Journal of Applied and Natural Science 8 (4): 2224-2230 (2016)

JANS

Evaluation of seeding rates of rice nursery on seedling vigour and its effect on crop productivity under system of rice intensification

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Received: April 1, 2016; Revised received: September 19, 2016; Accepted: November 28, 2016

Abstract: Four seeding rates (25, 30, 35 and 40 g/m^2) of rice in nursery were tested for seedling vigour recorded at 10, 17 and 24 DAS at Malan during 2013 and 2014. The seedling vigour so obtained in nursery was subsequently evaluated in field during *kharif* 2013. Thus twenty four treatments comprised of combinations of three seedling ages (10, 17 and 24 days) and two spacings (20 × 20 cm and 20 × 15 cm) in main plots and four seedling vigour from four seeding rates (25, 30, 35 and 40 g/m^2) in sub plots were evaluated in split plot design. Seedling shoot length under all seeding rates (25-35 g/m^2) was significantly higher compared to check (40 g/m^2) during 2013. In the next year, shoot and root length (30-35 g/m^2), tiller per seedling and leaves per seedling (25-30 g/m^2) of 24 days nursery was significantly higher over check (40 g/m^2). Plant height, tillers, leaves and dry matter accumulation were significantly higher when younger seedlings aged 10 and 17 days were used. The crop raised using 10 days old seedlings matured 3-5 days earlier than 24 days old seedlings. Wider spacing resulted in more plant height, tillers, leaves and dry matter accumulation. Seedlings from 25, 30 and 35 g seed/m^2 resulted in significantly taller plants than 40 g/m^2. The seeding rate, seedling age and plant spacing did not significantly influence rice productivity thereby permitting flexibility to the rice farmers in the adoption of these factors.

Keywords: Seeding rates, Seeding ages, Seedling vigour, Spacing, System of rice intensification

INTRODUCTION

Rice forms staple food for more than half of the world population. Globally, it occupied an area of 164.3 million hectare with a production of 744.9 million tonnes of paddy in 2013 (Anonymous, 2014). In India, rice the most important and extremely grown food crop, occupied 42.81 million hectare of land and produced 143.96 million tonnes paddy (95.97 million tonnes rice) (FAO, 2013). In Himachal Pradesh also, rice is one of the important cereal crops next to wheat and maize. The crop is cultivated from foothill plains to an altitude of 2290 m above mean sea level covering an area of 76.7 thousand hectare with total rice production of 118.28 thousand tonnes (Anonymous, 2012-13). At the current rate of population growth, India has to produce about 130 million tonnes of rice by 2025 to feed the growing population. Meeting the targeted demand of food grains is a challenging task for the policy makers, researchers and all other stakeholders. To safeguard and sustain the food security in India, it is therefore, imperative to explore and evaluate such technologies which may increase the productivity of rice under situations of dwindling resource base particularly when there is little scope of horizontal or lateral expansion. Growing rice by System of Rice Intensification (SRI) is a novel approach of rice cultivation which saves water and other inputs (Satayanarayana *et al.,* 2007). Young seedlings prior to the start of the 4th phyllochron of growth (< 15 days) possess higher tillering potential which drastically decreases with advancing age. Transplanting at wider spacing relieves the plant of adverse effects of closer spacing viz., severe competition between plants resulting in poor tillering; square geometry gives room for profuse root and tiller growth through more efficient harvest of solar energy and other growth resources, achieving 'the border effect' throughout the whole field (Satayanarayana *et al.,* 2007). Seedling vigour is an important contributor to subsequent tillering quality and yield of rice (TeKrony and Egli, 1991). It is found to be associated with the plant viability, height, thickness of stems and uniformity (Matsuo and Hoshikawa, 1993). These above and below-ground characteristics of rice plants, before and after transplanting, vary with seedling age (Himeda, 1994), growing environment (Kordon, 1974) and seeding rate (Sasaki, 2004). Though, the system of rice intensification is a set of principles based on the alleged synergy among several agronomic practices and their interaction with crop biophysical environment and management (Menete *et al.,* 2008), the optimum values of each one of these practices may vary with location. Since, working out these optima on the basis of a single experimentation involving so many

ISSN : 0974-9411 (Print), 2231-5209 (Online)

practices was not practically feasible, the present study had, therefore, was planned to refine only some of the most important SRI components viz. use of young healthy seedlings and optimization of the rice plant spacing.

