Research Article

Effect of Seeding Rate for Mat type Nursery on growth, Yield and Economic Efficacy of Mechanically Transplanted Fine Basmati Rice

Ali Zohaib*, Muzzammil Hussain, Iftikhar Ahmad and Adnan Bashir

Adaptive Research Farm, Gujranwala 52200, Pakistan.

Abstract | Mechanical transplanting with mat type nursery is quite a new planting technique for rice. However, optimization of seeding rate for producing mat type nursery is crucial to acquire suitable seedlings and planting density for better yield of mechanically transplanted rice (MTR). Current 2-years field study was conducted to determine effect of seeding rate (80, 90, 100 and 110 g per tray) for preparing nursery mats of fine basmati rice on plant growth, grain yield and economic benefits. Seeding rate significantly affected the growth, yield and related traits of fine basmati rice. Increase in seeding rate from 80 to 110 g per tray successively increased number of plants per tray and per hill after transplanting while decreased the root length and root/shoot ratio of rice. Plant height was not affected significantly by seeding rate. Highest increase in number of productive tillers (8%), 1000-grain weight (8%), total dry biomass (14-17%) and grain yield (10-16%) was caused by 90 g seed per tray, as compared to 110 g seed per tray. Order of grain yield produced by different seeding rates was 90 > 80 > 100 > 110 g per tray. Economic analysis exhibited that maximum net returns and benefit cost ratio (BCR) was achieved by using 90 g seed per tray. In conclusion, 90 g seed per tray improved the grain yield by enhancing number of productive tillers and grain weight of fine basmati rice; hence, could be adopted for better productivity and economic benefits of mechanically transplanted fine basmati rice.

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***Correspondence** | Ali Zohaib, Adaptive Research Farm, Gujranwala 52200, Pakistan; **Email:** alizohaib208@gmail.com
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Introduction

Rice (*Oryza sativa* L.) is utilized as staple food in many countries of the world and in Pakistan after wheat. Various management factors greatly affect its yield including planting method (Rani and Jayakiran, 2010). Rice is planted by different methods viz. conventional (manual transplanting), and simplified and mechanized (direct seeding, mechanical transplanting) (Ehsanullah *et al*., 2007; Bian *et al*., 2018). Conventional method of rice transplanting is quite laborious, expensive and time consuming. Moreover, unskilled laborer retains the plant population less than optimum required due to uneven plant spacing which results in yield reductions and economic losses (Mann and Ashraf, 2001; Rani and Jayakiran, 2010). Hence, the arising circumstances of labor scarcity, low plant population, low yield and increasing cost of production has led to conversion from conventional planting method to mechanical transplanting of rice (Shinde *et al*., 2018).

Mechanical rice transplanting ensures timely sowing of optimal aged seedlings which consequences in production of more productive tillers while avoids shortened period of vegetative growth and decreased dry matter accumulation thereby increasing crop yield (Malik *et al*., 2011; Liu *et al*., 2015). Moreover, in MTR seedlings are transplanted having soil attached to the roots and without breaking the roots which avoid early transplanting shock, and uniform plant spacing ensures optimum plant population as well thereby improving the grain yield (Malik *et al.*, 2011). However, management of seeding rate and proper plant density is essential for getting better yield of MTR (Yu *et al.*, 2006; Liu *et al.*, 2017). Plant density has established role in manipulating population characteristics (Li *et al.*, 2016), regulation of tiller production (Huang *et al.*, 2013), radiation use efficiency (Chen *et al.*, 2019), photo-assimilation and yield formation (Nakano *et al.*, 2012).

