INTERNATIONAL JOURNAL OF AGRICULTURE & BIOLOGY
ISSN Print: 1560–8530; ISSN Online: 1814–9596
19–0691/2019/22–6–1347–1355
DOI: 10.17957/IJAB/15.1207
http://www.fspublishers.org

Full Length Article

Agronomic Efficiency and Economics of Crop Establishing Techniques and Nitrogen Application in Fine Aromatic Rice (*Oryza sativa*)

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Abstract

Different crop establishing techniques and nitrogen application levels have crucial role in determining the production of rice. A field experiment was conducted at experimental farm of Rice Research Institute, Kala Shah Kaku, Pakistan during 2015 and 2016 to compare four planting methods *i.e.*, broadcast sowing (BS), drill sowing (DS), ridge sowing (RS) and puddled transplanted rice (PTR) along with four nitrogen rates *viz.*, N_0: control, N_{133}: 133 kg ha^{-1}, N_{166}: 166 kg ha^{-1} and N_{199}: 199 kg ha^{-1} using fine aromatic rice cultivar Super Basmati. Highest tiller density m^{-2}, panicle length, filled grain density per panicle, 1000 grain weight, grain yield, straw yield and harvest index were achieved for RS followed by DS while the minimum grain yield along with other yield contributing factors was recorded in PTR. Likely, highest filled grain density per panicle, grain yield, harvest index and minimum sterility percentage was recorded with 166 kg N ha^{-1} compared to control. For the interaction highest grain yield and harvest index was obtained in RS for 166 kg N ha^{-1} whereas minimum in PTR. Highest net profit and cost-benefit ratio was recorded with RS and 166 kg N ha^{-1}. Hence, RS with application of 166 kg N ha^{-1} can be recommended to harvest the maximum grain yield and net profit in rice. © 2019 Friends Science Publishers

Keywords: Dry seeded rice; Transplanted rice; Nitrogen rates; Grain yield; Profit; Cost-benefit ratio

Introduction

More than half of the world's population consumes rice as a staple food and it is also the second largest cereal crop of Pakistan as well an important exportable national commodity. It accounts for 3.1 percent of value added in agriculture and 0.6 percent of GDP. During 2017-2018, rice crop was sown on an area of 2.72 million hectares whereas the production was 6.85 million tons (Anonymous, 2018).

In Asian rice growing countries, transplanting rice seedling manually into puddled soil is most widely adopted method of rice planting but it consumes abundant quantity of water (Bouman and Tuong, 2001). As the water resources are declining, thus judicious use of irrigation water has gained a pivotal importance to meet the water and food needs of rapidly growing human population (Hanjar and Quereshi, 2010; Mahajan and Timsina, 2011; Mahajan *et al*., 2012). The shrinking water resources are threatening the rice growers of Asia for adequate availability of irrigation water in the coming years (Mahajan *et al*., 2012) that may adversely affect the sustainability of rice production in irrigated areas (Chauhan, 2012; Chauhan *et al*., 2014). Thus, there is dire need to explore water saving approaches in farming and water saving of 11-18% and 40% in direct seeded rice as compared to transplanting in puddled soil has been reported by Cabangon *et al.* (2002) and Tabbal *et al.* (2002), respectively. Furthermore, dry seeding on raised beds instead of puddled soil saves even more irrigation water (Bouman and Tuong, 2001). Moreover, applying irrigation precisely on the basis of soil surface tension (-20 kPa at 20 cm depth) in DSR, showed even higher saving of about 50% of water (Bhushan *et al*., 2007; Sudhir *et al*., 2007; Jat *et al*., 2009). DSR as water saving technology, owing to its popularity is getting momentum over puddled transplanted rice (Farooq *et al*., 2011).

Transplanting rice seedlings in puddled soil not only consumes more water but also involves intensive labour. It requires 25–50 man-days ha^{-1}as compared to direct seeded rice which needs about 5 man-days ha^{-1} (Dawe, 2005). Scarcity of skilled labour results in low plant population, eventually low crop productivity in PTR (Mann *et al*., 2007; Gill *et al*., 2014). Moreover, increasing wages result in an increase in cost of production, another factor contributing towards gradually replacing this conventional planting method with DSR (Bhushan *et al*., 2007; Saharawat *et al*., 2010). However, where labour is easily available and affordable, seedling transplanting could be chosen but on other hand, then it is more economical to opt for direct seeding (Laary *et al*., 2012). Moreover, direct seeded rice plays pivotal role to achieve optimum plant population and

To cite this paper: Iqbal, S., U.B. Khalid, M.U. Saleem, A. Iram, N. Ahmad, N. Iqbal, M. Sabar and T.H. Awan, 2019. Agronomic efficiency and economics of crop establishing techniques and nitrogen application in fine aromatic rice (*Oryza sativa*). *Intl. J. Agric. Biol*., 22: 1347–1355

high-water use efficiency in water scarce areas that translates into improvement in the yield components and eventually in the final grain yield (0.16 t ha^{-1}) over PTR (Sarkar and Das, 2003; Farooq *et al*., 2011). Furthermore, the DSR crop does not face the transplanting shock, that favors early crop establishment, accelerates the growth and hastens physiological maturity (Tuong, 2008) leading to shortening of crop duration (Ali *et al*., 2006) by seven days (Rana *et al*., 2014).