MATERIALS AND METHODS

The field investigation was carried out during *kharif* 2013 and 2014 at the experimental farm of CSK Himachal Pradesh Krishi Vishvavidyalaya, Rice and Wheat Research Centre, Malan ($32^0 07'$ N, $76^0 23'$ E and 950 m altitude) in North Western Himalayas. The region is endowed with mild summers and cool winters. The soil was silty clay loam, moderately acidic in reaction (pH 5.72), medium in organic carbon (0.58%), available N ($KMNO_4$ method) (Subbiah and Asija 1956), P (Olsen method) (Olsen *et al*., 1954) and K (Neutral normal ammonium acetate extraction method (AOAC, 1970)) content of 314.9, 24.2 and 232.2 kg/ha. During the season (June to September, *kharif* 2013), the crop experienced well distributed rainfall of 2323.5 in133 days. Prior to the commencement of the present study, the field was under rice (*kharif* 2012) –wheat (*rabi* 2012-13) cropping. The field experiment was conducted in split plot design during *kharif* 2013 with three replications. The six combinations of three seedling ages (10,17 and 24 completed days) and two plant spacings (20 × 20 cm and 20 × 15 cm) were allocated to the main plots and seedlings of variable vigour obtained from various seeding rates (25, 30, 35 and 40 g/m^2) in nursery to four sub plots. The normal seed (dry) of HPR 2612, a recommended scented rice variety treated with Bavistin (400:1) was sown in rows 10 cm apart using preplanned seeding rates (viz., 25, 30, 35 and 40 g/m^2) in distinct seed beds on 16th June, 2013. The nursery beds were fertilized using 6.5 g Urea and 7.5 g IFFCO (12:32:16) per m^2 which were drilled in rows prior to sowing of seed. For ensuring proper weed control in nursery, the beds were sprayed with butachlor 1.5 kg/ha immediately after sowing (Reddy,2004). Whole of recommended P and K (17.46 and 33.2 kg/ha, respectively) and half of N (45 kg/ha) were applied as basal dose at the time of puddling using IFFCO (12:32:16), muriate of potash and urea. Remaining half of the nitrogen was top dressed through urea in two equal splits each at tillering and panicle initiation stages of rice. The transplanting operation was carried out on three different dates viz., 27th June, 4th and 11th July, 2013 and 2014 as per the requirement of the experiment to transplant 10, 17 and 24 days old seedlings. The observations on seedling vigour viz., shoot length, number of leaves, root length, fresh and dry weights of seedling shoots and roots and number of tillers were recorded on 20 randomly selected seedlings immediately after their uprooting for transplanting in the main field experiment. The statistical analysis in respect of nursery data observations (shoot length/root length, number of tillers and number of leaves) was done using student´s t-test for unpaired observations comparing specific treatment with the check viz., 40 g seed/m^2 at a time. On the other hand, the combined fresh and dry weights of all twenty seedlings shoot and root component were recorded as single value without any statistical analysis. The plots were kept moist by regular watering as per requirement else the water level was maintained at 3-4 cm depth if available through rainfall. After panicle initiation, submergence up to 5 cm was followed. The weeds were controlled by using butachlor 5G @1.5 kg a.i/ha 4-5 days after transplanting followed by one hand weeding one month after transplanting.