In MTR, optimum seeding rate is essential for acquiring better quality seedlings and their establishment after transplanting, optimum plant population and plants per hill, improved subsequent plant growth and crop productivity (Hossen *et al.*, 2018). Low seeding rate produces superior quality seedlings but the twisting roots remain unable to curl up for mechanical transplanting. Moreover, low seeding rate produce less seedlings per tray which results in greater number of missing hills and low plant population per unit area (Yu *et al.*, 2006; Hossen *et al.*, 2018). Conversely, high seeding rate increases the plant population and plants per hill but produces poor quality seedlings (Yu *et al.*, 2006; Hossen *et al.*, 2018). Nonetheless, the seeding rate per unit area varies for coarse and fine types of rice (Dongarwar *et al.*, 2018). Similarly, seeding rate in MTR also varies for short, medium and long rice types (Hossen *et al.*, 2018). Hence, optimization of seeding rate for mechanically transplanted fine basmati rice is essential for acquiring optimum plant population and grain yield.

Mechanical transplanting of rice provides an alternative solution of labor shortage, and produces high yield due to optimum plant population and avoiding transplanting shock in comparison with conventional transplanting. Seeding rate per tray is important for attaining better quality seedlings, and optimum plant population and plants per hill in MTR. However, to best of our knowledge information is scarce regarding seeding rate of fine basmati rice for mechanical transplanting. It was hypothesized that proper seeding rate will produce optimum plant population and plants per hill, better growth and ultimately yield of mechanically transplanted fine basmati rice. This two years field study was conducted with objectives to ascertain influence of seeding rate per tray on growth, grain yield and economic benefits of mechanically transplanted fine basmati rice.

Materials and Methods

Experimental details

Experiment was performed at Adaptive Research Farm, Gujranwala, Pakistan (32°12′15″N 74°13′48″E and 227 m above sea level) during 2019 and 2020. Soil samples were collected from experimental field (0-30 cm depth) to analyze for physico-chemical characteristic. Working soil samples were drawn out of composite samples and submitted to Soil and Water Testing Laboratory, Gujranwala for analysis. The soil was heavy loam, having organic matter (0.91%), pH (7.6), electrical conductivity (1.3 mS/cm), total N (0.05), available P (10.5 ppm) and available K (142 ppm). Experiment was conducted by using the Randomized complete block design with three replications. The area of net plot was 15 m × 12 m. Treatments were comprised of different seeding rates including 80, 90, 100 and 110 g seed per tray. Meteorological data prevailed during experimental period is presented in Table 1.

Table 1: *Meteorological conditions during rice growing seasons.*

Month	Total Rainfall (mm)		Relative Humidity (%)		Temperature (°C)					
					Monthly Maximum		Monthly Minimum		Daily Mean	
	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
June	96.5	97.6	74.3	75.1	37.5	37.5	25.3	23.9	31.4	30.7
July	240.0	79.6	82.4	80.3	39.3	35.9	25.5	26.5	32.4	31.2
August	138.3	333.3	85.7	89.5	36.1	34.3	27.2	26.5	31.7	30.4
September	52.9	49.2	84.1	85.4	34.9	36.1	24.7	25.0	29.8	30.6
October	28.9	0.0	83.4	82.2	31.5	33.6	17.9	17.7	24.7	25.6
November	17.3	15.5	85.2	84.3	24.6	24.8	13.3	10.8	19.0	17.8

Source: *Meteorological Department, Punjab*

Crop husbandry

Fine basmati rice cultivar Super basmati was used for conducting experiment. The nursery was sown in trays (60 cm × 30 cm × 2.5 cm) to prepare the mats on 14th and 25th June during 2019 and 2020, respectively using seeding rates according to treatments. The soil was puddled and nursery was transplanted using four row walk after type mechanical transplanting machine in standing water up to a depth of 2.5 cm on 14th and 25th July during 2019 and 2020, respectively. Inter and intra row plant spacing was kept 25 and 20 cm, respectively. The fertilization was carried out at the rate of 120-88-62 kg/ha NPK. Complete P, K, and one-third of N was applied at transplanting while left over N was split applied at 30 and 45 days after transplanting (DAT). Zinc sulfate (33%) was utilized at application rate of 15 kg ha^{-1}, 10 DAT. Water was kept standing in field at 5 cm depth up to 25 days. After that irrigation was applied just to keep soil moistened and halted 15 days prior to harvesting. Plant protection was accomplished using local recommendations. The crop was harvested manually in first week of November and threshed by beating against drums during both years.