Therefore, sowing of rice crop by direct seeding is being practiced successfully in Europe, USA, Brazil, India, Philippines, Thailand, Malaysia and Sri Lanka (Farooq *et al*., 2011; Kumar and Ladha, 2011; Weerakoon *et al*., 2011).

Planting methods not only significantly affect yield and grain quality of rice crop but also influence health and productivity of soil. The yield of DSR can be increased by adopting suitable planting pattern which is considered an important agronomic factor (Iqbal, 2014; Rani and Jayakiran, 2010). Moreover, direct seeding had better plant establishment producing higher yield than transplanting (Laary *et al.*, 2012). However, various site-specific changes in method of land preparation and crop establishment may be applied in directly sown crop to enhance the crop yield (Farooq *et al*., 2008). In addition, highest cost benefit ratio (1:1.91) had been recorded in DSR (Aslam *et al*., 2008) along with about 20% reduction in production cost (Rana *et al*., 2014).

Maximum paddy yield in drill sowing, broadcasting and bed sowing was achieved while lowest was found in puddled transplanted rice (Ali *et al.*, 2012) whereas Pasha *et al.* (2011) found that among different methods of direct rice seeding, highest paddy yield was achieved by drilling the dry seed. Moreover, in survey-based study of different rice growers in Pakistan, it was revealed that 0.70 to 0.89 t ha^{-1} higher yield obtained in DSR over conventional method of transplanting. The succeeding wheat crop also gave higher yield in field where previous rice crop was sown by DSR (Ali *et al*., 2014). In a previous study found that mechanical transplanting, DSR by broadcast, bed sowing and drill sowing have superior results equally over farmers conventional transplanting (Ali *et al.*, 2012). In another study, DSR cultivation on ridges resulted in increased grain yield as compared to DSR by drill and broadcast sowing (Jamil *et al*., 2017). Moreover, in China DSR ridge sowing also produced better results due to improved tillers, higher flag leaf chlorophyll content, slowed leaf aging, higher net photosynthetic rate, increased leaf area index, promotion of root development in upper soil at grain filling stage and finally resulting higher grain yield (Zhang *et al*., 2003; Zhang *et al*., 2009; Ting *et al*., 2013).

The deficiency of nitrogen generally causes chlorosis in leaves leading to stunted growth (Zou *et al.*, 2018). This is because of the poor formation of assimilates which ultimately results in early flowering and overall growth cycle of the plant is shortened, conversely, when nitrogen applied in excessive amount it accelerates vegetative growth of above ground parts of the plant due to enhanced chlorophyll content thus, giving dark greenish colour and succulence to the crop, making crop more vulnerable to disease incidence, insect attack and severe lodging (Alam *et al.*, 2005). Generally, nitrogen uptake by the plant is merely 40% of the total nitrogen applied and this lower efficiency of the nitrogen fertilizer is due to its losses through denitrification, runoff, volatilization and leaching (Ladha *et al*., 2005). In rice cultivation systems, nitrogen nutrition is the key factor which limits both the growth and quality of the crops (Khan *et al*., 2012) as almost all agronomic parameters are affected with the changes of nitrogen input (Anisuzzaman *et al.*, 2010; Abou-Khalifa, 2012; Pramanik and Bera, 2013; Yoseftabar, 2013; Singh *et al*., 2015) and grain yield is enhanced by altering nitrogen rate in different ecological zones (Sharma *et al*., 2007; Ahmed *et al*., 2015; Singh *et al*., 2015). Moreover, super rice varieties show more positive response to the higher rates of nitrogen as compared to non-super rice varieties (Chen *et al*., 2014). A slight increase in nitrogen dose (22.5–30 kg ha^{-1}) is suggested in DSR which is only to meet the rice crop nitrogen requirements as it faces greater losses and lesser availability of nitrogen from the soil as mineralization occurs at early growth stage. In India, 25% more nitrogen is applied in DSR as compared to puddled rice (Varinderpal-Singh *et al*., 2010; Mahajan and Timsina, 2011). Whereas, in Pakistan, nitrogen requirement of the rice crop cultivated as DSR seems relatively higher (55 kg N ha^{-1}) than the transplanted rice (Jamil *et al*., 2017) in addition to the recommended dose.

Therefore, present study investigated response of fine aromatic rice Super Basmati variety with objectives to explore appropriate planting techniques in dry direct seeded rice and optimization of nitrogen application dose.

Materials and Methods

Experimental Site, Design and Treatments

The study was conducted at experimental area of Rice Research Institute, Kala Shah Kaku, Pakistan during 2015 and 2016. Randomized complete block design (RCBD) with split plot arrangement was used with three replications having net plot size of 4.5 m × 27 m. Four crop establishing methods *viz*., broadcasting in well prepared dry soil (BS), drilling in well prepared dry soil (DS), ridges made after broadcasting of dry seed *i.e*., ridge sowing (RS) and puddled transplanted rice (PTR) were compared. Four nitrogen rates *viz*., N_0: Control, N_{133}:133 kg N ha^{-1}, N_{166}: 166 kg N ha^{-1} and N_{199}: 199 kg N ha^{-1} were applied. The physico-chemical characteristics of experimental soil are given in Table 1.