RESULTS AND DISCUSSION

Effect on seedling vigour: The seedlings shoot length under the seeding rates 25-35 g/m^2 was significantly higher compared to standard check of 40 g/m^2; the differences being highly significant (1% level) at all seedling ages from 10-24 days with few exceptions under 10 days old seedlings. Seedling root length under different seeding rates did not differ significantly for 10-17 days old seedlings, but the results were inconsistent in respect of 24 days old seedlings. Number of tillers/seedling and number of leaves/seedling were also not significantly influenced by different seeding rates. Fresh and dry weights of shoot and root components as well as root: shoot ratio of seedlings were numerically lower under seeding rate of 40 g/m^2 (check), the results being inconsistent for the remaining seeding rates ranging from 25-35 g/m^2. Whereas during next year of seeding, seedling s’ shoot length of 30-35 g/m^2 nursery is significantly higher at 1% level except during 17 days where at 5% only for 35 g/m^2. Root length having similar result like seedling s’ shoot length except during 24 days nursery, when 25 g/m^2 nursery seeding rate had root length significantly higher than others. Among the number of tillers and leaves per seedling plant, the significant results were obtained at 24 days nursery growth stage where 25-35 g/m^2 nursery seeding rate had higher tillers and leaves than 40 g/m^2 (check) seeding rate at 5% level (Table 1). Lima *et al.* (2010) documented similar findings under a plastic tunnel and revealed that tillering decreased as seeding density increased, with greater participation of the main stems; however, this did not result in increased yield, due to the plasticity shown by rice plants in influencing yield components.

Growth: Plant height was significantly affected due to seedling ages (Table 2). Younger seedlings (10 or 17 days old) resulted in significantly taller rice plants than older ones (24 days old). This was probably when a seedling is transplanted carefully at the initial growth stage, the trauma due to root damage caused during uprooting is reduced which stimulate increased cell division causing more stem elongation. These results

Table 1. Effect of seeding rates of rice nursery on seedling characteristics.

Seeding rates (g/m^2)	Shoot length (cm) [a]						Root length (cm) [a]					
	10 days		17 days		24 days		10 days		17 days		24 days	
	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014
25	11.7 ± 0.69	11.49 ± 0.528	16.8 ± 0.52**	15.51 ± 0.354	24.4 ± 1.00**	24.605 ± 0.548	3.5 ± 0.19	3.23 ± 0.109	5.0 ± 0.27	5.01 ± 0.136	8.7 ± 0.50**	8.45 ± 0.301**
30	13.3 ± .56**	13.50 ± .486**	16.3 ± 0.36**	15.23 ± 0.300	27.3 ± 1.40**	26.630 ± 1.092*	3.7 ± 0.20	3.43 ± 0.070**	4.7 ± 0.30	4.82 ± 0.117	7.8 ± 0.61**	8.43 ± 0.55
35	13.1 ± .60*	13.24± .428**	16.6 ± 0.56**	15.80± 0.418*	31.5 ± 1.05**	25.900± 0.488**	3.2 ± 0.17	3.45 ± 0.084**	5.3 ± 0.30	5.21 ± 0.116**	6.2 ± 0.30**	8.24 ± 0.305*
40	10.9 ± .66	11.49 ± .500	13.8 ± 0.57	14.48± 0.420	19.1 ± 1.01	23.790 ± .624	3.3 ± 0.18	3.40 ± 0.096	4.4 ± 0.33	4.64 ± 0.179	10.8 ± 0.53	7.42 ± 0.210
	No. of tillers/plant [a]						No. of leaves/plant [a]					
	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014
25	0	0	1.3 ± 0.17	1.50 ± 0.118*	1.3 ± 0.24	1.55 ± 0.203*	3.2 ± 0.10	3.25 ± 0.101	7.1 ± 0.41*	7.00 ± 0.400**	7.2 ± 0.48	7.55 ± 0.611**
30	0	0	0.9 ± 0.21	1.15 ± 0.186	1.0 ± 0.19	1.50 ± 0.158*	3.4 ± 0.16*	3.55 ± 0.139**	5.9 ± 0.42	5.45 ± 0.559	6.7 ± 0.44	7.00 ± 0.473*
35	0	0	0.8 ± 0.20	1.10 ± 0.200	0.9 ± 0.21	1.45 ± 0.158	3.1 ± 0.11	3.40 ± 0.132	5.5 ± 0.36	5.30 ± 0.587	6.8 ± 0.51	6.80 ± 0.369*
40	0	0	0.8 ± 0.19	1.05 ± 0.189	0.9 ± 0.19	1.00 ± 0.182	2.9 ± 0.14	3.05 ± 0.117	5.4 ± 0.34	5.15 ± 0.562	6.6 ± 0.44	5.43 ± 0.525
	Fresh weight of shoot/plant(g) [b]						Fresh weight of root/plant(g) [b]					
	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014
25	0.10	0.12	0.34	0.33	0.72	0.74	0.06	0.06	0.09	0.10	0.35	0.37
30	0.11	0.14	0.19	0.30	0.66	0.78	0.06	0.07	0.08	0.10	0.34	0.38
35	0.10	0.13	0.27	0.35	0.88	0.78	0.06	0.07	0.09	0.12	0.26	0.36
40	0.07	0.12	0.17	0.29	0.74	0.73	0.04	0.04	0.08	0.08	0.14	0.35
	Dry weight of shoot/plant (g) [b]						Dry weight of root/plant (g) [b]					
	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014
25	0.02	0.02	0.08	0.08	0.15	0.16	0.02	0.02	0.05	0.06	0.09	0.10
30	0.02	0.03	0.06	0.07	0.15	0.18	0.02	0.03	0.04	0.07	0.09	0.11
35	0.02	0.03	0.06	0.09	0.18	0.18	0.02	0.03	0.04	0.09	0.08	0.10
40	0.01	0.02	0.05	0.07	0.16	0.17	0.01	0.01	0.03	0.02	0.07	0.10