Measurements

Plants from nine selected trays were counted after completion of emergence to determine the number of plants per tray. Average number of plants transplanted per hill was determined by calculating number of plants m^{-2} and dividing with number of hills m^{-2}. At harvest, data were collected regarding growth and yield traits. The plant height of randomly selected four plants was measured with meter rod and averaged. Root length was determined without uprooting the plants by digging but instead sliced the soil along the selected plants until full depth of roots was achieved, and measured using meter rod and averaged. Root/shoot ratio was determined by dividing the root length with plant height. Number of productive tillers m^{-2} and hill^{-1} was ascertained by counting productive tillers from one m^{2} area and dividing with number of hills m^{-2}, respectively. Grains obtained from selected plants were counted and averaged to determine number of grains per panicle. The 1000-grain weight was determined by counting and weighing the grains with electric balance. Plants harvested from selected area were weighed before threshing, sub-samples drawn, dried and weighed again to determine total dry biomass, and expressed as t ha^{-1}. Grain yield was ascertained by manually threshing the harvested plants and weighing grains, and expressed as t ha^{-1}.

Economic analyses

Total cost, net returns and BCR was determined by adopting the methods described CIMMYT (1988). Fixed cost was determined by summing prices of all used inputs. Variable cost was comprised of cost of seed used in each treatment. Total cost was computed by summing the fixed and variable cost. Net returns were computed by utilizing formula;

Net returns = gross income – total cost. The BCR was calculated by using formula; BCR = (Gross income / total cost).

Statistical analyses

Data were tested for normality with scatter plot technique. The data were normal and analyzed using the analysis of variance (ANOVA) technique (Steel *et al*., 1997). Comparison of treatments' means was carried out by using the least significant difference (LSD) test at 5% probability.

Results and Discussion

Plant population and growth attributes

Seeding rate significantly affected the number of plants per tray and per hill after transplanting, root length and root/shoot ratio of rice during both years. However, the influence of seeding rate on number of hills m^{-2} and plant height was found non-significant, during both years. Highest number of plants per tray (2574 and 2625) and number of plants per hill after transplanting (3.39 and 3.52) were recorded by increasing the seeding rate up to 110 g per tray during both years. On the other hand, the maximum root length and root/shoot ratio was achieved at low seeding rate and decreased with increase in seeding rate. The greatest increase in root length (12-17%) and root/shoot ratio (13-17%) was noticed by using 80 g seed per tray as compared to 110 g seed per tray, during both years; however, 90 g seed per tray gave similar root length and root/shoot ratio during both years (Tables 2 and 3).

In present study the number of plants of rice per tray and average number of plants per hill after transplanting were increased by increasing the seeding rate (Table 2). Similarly, Hossen *et al*. (2018) reported that increase in seeding rate per tray increased the number of seeds and plants but decreased the emergence percentage. In present study, root length and root/shoot ratio of rice were decreased with increase in seeding

Table 2: *Effect of seeding rate on number of plants and hills of mechanically transplanted rice.*

Seed rate (g tray^{-1})	No. of plants tray^{-1}		No. of hills m^{-2}		No. of plants hill^{-1}	
	2019	2020	2019	2020	2019	2020
80	1372 d	1389 d	18.0	17.7	1.91 d	1.97 d
90	1840 c	1804 c	18.0	18.0	2.56 c	2.51 c
100	2172 b	2198 b	18.7	18.7	2.91 b	2.94 b
110	2574 a	2625 a	19.0	18.7	3.39 a	3.52 a
LSD $_{P < 0.05}$	87.372	79.998	ns	ns	0.226	0.234

Means in a column having same letters don't differ significantly at P < 0.05

Table 3: *Effect of seeding rate on plant growth of mechanically transplanted rice.*