Crop sowing: Super Basmati was used as test variety. Dry seeding was done in first and second year on 14 June using rice seeding drill (DS), manual broadcasting (BS) and after manual broadcasting ridges were made by the ridger (RS). However, in PTR, seedlings transplanting was done on 18 July manually using thirty days old seedlings in both the years. Seed at the rate of 30 kg ha^{-1} in case of DSR method and 15 kg ha^{-1} by nursery raising for transplanting was used.

Weed control: Bispyribac sodium (Clover) 20% SC at the rate of 250 g ha^{-1} was sprayed after 20 days of seeding in moist soil conditions and its application was repeated at 38 days after seeding as weeds again germinated in the field. Weed control in PTR was done by using Butachlor 60% EC at the rate of 2000 mL ha^{-1} at 5 days after transplanting (DAT) in standing water.

Fertilizer management: Fertilizers phosphorus and potash at the rate of 85 and 62 kg ha^{-1}, respectively was used in the study. Full dose of phosphorus, potash, and 1/3rd nitrogen (N) were applied during last cultivation while remaining 2/3 was applied in two splits 35 and 55 days after transplanting or seeding.

Irrigation management: Drilling, ridge making and broadcasting of dry seed was done in a well-prepared dry seed bed following immediate flood irrigation and re-irrigated after 4 days to enhance germination and then irrigated with almost 4–5 days interval at early growth stage and 5–7 days at later stages of development. In case of PTR, continuous flooding of water was done for 30 days after transplanting (DAT) and then irrigated at about one-week interval. For insects and disease control, recommended plant protection measures were adopted to save the crop from loss. The crop was harvested at full physiological maturity and threshed manually.

Data Recording

Plant height of 05 randomly selected plants from each of the experimental unit was recorded from soil surface to the tip of the main panicle with the help of a meter rod and then averaged. The numbers of tillers was recorded at harvest from an area of 1 m^2 from three different places in each plot and averaged to calculate the tiller density m^{-2}. Five randomly selected panicles from each plot at harvest time were taken to determine the panicle length (cm), filled and unfilled grain density per panicle. 1000-grain weight of the normal kernels was recorded in grams using digital balance. After harvesting and threshing, the clean rough rice was air dried, bulked and weighed. Moisture content in grain was determined by using LKB-PRODUK TERAB-Sweden Grain Moisture Meter. The grain weight was adjusted at 14% moisture content and the yield of clean rough rice was expressed in tons ha^{-1}.

Sterility percentage, harvest Index (HI) and cost-benefit ratio (CBR) were determined by following equations:

$$\text{Sterility \%} = \frac{\text{unfilled spikelets per panicle}}{\text{total spikelets per panicle}} \times 100$$

$$\text{HI \%} = \frac{\text{Grain yield}}{\text{Total Biological Yield}} \times 100$$

$$\text{CBR} = \frac{\text{total income}}{\text{total cost of production}}$$

Agronomic efficiency for nitrogen was determined by following this equation:

$$\text{AE} = \frac{\text{GYNA} - \text{GYN0}}{\text{NRN}}$$

Where:

AE: Agronomic efficiency

GYNA: grain yield (kg ha^{-1}) with nitrogen addition

GYN0: grain yield (kg ha^{-1}) without nitrogen addition

NRN: Rate of nitrogen addition (kg ha^{-1})

For planting methods agronomic efficiency was determined as follow

$$\text{AE} = \frac{\text{X Yield} - \text{PTR Yield}}{\text{PTR Yield}} \times 100$$

Where, X is the DSR by broadcast, drill or ridge sowing and PTR is puddled transplanted rice.

Statistical Analysis

The data collected was statistically analyzed using computer statistical package *STATISTIX 8.1*. Least significance difference (LSD) test at $P \leq 0.05$ was used to compare the treatment means.

Results

The cropping years had a significant effect on filled grain density per panicle, sterilty percentage, 1000 grain weight, grain yield, straw yield, grand income, net profit and cost-benefit ratio and non-significant results observed for plant height, tiller density m^{-2}, panicle length and harvest index (Table 2). Therefore, the results are presented years wise. Different crop establishing techniques showed a significant effect ($P \leq 0.05$) on plant height in both years. The maximum height was recorded in DS that was similar with RS with an increment of 6 and 4%, 8 and 11% during the first and second year respectively (Table 4). The tiller density m^{-2} was also affected significantly ($P \leq 0.05$) and 24, 20 and 15% more tillers were observed in RS, DS and BS, respectively over PTR and in second year increase of 22, 17 and 4% was observed. In case of panicle length (cm) 13, 5, 2% in 2015 and 14, 12, 5% in 2016 longer panicles were found in RS, DS and PTR than BS, respectively (Table 5). Number of filled grains per panicle (Table 4) was 19% and 13% more in RS and DS than PTR in 2015 and 22 and 9% in 2016. For the sterility percentage, BS, DS and RS recorded 26, 11 and 1.5% increase over PTR in 2015 with a similar trend observed in 2016. The thousand grain weight was non-significantly affected by planting techniques during both years (Table 5), however, 5% heaviest grains were achieved in RS than PTR during 2015 and 2% in 2016. Grain yield (t/ha^{-1}) varied