[a] The data represents arithmetic mean ± standard error, [b] the data is based on observations of 20 plants, * Significant at 5% , and ** Significant at 1% level.

Table 2. Effect of treatments on growth, yield attributes and yield of rice.

Treatment	Plant height (cm) (At maturity)	No. of tillers/m² (70 DAS)	Dry matter accumulation (g/m²) (At maturity)	Panicles/m² (no.)	Spikelets/panicle (no.)	Spikelet fertility (%)	Test weight (g)	Grain yield (kg/ha)	Straw yield (kg/ha)	Harvest index
Seedling ag (days)										
10	99.9	486.1	1264.3	339	155	77.9	22.4	5386	7415	0.41
17	100.9	538.3	1271.6	345	150	75.3	22.5	5408	7528	0.41
24	96.9	475.9	1223.2	313	152	70.8	22.2	5260	7146	0.42
SE (m±)	0.79	7.96	37.99	23.70	2.66	1.17	0.08	139.5	205.6	0.01
LSD $_{0.05}$	2.48	25.08	NS	NS	NS	3.69	0.26	NS	NS	NS
Spacing (cm)										
20 x 20	101.0	524.3	1268.5	355	153	74.3	22.1	5413	7403	0.41
20 x 15	98.6	490.0	1239.6	312	154	75.6	22.7	5245	7335	0.41
SE (m±)	0.64	6.50	31.02	19.35	2.17	0.96	0.07	113.9	167.8	0.00
LSD $_{0.05}$	2.03	20.47	NS	NS	NS	NS	0.21	NS	NS	NS
Seeding rate (gm²)										
25	100.0	486.9	1235.8	331	152	75.5	22.4	5303	7253	0.42
30	99.2	526.8	1279.5	332	151	74.7	22.5	5298	7569	0.41
35	100.0	507.9	1246.8	337	158	74.6	22.4	5387	7283	0.42
40	97.6	478.9	1250.0	328	148	73.9	22.2	5416	7346	0.42
SE (m±)	0.64	13.89	25.92	13.31	3.52	1.43	0.12	80.8	190.7	0.01
LSD $_{0.05}$	1.82	NS	NS	NS	NS	NS	NS	NS	NS	NS