Plant height (cm)		Root length (cm)		Root/shoot ratio	
2019	2020	2019	2020	2019	**2020**
116.67 b	115.00 a	38.50 a	37.18 a	0.33 a	0.32 a
119.33 a	116.67 a	38.18 a	36.16 ab	0.32 ab	0.31 ab
117.67 a	116.00 a	35.69 b	33.62 bc	0.30 bc	0.29 bc
117.00 a	115.00 a	34.31 b	31.80 c	0.29 c	0.28 c
ns	ns	1.862	2.664	0.018	0.030

Means in a column having same letters don't differ significantly at P < 0.05

rate although plant height was not affected significantly (Table 3). This decrease is attributed to greater competition among plants due to more seedlings per hill at high seeding rates (Table 2). Deng *et al.* (2020) observed that increasing the plant density by seeding rate while keeping the inter-row plant spacing fixed but not caring of intra-row plant spacing in direct seeded rice resulted in improved root growth. However, Wang *et al.* (2010) observed that increasing the number of seedlings per hill without variation in hills per unit area in transplanted rice increased the dry matter partitioning to the above ground plant parts more than roots. Similarly, in present study, the plants of MTR per hill were increased by increasing the seeding rate per tray which might have decreased the root growth at higher seeding rates (Tables 2 and 3).

Grain yield and related attributes

Number of productive tillers m^{-2} and hill^{-1} (Table 4), total dry biomass (Figure 1 a, b) and grain yield of rice (Figure 2 a, b) was significantly affected by seeding rate during both years. However, seeding rate didn't affect significantly the number of grains per panicle during both years and 1000-grain weight during 2019 (Table 4). Grain yield and related attributes of rice were higher at lower seeding rate when compared with higher seeding rate (Table 4, Figure 2 a,b). Maximum increase in number of productive tillers m^{-2} (8%) was caused by 90 g seed per tray while number of productive tillers hill^{-1} (12-13%) was increased the most by 80 g seed per tray, as compared to 110 g seed per tray, during both years. The 1000-grain weight was higher by 8% in response to 90 g seed per tray, as compared to 110 g seed per tray and it was followed by 100 g seed per tray, during 2020 (Table 4). Exaggeration in total dry biomass (14-17%) and grain yield (10-16%) of rice was occurred by 90 g seed per tray, as compared to 110 g seed per tray and it was followed by 80 g seed per tray, during both years (Figures 1 a,b and 2 a,b).

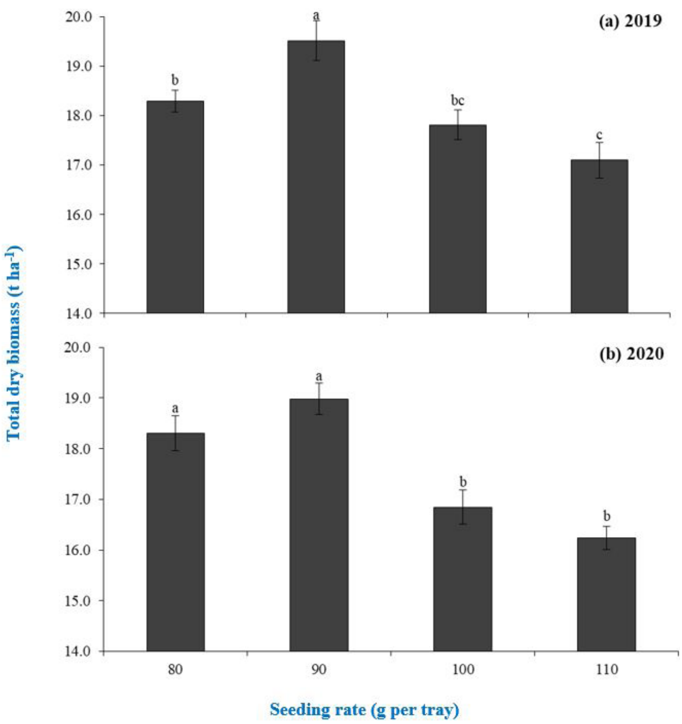

Figure 1: *Effect of seeding rate on total dry biomass of mechanically transplanted rice during (a) 2019 and (b) 2020; Bars are mean ± SE (n = 3). Bars sharing same letter don't differ significantly at P < 0.05.*