Table 1: Physico-chemical properties of experimental field

Parameter	Soil depth	
	0-6 inch	6-12 inch
Texture	Clay loam	Clay loam
Organic matter (%)	0.39	0.25
Soil pH	8.31	8.14
EC (dS m^{-1})	1.42	0.89
SAR (m mol $L^{-1})^{1/2}$	7.23	7.14
Saturation (%)	41	36
Nitrogen (%)	0.47	0.26
Available P (ppm)	5.5	5.2
Available K (ppm)	94	76

Table 2: Analysis of Variance of cropping years, crop establishing techniques and nitrogen application on different parameters of fine aromatic rice during 2015-16 (Total *df* = 95)

Sources	*df*	PH	TD	PL	FG	St	TGW	GY	SY	HI	GI	NP	BCR
Y	1	0.39^{NS}	10292^{NS}	55.21^{NS}	72.25^{**}	88.34^{*}	15.64^{*}	5.05^{*}	8.66^{*}	32.82^{NS}	328297^{*}	32830^{**}	1.36^{*}
PM	3	265.82^{*}	22216^{**}	46.35^{**}	1252.42^{**}	97.42^{**}	2.18^{**}	3.31^{**}	1.85^{NS}	92.04^{**}	210811^{**}	341957^{**}	1.36^{**}
Y×PM	3	14.28^{NS}	1329^{NS}	3.46^{NS}	29.69^{**}	8.39^{*}	0.50^{*}	0.32^{**}	0.64^{NS}	18.56^{NS}	20373^{**}	20372^{**}	0.05^{**}
NL	3	1619.69^{**}	137100^{**}	326.75^{**}	8560.73^{**}	546.91^{**}	25.63^{*}	19.88^{**}	38.38^{**}	251.68^{**}	1294226^{**}	1086675^{**}	3.73^{**}
Y×NL	3	23.14^{NS}	1312^{NS}	7.10^{NS}	61.68^{**}	3.41^{**}	0.83^{**}	0.32^{**}	1.20^{*}	0.86^{NS}	20696^{**}	20696^{**}	0.06^{**}
PM×NL	9	27.01^{**}	399^{NS}	9.98^{NS}	21.51^{**}	3.29^{**}	0.08^{NS}	0.16^{**}	0.28^{NS}	3.92^{NS}	10096^{**}	10095^{**}	0.03^{**}
Y×PM×NL	9	27.95^{**}	229^{NS}	3.62^{NS}	9.08^{NS}	3.13^{**}	0.10^{NS}	0.20^{**}	0.49^{NS}	4.27^{NS}	13067^{**}	13067^{**}	0.04^{**}

Y = Years; PM = Planting methods; NL = Nitrogen levels; PH = Plant height (cm); TD = Tiller density m^{-2}; PL = Panicle length (cm); FG = Filled grain density per panicle; St = Sterility (%); TGW = 1000-grain weight (g); GY = Grain yield (t ha^{-1}); SY = Straw yield (t ha^{-1}); HI = Harvest Index (%); GI = Grand Income (\$ ha^{-1}); NP = Net profit (\$ ha^{-1}); BCR = Benefit-cost ratio; NS= Non Significant, *= Significant; **= highly significant

Table 3: Analysis of Variance of crop establishing techniques and nitrogen application on different parameters of fine aromatic rice during 2015 and 2016 (Total *df* = 47)

Sources	*df*	PH	TD	PL	FG	St	TGW	GY	SY	HI	GI	NP	BCR
						2015							
PM	3	101.19^{**}	12268.70^{*}	20.37^{**}	533.31^{**}	35.10^{**}	2.33^{NS}	0.82^{**}	0.48^{NS}	28.40^{*}	51860^{**}	98106^{**}	0.45^{**}
NL	3	693.99^{**}	82207.50^{*}	142.65^{**}	4476.03^{**}	315.33^{**}	17.20^{**}	12.51^{**}	26.75^{**}	122.01^{**}	815629^{**}	698269^{**}	2.36^{**}
PM×NL	9	32.71^{*}	76.70^{NS}	9.42^{NS}	9.69^{**}	5.61^{**}	0.11^{NS}	0.18^{*}	0.58^{NS}	5.88^{NS}	11656^{*}	11659^{*}	0.04^{NS}
						2016							
PM	3	178.91^{**}	11276.90^{**}	29.44^{NS}	748.80^{**}	70.71^{**}	0.35^{NS}	2.81^{**}	2.00^{**}	82.19^{**}	179324^{**}	264223**	0.97^{**}
NL	3	948.83^{**}	56203.80^{**}	191.20^{**}	4146.39^{**}	234.99^{**}	9.27^{**}	7.69^{**}	13.46^{**}	130.53^{**}	499293^{**}	409102**	1.43^{**}
PM×NL	9	22.24^{**}	551.70^{NS}	4.81^{NS}	20.91^{**}	0.81^{NS}	0.07^{NS}	0.18^{**}	0.19^{NS}	2.31^{NS}	11504^{**}	11503**	0.04^{**}