were supported by the findings of Mishra and Salokhe (2008) who recorded more plant height after transplanting younger seedlings (12 days) as compared to the older (30 days). This might be due to higher phyllocrone production in younger seedlings before entering to reproductive stage as well as less transplanting shock at this stage. Similar results were also reported by Rahman (2001) where the plant height was significantly affected by seedling age. Spacing of 20 × 20 cm resulted in significantly taller plant at maturity stage as compared to 20 × 15 cm. This indicated possibility of competition for nutrients and water but not for light. Plant height was also influenced by seeding rate at maturity stage. The lower seed rates of 25, 30 and 35 g/m² statistically remaining at par with each other resulted in significantly taller plant than the check (40 g/m²). The significant positive influence in shoot length of seedlings produced under lower seeding rates (25-35 g/m²) compared to 40 g/m² and the higher dry matter of shoots and roots under the former (lower seeding rates) at the time of transplanting seedlings, continued to keep the momentum high enough throughout the crop season thereby producing taller plants. The number of tillers increased progressively up to 70 DAS and decreased thereafter probably due to degeneration of late emerging tillers (Table 2). Seedlings aged 17 days resulted in significantly highest number of tillers which was followed by 10 days and 24 days old seedlings, respectively. Mobasser *et al.* (2007) also observed that when seedlings stayed for a longer period of time in the nursery beds, primary tiller buds on the lower nodes of the main culm become degenerated leading to reduced tiller production. Wider spacing of 20 × 20 cm resulted in significantly higher number of tillers than 20 × 15 cm at 70 DAS. However, no significant difference was observed at other stages. Superiority of wider spacing over close spacing in respect of number of tillers was attributed to more space available for plant allowing better aeration and less competition for light, space and better root growth akin to border affect. These results confirm the findings of Kumar *et al.* (2004) where the higher tiller number and yield attributes observed in wider spacing i.e. 25 x 25 cm. It was also emphasized that wider spacing, availability of

Table 3. Interaction effect of spacing and seeding rate on grain yield (kg/ha) of rice.

Seeding rate (g/m²)	Spacing (cm) 20 × 20	Spacing (cm) 20 × 15
25	5500	5105
30	5210	5387
35	5531	5243
40	5353	5479
LSD $_{0.05}$		
For comparison of seeding rate at same spacing		327
For comparison of spacing at same or different seeding rate		461

Table 4. Economics of treatments.

Treatment	Cost of cultivation (Rs/ha)	Gross return (Rs/ha)	Net return (Rs/ha)	B:C ratio
Seedling age (days)				
10	32143	124220	92077	3.87
17	31774	124854	93080	3.93
24	31355	121181	89827	3.87
SE (m±)	-	3127	3086	0.09
LSD $_{0.05}$	-	NS	NS	NS
Spacing (cm)				
20 x 20	31098	124786	93689	4.01
20 x 15	32698	121153	88456	3.70
SE (m±)	-	2553	2519	0.07
LSD $_{0.05}$	-	NS	NS	0.24
Seeding rate (g/m^2)				
25	32115	122233	90118	3.81
30	31936	122622	90686	3.84
35	31642	124055	92413	3.92
40	31336	124763	93428	3.98
SE (m±)	-	1777	1753	0.05
LSD $_{0.05}$	-	NS	NS	NS

solar radiation, medium temperature, soil aeration, and nutrient supply promote shorter *phyllochrons* which increase the number of tillers in the rice plant. Seeding rate did not influence production of tillers on unit area basis at 70 DAS stage.

The amount of dry matter production depends on effectiveness of photosynthesis of crop and furthermore, on plants whose vital activities are functioning effectively. Dry matter accumulation by shoots increased progressively up to the crop maturity. Statistically, 17 days seedlings accumulated significantly higher dry matter followed by 10 and 24 days old seedlings, respectively at all stages except maturity. Similarly, More *et al*. (2007) reported that planting younger rice seedlings of 15 days led to significant increase in dry matter production as compared to use of older seedlings of 20 and 28 days age and the extent of increase was 9.62 and 18.80%, respectively. Plant spacing had no effect on dry matter accumulation at all stages except 100 days stage when wider spacing of 20 × 20 cm resulted significantly higher dry matter accumulation than 20 × 15 cm spacing. Higher total dry matter production under wider spacing was explained due to increase in number of tillers in rice as reported earlier by Rajesh and Thanunathan (2003). The effects of seeding rates on dry matter accumulation, though significant at most of the growth stages in rice except maturity, were quite inconsistent. However, in general, 35 g/m^2 seeding rate resulted in significantly higher dry matter accumulation than other seeding rates. Greater dry matter production might be due to the contribution of greater number of tillers/area and leaf area index.