In present study, maximum productive tillers per hill were exhibitedd by 80 g seed per tray while productive tillers m^{-2} were the highest by 90 g seed per tray (Table 4) due to higher missing hills in 80 g seed per tray (Table 2). However, seeding rate higher than 90 g per

Table 4: *Effect of seeding rate on yield related attributes of mechanically transplanted rice.*

Seed rate (g tray^{-1})	No. of productive tillers m^{-2}		No. of productive tillers hill^{-1}		No. of grains panicle^{-1}		1000-grain weight (g)	
	2019	2020	2019	2020	2019	2020	2019	2020
80	348 a	344 a	19.37 a	19.54 a	102.33 a	111.33 a	22.00 a	22.17 ab
90	349 a	351 a	19.37 a	19.48 a	102.33 a	110.33 a	22.67 a	23.50 a
100	335 ab	328 b	17.97 ab	17.58 b	103.67 a	109.67 a	21.33 a	22.50 a
110	324 b	325 b	17.07 b	17.43 b	102.67 a	108.33 a	22.00 a	21.83 b
LSD $_{P < 0.05}$	14.776	12.176	1.479	1.297	ns	ns	ns	1.141

Means in a column having same letters don't differ significantly at P < 0.05

Table 5: *Effect of seeding rate on economic efficiency of mechanically transplanted rice.*

Seed rate (g tray^{-1})	Adjusted Grain yield (t/ha)		Gross income (Rs/ha)		Variable cost (Rs/ha)		Total Cost (Rs/ha)		Net returns (Rs/ha)		Benefit cost ratio	
	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
80	4.00	3.98	243693	232870	3000	3000	119365	124188	124328	108683	2.04	1.88
90	4.21	4.26	255768	247885	3375	3375	119740	124563	136028	123323	2.14	1.99
100	3.93	3.77	239553	221155	3750	3750	120115	124938	119438	96218	1.99	1.77
110	3.81	3.68	232998	216370	4125	4125	120490	125313	112508	91058	1.93	1.73

Adjusted grain yield: 10% less than actual grain yield; Cost and income was estimated by using the prevailing market prices for inputs and paddy, respectively, in Pakistan.

tray increased the plant population (Table 2) but reduced productive tillers hill^{-1} and m^{-2} (Table 4). Productive tillers per unit area are decreased at high plant population because most of the tillers remain infertile possibly due to smaller tiller size and lower nitrogen content in plants (Hayashi *et al*., 2006). In present study, the grains per panicle of rice were not affected significantly while grain weight was significantly higher at lower seeding rates (Table 4). This might be explained on the basis of trade-off relationship between productive tillers, grains number and grain weight (Wang *et al*., 2014). Lower seeding rates produce sparse plant populations but higher productive tillers which don't allow the plants to produce more grains per panicle of rice; however, plants compensate this by enhancing grain filling rate (Gravios and Helms, 1992; Shu *et al*., 2009). Previous studies have reported similar results pertaining to the effect of seeding rate on yield attributes (Sarwar *et al*., 2011; Cui *et al*., 2014).

In current study, total dry biomass and grain yield of MTR was greater with lower seeding rate (*i.e.* 90 g per tray followed by 80 g per tray) as compared to higher seeding rate (Figures 1 a,b and 2 a,b). The greater yield with low seeding rate was related with greater number of productive tillers and grain weight of rice (Table 4). Mechanically transplanted rice with lower seeding rates had less number of plants per hill than high seeding rates which might have improved the total dry biomass and grain yield due to better root morphological indices and less inter-plant competition (Wang *et al*., 2010; Yang *et al*., 2012). Previous studies have reported similar findings that low seeding rate and/or fewer seedlings per hill had better biomass and grain yield than higher number of seedlings per hill owing to less productive tillers, grains per panicle and grain weight (Srinivasulu *et al*., 1999; Ottis and Talbert, 2005; Baloch *et al*., 2006).