PM = Planting methods; NL = Nitrogen levels; PH = Plant height (cm); TD = Tiller density m^{-2}; PL = Panicle length (cm); FG = Filled grain density per panicle; St = Sterility (%); TGW = 1000-grain weight (g); GY = Grain yield (t ha^{-1}); SY = Straw yield (t ha^{-1}); HI = Harvest Index (%); GI = Grand Income (\$ ha^{-1}); NP = Net profit (\$ ha^{-1}); BCR = Benefit-cost ratio; NS= Non Significant; *= Significant; **= highly significant

Table 4: Effect of planting methods and nitrogen rates on agronomic and yield traits

Treatment/Parameters	Plant height (cm)		Tiller density m^{-2}		Panicle length (cm)		Filled grain density per panicle		Sterility (%)	
Planting methods	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016
BS	115.73	115.63	350.50	308.48	23.30	24.10	72.95	73.63	17.81	19.79
DS	119.83	119.40	365.00	348.02	24.44	27.02	81.13	80.63	15.67	18.91
RS	116.90	118.78	377.00	360.50	26.29	27.50	85.95	90.62	14.30	16.39
PTR	112.82	110.96	304.00	296.67	23.83	25.32	72.10	74.20	14.10	14.46
LSD ($P \leq 0.05$)	3.070	3.443	38.520	19.026	1.089	3.009	3.007	6.219	1.009	0.849
					Nitrogen Levels					
N_0	105.37	104.26	229.42	230.52	19.80	20.13	49.52	53.15	22.93	23.73
N_{133}	117.02	114.70	359.25	332.38	24.01	26.73	85.23	82.17	14.39	16.65
N_{166}	121.00	121.83	396.33	370.94	26.51	28.60	92.35	95.69	11.36	13.52
N_{199}	121.90	123.98	411.50	379.83	27.55	28.47	85.03	88.06	13.19	15.64
LSD ($P \leq 0.05$)	2.942	2.228	19.276	29.055	1.994	2.284	2.421	2.391	0.614	1.707

BS: Broadcast sowing; DS: Drill sowing; RS: Ridge sowing; PTR: Puddled transplanted rice N_0: control; N_{133}: 133 kg N ha^{-1}; N_{166}: kg N ha^{-1}; N_{199}: 199 kg N ha^{-1}

significantly ($P \leq 0.05$) among different planting techniques in both years (Table 5) with maximum for RS that was similar with DS and BS indicating 20, 14 and 7% increase over the PTR. Straw yield showed a non-significant response during both the years with a 6, 2 and 6% increase in RS, BS and DS respectively over PTR in first year and with similar trend were recorded in second year (Table 5). Different planting methods affected HI (%) significantly, with highest in RS and DS showing an increase of 9 and 8% respectively than BS and PTR with lower HI (Table 5). Highest agronomic efficiency was of 20 and 51% observed in RS and followed by DS (14 and 35%) and BS (7 and

Table 5: Effect of planting methods and nitrogen rates on yield traits and agronomic efficiency (AE)

Treatment	1000-grain weight (g)		Grain yield (t ha^{-1})		Straw yield (t ha^{-1})		Harvest Index (%)		Agronomic efficiency	
Planting methods	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016
BS	20.46	21.38	3.26	2.84	6.97	6.00	31.22	31.82	7.13	25.39
DS	20.37	21.37	3.46	3.05	6.69	6.12	33.61	32.92	13.99	34.77
RS	21.23	21.61	3.64	3.42	6.98	6.80	33.95	32.97	19.89	51.15
PTR	20.26	21.19	3.04	2.26	6.58	5.90	31.04	27.44	-	-
LSD ($P \leq 0.05$)	0.736	0.280	0.422	0.261	0.583	1.000	2.075	2.747	-	-
Nitrogen levels										
N_0	19.06	20.30	1.91	1.79	4.78	4.82	28.29	27.00	-	-
N_{133}	20.21	21.17	3.38	2.84	6.66	6.00	33.69	32.04	11.09	8.85
N_{166}	21.33	21.70	4.23	3.61	7.55	6.68	35.84	34.98	14.22	10.96
N_{199}	21.72	22.38	3.88	3.33	8.23	7.31	32.00	31.13	10.68	7.74
LSD ($P \leq 0.05$)	0.431	0.258	0.308	0.147	0.544	0.483	1.364	1.214	-	-

BS: Broadcast sowing; DS: Drill sowing; RS: Ridge sowing; PTR: Puddled transplanted rice N_0: control; N_{133}: 133 kg N ha^{-1}; N_{166}: kg N ha^{-1}; N_{199}: 199 kg N ha^{-1}

Table 6: Interaction of planting methods and nitrogen levels on plant height (cm), tiller density m^{-2}, panicle length (cm), filled grain density per panicle and sterility percentage during 2015 and 2016

