in significantly higher grain yield over 140 and 160 g/m^2. The seeding density 40, 60 and 80 g/m^2 resulted in 32.5, 27.4 and 20.5 higher grain yield over the highest seeding density (160 g/m^2), respectively. Increases

Table 3. Effect of seeding density on plant height and yield attributes of rice (pooled data of 2 years)

Seeding density (g/m^2)	Plant height (cm)	Effective tillers/m^2	Panicle length (cm)	Filled grains/panicle	1,000-grain weight (g)
40	108.9	362.7	22.4	133.1	22.4
60	107.3	357.0	22.1	130.2	22.3
80	106.5	346.2	21.7	127.6	22.3
100	105.6	343.1	20.9	127.4	22.3
120	104.5	325.1	20.8	124.2	22.2
140	103.4	323.8	20.8	119.8	22.1
160	102.2	307.1	20.1	114.7	22.0
SEm±	3.6	14.1	0.5	4.7	0.17
CD (P=0.05)	NS	30.6	1.0	10.3	0.36

Table 4. Effect of seeding density on yield and economics of rice (pooled data of 2 years)

Seeding density (g/m^2)	Straw yield (t/ha)	Grain yield (t/ha)	Harvest index	Gross returns (×10^3₹/ha)	Net returns (× 10^3₹/ha)	Benefit: cost ratio
40	5.77	5.17	0.47	71.9	38.7	2.17
60	5.47	4.97	0.47	69.0	35.5	2.06
80	5.33	4.70	0.47	65.5	31.6	1.93
100	5.17	4.54	0.47	63.2	29.0	1.85
120	4.87	4.50	0.48	62.5	27.8	1.80
140	4.73	4.07	0.46	56.8	21.7	1.62
160	4.33	3.90	0.47	54.3	18.8	1.53
SEm±	0.40	0.34	0.03	–	–	–
CD (P=0.05)	0.90	0.74	NS	–	–	–

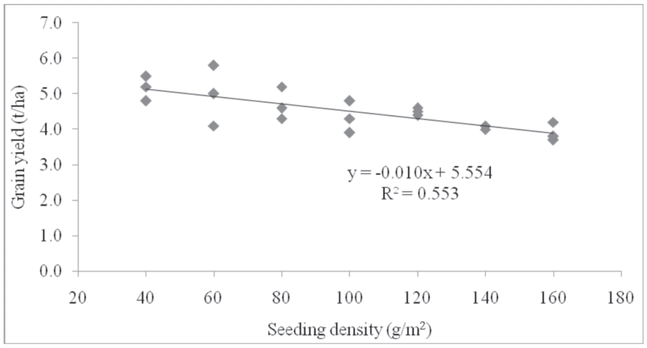

Fig. 2. Relationship between grain yield and seeding density

in the seeding density were negatively correlated with grain yield (Fig. 2). The higher productivity of rice with lower seeding density is owing to better plant growth and higher values of yield attributes as compared to higher seeding density. Maiti and Bhattacharya, (2011) also reported 12–33% increase in grain yield of hybrid rice with 10 and 20 g/m^2 seeding rate over 30 g/m^2. Economic analysis pooled over 2 years (Table 4) revealed that treatment 40 g/m^2 seeding density resulted the maximum net returns (₹38,713) and benefit: cost ratio (2.17) owing to comparatively lower cost of cultivation which was closely followed by treatment 60 g/m^2 with net return (₹35,478) and benefit: cost ratio (2.06). However, there was decreasing trends in net returns and benefit: cost ratio with increasing seeding density from 40 to 160 g/m^2 which might be due to decrease in grain yield with higher seed rate and higher cost of cultivation.

Based on the above findings it may concluded that rice productivity is increased with lower seeding density (40–60 g/m^2) in nurseries and cost of production is also reduced by saving valuable seed. Thus, in the rainfed lowland conditions where farmers generally follow very high seeding density in flat seed beds due to uncertainty of rainfall and obtain poor seedling growth are suggested to raise seedlings on raised bed with low seeding density.

REFERENCES

Adhikari, B.B., Mehera, B. and Haefele, S. 2013. Impact of rice nursery management, seeding density and seedling age on yield and yield attributes. *American Journal of Plant Sciences* **4**: 146–155.

Ashkan, A. and Jalal, M. 2013. Effects of salinity stress on seed germination and seedling vigour indices of two halophytic plant species (*Agropyron elongatum* and A. *pectiniforme*). *International Journal of Agriculture Crop Science* **5**(22): 2,669–2,676.

Bond, J.A., Walker, T.W., Bollich, P.K., Koger, C.H. and Gerard, P. 2005. Seeding rates for stale seedbed rice production in the Mid-southern United States. *Agronomy Journal* **97**(6): 1,560–1,563.

CRRI. 2013. *Vision 2050, p.* 9. Central Rice Research Institute, Cuttack, Odisha.

GoI. 2014. *Economic Survey* A-17. Ministry of Finance, Government of India, New Delhi.

Gorgy, R.N. 2012. Performance of transplanted hybrid rice varieties under different seed rates and N-levels. *Journal of Plant Production* **3**(1): 75–89.

Jayawardena, S.N., Abeysekera, S.W., Dharmasena, A.G.S.P. and Subasinghe, S. 2004. Effect of seed bed seed rate on the quality of the seedlings and the grain yield of three rice hybrids. *Annals of Sri Lanka Department of Agriculture* **6**: 115–122.

Kewat, M.L., Agrawal, S.B., Agrawal, K.K. and Sharma, R.S. 2002. Effect of divergent plant spacing and age of seedlings on yield and economics of hybrid rice (*Oryza sativa* L.). *Indian Journal of Agronomy* **47**(3): 367–371.

Khush, G.S. 2005. Taxonomy, ecology and agronomy of rice cultivation vis-avis genetic engineering of rice. (In) *Biosafety of Transgenic Rice,* pp. 26–37. Chopra, V.L., Shantharam, S. and Sharma, R.P. (Eds). National Academy of Agricultural Sciences, New Delhi, India.

Lal, M. and Roy, R.K. 1996. Effect of nursery seeding density and fertilizer on seedling growth and yield of rice (*Oryza sativa*). *Indian Journal of Agronomy* **41**(1): 642–644.

Maiti, P.K. and Bhattacharya, B. 2011. Effect of seeding rate and number of seedlings/hill on the growth and yield of hybrid rice (*Oryza sativa*) grown in dry (*boro*) season. *Crop Research* **42**(1, 2, and 3): 18–22.

Prasad, R. 2005. Rice–wheat cropping system. *Advances in Agronomy* **86**: 255–339.

Sarwar, N., Muhammad, M., Wajid, S.A. and Anwar-ul-Haq, M. 2011. Impact of nursery seeding density, nitrogen, and seedling age on yield and yield attributes of fine rice. *Chilean Journal of Agricultural Research* **71**(3): 343–349.

Singh, K.N., Hassan, B., Kanday, B.A. and Bhat, A.K. 2005. Effect of nursery fertilization on seedling growth and yield of rice (*Oryza sativa*). *Indian Journal of Agronomy* **50**(3) : 187–189.

Singh, S.P., Singh, A. and Singh, B. 1997. Effect of nitrogen and seed rate on rice, cv. Aswani under rainfed conditions. *Journal of Applied Biology* **7**(1/2): 38–40.

Subedi, R. 2013. Nursery management influences yield and yield attributes of rainfed lowland rice. *Journal of Sustainable Society* **2**(4): 86–91.