Economic efficiency

The economic analyses revealed that highest variable and total cost was incurred when 110 g seed per tray was used while minimum costs were observed for 80 g seed per tray during both years. However, highest gross income (Rs. 255768 and 247885), net returns (Rs. 136028 and 123323) and BCR (2.14 and 1.99) was obtained by using 90 g seed per tray (during 2019 and 2020, respectively). The order of BCR for different seeding rates was 90 > 80 > 100 > 110 g seed per tray during both years (Table 5).

In present study, it was noticed that increasing the seeding rate caused an increase in cost but the net returns and BCR was decreased as compared to lower seeding rates. However, highest net returns and BCR was recorded by using 90 g seed per tray which was associated with better grain yield (Figure 2 a,b) and hence gross income (Table 5). Previous studies have reported that aside from sowing method of rice the optimum seeding rate enhances the grain yield which ensues in higher economic returns and BCR, minimize economic losses and hence must be adopted to enhance crop productivity and economic benefits (Corbin *et al*., 2016; Dongarwar *et al*., 2018; Li *et al*., 2020).

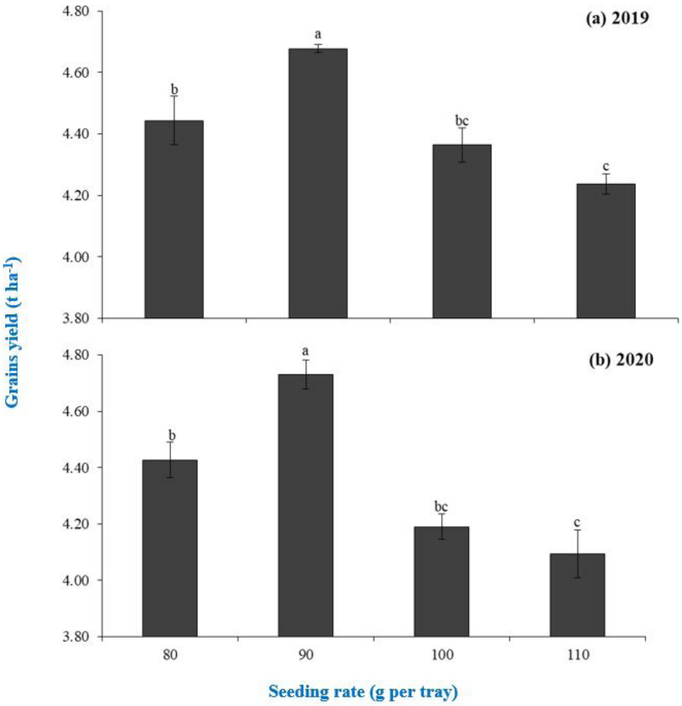

Figure 2: *Effect of seeding rate on grain yield of mechanically transplanted rice during (a) 2019 and (b) 2020; Bars are mean ± SE (n = 3). Bars sharing same letter don't differ significantly at P < 0.05.*

Conclusions and Recommendations

Seeding rate per tray of rice significantly affected the plant population, growth and yield. Optimum plant population, and maximum root growth, number of tillers, grain weight, dry biomass and grain yield was produced with lower seeding rates (specifically 90 g) than higher seeding rates per tray. In conclusion, 90 g seed per tray improved the grain yield by enhancing number of productive tillers and grain weight of fine basmati rice; hence, could be adopted for better productivity and economic benefits of mechanically transplanted fine basmati rice.

Novelty Statement

Seeding rate is imperative to produce mat type nursery for mechanically transplanted rice and achieve vigorous seedlings and optimum planting density in order to obtain better yield. Current study was performed to optimize seeding rate of fine basmati rice per tray for better plant growth, grain yield and economic benefits.

Author's Contribution

Ali Zohaib: Planned and performed experiment, performed statistical and economic analyses, carried out write up and overall management of paper.
Muzzammil Hussain: Gave technical input at every step.
Iftikhar Ahmad: Supervised the study. Adnan Bashir managed crop in field.

Conflict of Interest

The authors have declared no conflict of interest.

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