Treatment/parameters		Plant height (cm)		Tiller density m^{-2}		Panicle length (cm)		Filled grain density per panicle		Sterility (%)	
Planting methods	Nitrogen levels	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016
BS	N_o	98.87	103.53	235.67	229.83	16.73	17.60	47.87	50.87	26.14	26.49
	N_{133}	118.73	113.40	355.00	290.25	24.13	26.40	78.40	77.00	16.83	19.31
	N_{166}	121.60	122.27	397.33	352.75	25.67	27.20	85.40	85.93	13.41	16.13
	N_{199}	123.73	123.33	414.00	361.08	26.67	25.20	80.13	80.70	14.86	17.24
DS	N_o	111.27	105.73	239.67	249.00	22.00	22.93	50.73	52.60	25.40	24.82
	N_{133}	118.20	119.93	382.00	357.00	22.43	27.00	89.33	84.60	13.16	17.97
	N_{166}	124.33	125.40	411.67	387.67	26.07	28.73	96.00	97.47	11.00	15.62
	N_{199}	125.53	126.53	426.67	398.42	27.27	29.40	88.47	87.87	13.14	17.22
RS	N_o	105.67	104.07	252.33	247.92	23.73	21.07	56.53	62.07	19.84	22.40
	N_{133}	120.53	115.53	386.33	385.58	24.53	27.33	94.60	90.00	14.57	15.90
	N_{166}	121.53	126.13	426.33	402.00	27.97	30.73	100.47	108.87	10.57	12.21
	N_{199}	119.87	129.40	443.00	406.50	28.93	30.87	92.20	101.53	12.21	15.06
PTR	N_o	105.67	103.69	190.00	195.33	16.73	18.93	42.93	47.07	20.34	21.20
	N_{133}	110.60	109.93	313.67	296.67	24.93	26.20	78.60	77.09	13.00	13.44
	N_{166}	116.53	113.53	350.00	341.33	26.33	27.73	87.53	90.50	10.49	10.15
	N_{199}	118.47	116.67	362.33	353.33	27.33	28.40	79.33	82.13	12.57	13.04
LSD ($P \leq 0.05$)		5.933	5.088	50.792	53.726	3.617	4.955	5.145	2.471	1.460	2.245

BS: Broadcast sowing; DS: Drill sowing; RS: Ridge sowing; PTR: Puddled transplanted rice N_0: control; N_{133}: 133 kg N ha^{-1}; N_{166}: kg N ha^{-1}; N_{199}: 199 kg N ha^{-1}

25%) during 2015 and 2016, respectively as compared to PTR (Table 5). Economic analysis for both the years (Table 4) indicated that the highest net profit and benefit-cost ratio were found in RS which was followed by DS and BS, whereas, minimum were observed in PTR (Table 6).

Nitrogen (N) had a significant ($P \leq 0.05$) effect on plant height (cm), tiller density m^{-2}, panicle length (cm), filled grain number per panicle, sterility (%), 1000 grain weight (g), grain yield (t ha^{-1}), straw yield (t ha^{-1}) and HI (%) in both years (Table 3). In case of plant height (cm), the N_{199} and N_{166} applied expressed similar tallest plants and response was followed by N_{133}. These N levels expressed 16, 15, 11% (2015) and 19, 17, 10% (2016) more height over the N_0 treatment (Table 4). The production of tillers m^{-2} increased with increasing N level. It was observed that N_{199}, N_{166} and N_{133} resulted in 80, 72, 57 (2015) and 65, 61, 44% (2016) more tiller density m^{-2} than the plots without N (Table 4). Different N levels had significant ($P \leq 0.05$) impact on panicle length which increased by 39, 34 and 21% for N_{199}, N_{166} and N_{133} over control in 2015 and similar trend was observed during the second year of experimentation (Table 4). Different N rates showed a significant ($P \leq 0.05$) behavior on filled grain density per panicle (Table 4) and maximum number was observed in N_{166}. Nonetheless, N_{199}, N_{166}, N_{133} resulted in 72, 87, 72 (2015) and 66 80, 55% (2016) more filled grain number per panicle respectively than control. The sterility percentage significantly ($P \leq 0.05$) varied under both years (Table 4). In 2015 and 2016 42, 50, 37% and 43, 34, 30% less sterility was observed with N_{199}, N_{166} and N_{133} respectively over control. The 1000-grain weight was also significantly ($P \leq 0.05$) affected by different levels of N (Table 5) and increase in grain weight was found with increments of N doses. For N_{199}, N_{166} and N_{133}, an increase of 14, 12, 6 and 10, 7, 4% was recorded in 2015 and 2016, respectively, over control. Grain yield (t ha^{-1}) is the most crucial and important parameter which also significantly ($P \leq 0.05$) affected by varying N doses (Table 5). It was observed that during 2015, an increase of 122% for N_{166} over control. Moreover, 103 and 77% increase of grain yield was found for N_{199} and N_{133} over control treatment respectively. In addition, N_{166} resulted in 25 and 9% more yield than N_{133} and N_{199}. In second year, treatments N_{166}, N_{199}, N_{133} produced 102, 86, 59% more yield than N_0, even N_{166} better performed (27 and 8%) than N_{199} and N_{133}. Straw yield (t ha^{-1}) was significantly ($P \leq 0.05$) altered by

Table 7: Interaction of planting methods and nitrogen levels on 1000-grain weight (g), grain yield (t ha^{-1}), straw yield (t ha^{-1}) and harvest Index (%) during 2015 and 2016