Yield attributes and yield: A perusal of the data revealed that seedling age significantly influenced the spikelet fertility and test weight but had no effect on number of panicles /m^2 and the number of spikelets per panicle. Ten days old seedling remaining at par with 17 days old seedlings resulted in significantly higher spikelet fertility than 24 days old seedlings. Low level of spikelet fertility ranging from 70.8 to 77.9% in present experiment is probably because of reduced duration of sunshine hours accumulated to 260 hours during the last 45 days of crop growth (prior to maturity) compared to 300 hours required for optimum growth. With regards to test weight, 10 days old seedlings resulted in intermediate values, whereas 17 days old seedlings gave significantly higher grain weight than 24 days old seedlings. Faruk *et al.* (2009) also reported that 1000-grain weight was unaffected by age of seedling. In contrast, Gill and Sahi (1987) stated that transplanting of 60 days old seedlings resulted in higher 1000-grain weight. The positive effects of seedling age on spikelet fertility and grain test weight, however, were not reflected in grain yield of rice which varied in the range of 5245-5416 kg/ha. The findings were in conformity with results of Krishna and Biradarpatil (2009) where seedling age and planting pattern were not significant on grain yield. Nursery seeding rate did not significantly influence the yield attributes and there by grain and straw yield of rice. It was also seen from the data presented in Table 2 that the varying seed rates did not influence any of the growth parameters significantly. In contrast, Maiti and Bhattacharya (2011) reported the lower seeding rates of 10 and 20 g/m^2 resulted in significant increase in number of tillers and all yield attributing parameters except the 1000 grain weight and ultimately brought increases in gain yield. Interaction effects between seedling ages x spacing, spacing x seeding rate and seeding rate × seeding age were not significant on yield attributes and yield except interaction effect of spacing and seeding rate on grain yield. The data presented in Table 3 revealed that seeding rate of 40 g/m^2 produced significantly higher grain yield as compared to 25 g/m^2 at 20 × 15 cm spacing but the difference was not significant at wider spacing of 20 × 20 cm. The differences amongst all other seeding rates at both the spacing were also not significant.

Economics: Economic parameters viz. gross return and net return were not significantly influenced due to either seedling ages or the plant spacing. However, B: C ratio was significantly higher under wider spacing compared to narrow (20 × 15 cm) spacing. Cost of cultivation varied significantly amongst various seeding rates with maximum and minimum costs recorded under 25 and 40 g/m^2, respectively. Though, the net returns did not differ significantly amongst seeding rates; 35 and 40 g/m^2 seeding rates remaining statistically alike resulted in significantly higher net returns per rupee invested as compared to 25 and 30 g/m^2 seeding rates. According to Bhandari (1993) minimum B: C ratios of 1.5 for the agricultural sector have been fixed for any enterprise to be economically viable and therefore, a crop enterprise must maintain a 1.5 B: C ratio to be economically sustainable. Further, Reddy and Reddi (2002) reported that any B: C value greater than 2.0 is considered safe as the farmer gets Rs. 2.00 for every rupee invested.

Conclusion

Seeding rates of rice nursery did not influence various seedling vigour parameter except seedling shoot length which was significantly higher under all seeding rates than the recommended check 40 g/m^2. However in the final analysis seeding rates had no effect on rice crop productivity and monetary returns. Spacing and seedling age also failed to influence rice crop productivity significantly. Thus there is an ample opportunity to the rice farmer to adopt various SRI components viz., seeding rate, plant spacing and seedling age as per his choice and convenience within the range investigated. Thus, the study clearly indicated that rice under SRI may be raised using 10-24 days old seedling at spacing of 20 × 20 cm with nursery seeding rate of 40 g/m^2.

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