Treatment/Parameters		1000-grain weight (g)		Grain yield (t ha^{-1})		Straw yield (t ha^{-1})		Harvest Index (%)	
Planting methods	Nitrogen levels	2015	2016	2015	2016	2015	2016	2015	2016
BS	N_o	19.12	20.25	1.65	1.86	4.62	4.88	26.21	27.64
	N_{133}	20.02	21.32	3.47	2.78	7.42	5.74	31.89	32.87
	N_{166}	21.17	21.78	3.87	3.54	7.45	6.50	34.14	35.28
	N_{199}	21.54	22.18	4.03	3.16	8.38	6.88	32.63	31.49
DS	N_o	18.76	20.24	2.02	1.86	4.88	4.84	29.35	27.95
	N_{133}	19.97	21.14	3.50	3.19	6.48	6.09	34.90	34.46
	N_{166}	21.07	21.64	4.33	3.58	7.57	6.38	36.41	35.99
	N_{199}	21.67	22.47	4.00	3.56	7.82	7.17	33.79	33.29
RS	N_o	19.93	20.45	2.45	1.95	5.45	5.08	30.89	27.88
	N_{133}	20.73	21.33	3.45	3.26	6.72	6.42	33.93	33.77
	N_{166}	22.08	22.08	4.45	4.33	7.35	7.38	37.64	37.00
	N_{199}	22.17	22.55	4.22	4.13	8.42	8.33	33.35	33.22
PTR	N_o	18.44	20.25	1.52	1.48	4.18	4.54	26.72	24.53
	N_{133}	20.11	20.87	3.12	2.13	6.02	5.75	34.04	27.07
	N_{166}	21.00	21.31	4.27	2.98	7.85	6.46	35.17	31.67
	N_{199}	21.49	22.32	3.25	2.46	8.28	6.85	28.23	26.51
LSD ($P \leq 0.05$)		1.045	0.526	0.424	0.364	0.881	1.300	3.133	3.447

BS: Broadcast sowing; DS: Drill sowing; RS: Ridge sowing; PTR: Puddled transplanted rice N_0: control; N_{133}: 133 kg N ha^{-1}; N_{166}: kg N ha^{-1}; N_{199}: 199 kg N ha^{-1}

Table 8: Economics of different planting techniques and nitrogen levels and their impact on grand income, net profit and benefit cost ratio for 2015 and 2016

Treatments		Total cost ($ ha^{-1})	2015			2016		
Planting techniques	Nitrogen levels		Grand Income ($ ha^{-1})	Net profit ($ ha^{-1})	Benefit-cost ratio	Grand Income ($ ha^{-1})	Net profit ($ ha^{-1})	Benefit-cost ratio
BS	N_o	475.62	430.27	-45.35	-0.10	484.94	9.32	0.02
	N_{133}	506.76	895.22	388.46	0.77	716.95	210.19	0.41
	N_{166}	514.48	1036.18	521.70	1.01	909.36	394.88	0.77
	N_{199}	522.21	999.78	477.57	0.91	816.47	294.26	0.56
DS	N_o	496.28	522.97	26.69	0.05	484.12	-12.16	-0.02
	N_{133}	527.42	899.96	372.54	0.71	820.59	293.18	0.56
	N_{166}	535.14	1112.47	577.32	1.08	919.90	384.75	0.72
	N_{199}	542.87	1030.09	487.23	0.90	916.94	374.07	0.69
RS	N_o	488.68	633.48	144.80	0.30	507.07	18.39	0.04
	N_{133}	519.82	888.36	368.54	0.71	838.87	319.05	0.61
	N_{166}	527.54	1140.80	613.25	1.16	1111.23	583.69	1.11
	N_{199}	535.27	1086.57	551.30	1.03	1065.25	529.98	0.99
PTR	N_o	548.91	395.27	-153.64	-0.28	382.96	-165.95	-0.30
	N_{133}	580.05	802.33	222.28	0.38	679.46	99.41	0.17
	N_{166}	587.77	1096.89	509.12	0.87	770.54	182.76	0.31
	N_{199}	595.50	1044.39	448.89	0.75	641.21	45.71	0.08
LSD ($P \leq 0.05$)	-	-	164.41	147.08	0.275	93.892	76.236	0.174

PKR is Pakistan's currency. US$1=PKR 130. Paddy market price=250 $ t^{-1}. Straw market price =3.85 $ t^{-1}. Grand income= [(grain yield× paddy market price t^{-1}) + (Straw yield× straw market price t^{-1}). Net benefit= (grand income - total production cost). Benefit-cost ratio =Net profit/production cost)

Abbreviations: DS= DSR-drill sowing, RS= DSR-ridge sowing, BS=DSR-broadcast, PTR = conventional transplanting, N_0=Control; N_{133} = 133 kg N ha^{-1}; N_{166}= 166 kg N ha^{-1}; N_{199}=199 kg N ha^{-1}

different N doses and maximum was produced by N_{199} ($P \leq 0.05$), 72 and 51% more than the control treatment in 2015 and 2016, respectively (Table 5). Harvest index (%) was significantly ($P \leq 0.05$) affected by different levels of N in both years. In the first year, 27, 13 and 19%, more HI with N_{166}, N_{133} and N_{199} was achieved over control respectively. Similar response was observed during 2016 (Table 5). The highest agronomic efficiency (AE) was observed with the N application of N_{166} in both the years. AE for N_{133} and N_{199} was 22% and 25% lower than N_{166} in first year and 19 and 29% in second year (Table 5). Economic analysis revealed that maximum profit and cost-benefit ratio were achieved in N_{166} but for control treatment income didn't even touch the total investments (Table 6).

In case of combined effect of both factors under investigation (planting method and N levels) significant ($P \leq 0.05$) behavior was observed regarding the parameters plant height, filled grain density per panicle, sterility percentage, grain yield (t ha^{-1}), grand income and net profit. However, all other parameters were non-significant ($P \leq 0.05$) in the first year of study. In the second year, plant height, filled grain density per panicle, grain yield, grand income, net profit and benefit-cost ratio had also significant ($P \leq 0.05$) impact while other components remained non-significant ($P \leq 0.05$). During first year, maximum plant height (Table 6) and panicle length (Table 6) was recorded in DS×N_{199} and minimum in DS×N_0. However, in case of number of filled grains per panicle (Table 6) and grain yield (Table 7), highest values were achieved in BS×N_{166} and lowest were recorded for PTR×N_0. In case of sterility percentage (Table 6), lowest in BS×N_{166} and maximum in DS×N_0 was found and HI% (Table 7) showed a contrary response to this. Number of tillers m^{-2} (Table 6), 1000-grain weight (Table 7) and straw yield (Table 7) were highest in BS×N_{199} and lowest in PTR×N_0. On examining the interaction of both the factors under investigation, it becomes clear that RS × N_{166} resulted in highest net profit and cost-benefit ratio and lowest was recorded in PTR × N_0 (Table 8).

Discussion

Different planting techniques had significant effect on rice growth and development. Maximum plant height in DS might be attributed to better soil condition and more root proliferation leading increased plant height. Jamil *et al*. (2017) reported more plant height in DSR ridge sowing than drill and broadcast methods. More tiller density per unit area in RS was owed to more surface area available with looser and porous soil, ultimately enabling plants to uptake nutrient and water more efficiently, to enhance tillering (Zhang *et al*., 2003). Baloch *et al*. (2007) reported more tillers density in DSR ridge over parachute technology, PTR and DSR on flat. The effect of different planting methods was non-significant on panicle length as reported in DSR for broadcast and line sowing methods (Das *et al.*, 2015). More grain filling and less sterility in RS might be due to better vegetative growth on ridges that promoted higher assimilates contribution during the grain filling stage (Song *et al*., 2009). Thousand grain weight was not much influenced by planting techniques; however, comparatively heavier grains were recorded in RS might be due to more water retention in ridges for nutrient transportation during physiological maturity (Yuan-Zhi, 2015). Zhang *et al*. (2003) also reported more thousand grain weight in ridge cultivation over conventional rice cultivation. Grain yield and HI (%) are the most crucial components greatly influenced under varying plant establishment techniques and associated to other allometric traits like more plant population, higher filled grain number per panicle, 1000 grain weight and lowest sterility. This might be due to higher flag leaf chlorophyll content, slowed leaf aging, higher net photosynthetic rate (Ting *et al*., 2013), higher root biomass and root vitality (Dan-Ying *et al.*, 2008), enhanced tillering, increased leaf area index and ultimately contributing to higher grain yield and HI (Feng *et al.*, 2010). Lower yield in PTR was seem to be suffered by subsurface plough pan hindering root development and eventually crop growth and grain yield. Yuan-Zhi (2015) and Jamil *et al*. (2017) also reported higher grain yield in ridge cultivation over PTR, broadcast and drill sowing. Any of the crop establishment DSR methods were either more profitable as compared to PTR which is practiced by common farmers in Indo-Pakistan (Singh *et al*., 2004; Ali *et al*., 2012).

N is more volatile in nature and less stable in water, hence its efficiency is reduced due to volatilization and leaching (Ladha *et al*., 2005; Xu *et al*., 2013). Therefore, N fertilization management has a key role for the productivity enhancement of rice (Zou *et al.*, 2018). Thus, optimum supply of N is prerequisite need for enhancing farm yield. Higher dose of N probably promoted cellular activity giving more vegetative growth resulting in taller plants and more tillers. Manzoor *et al*. (2006); Pramanik and Bera (2013) reported 150 and 175 kg N ha^{-1} optimum N levels above and below of that significant yield losses were observed. However, filled grain density per panicle increased up to a certain level above that fell down and it might be due to excessive vegetative growth because of accelerated metabolic activity offering more accumulation in shoots (Hu *et al*., 2007; Huang *et al*., 2008; Yoseftabar, 2013; Hirzel *et al*., 2014). Increase in grain weight and grain yield with increments in N dose was observed up to a certain level after that it declined (Chen *et al*., 2014; Singh *et al*., 2015). Moreover, grain yield increases only up to particular level (Khan *et al*., 2006; Manzoor *et al*., 2006) above which more straw is produced (Yadi *et al*., 2012). In case of HI, results of present study are in conformity with Feng *et al.* (2010) who reported alternate wetting and drying performed better than submerged conditions.

Conclusion

Among all crop establishment methods, RS with 166 kg N ha^{-1} was the best combination producing maximum grain yield attributes, grain yield, and more economic returns under alkaline soil conditions and can be recommended for rice growers.

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[Received 24 Apr 2019; Accepted 15 Jul 2019; Published (online) 22 Dec 2019]