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Rice cultures and nitrogen rate effects on yield and quality of rice (*Oryza sativa* L.)

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Abstract: Field studies in 2010 and 2011 were conducted to evaluate the effect of variable nitrogen rates (0–100 kg N ha^{-1}) and culture methods (transplanted and direct) on chlorophyll contents, yield, grain quality, and economics in rice crop (*Oryza sativa* L. 'Basmati-385'). Transplanted rice gave a significantly higher paddy yield of 19.18% versus direct-seeded crop. Nitrogen application at 100 kg N ha^{-1} provided a maximum paddy yield (4.39 and 4.67 t ha^{-1}) in both years. The rice kernel characteristics were also affected by culture methods and nitrogen levels. In addition, return variable cost in the transplanted rice increased by 22.27% over direct-seeded rice. Regarding quality, the amylose (24.35%) and protein (8.56%) contents were also higher in transplanted rice as compared to direct seeding at 100 kg N ha^{-1} application. The lowest amylose contents were recorded in N_0 (23.55%) and N_1 (23.69%) treatments, and amylase contents were also found lower in N_0 and N_1 in the direct seeding method. The nitrogen rate and cultures method also affect the chlorophyll contents positively in transplanted plants at higher level of nitrogen. From the results, it is concluded that under the climatic conditions of Faisalabad, Pakistan, higher paddy yield and yield components, as well as greater economic benefits, can be obtained for the transplanted method at 100 kg N ha^{-1} nitrogen application as compared to the direct seeding method.

Key words: Rice culture, planting methods, nitrogen application, yield, quality, amylose content, *Oryza sativa* L.

1. Introduction

Rice is an important cereal crop of the world that provides the primary staple food for more than 2 billion people in Asia, the world's most densely populated region, and for hundreds of millions of people in Africa and Latin America. It is also the main cash crop and livelihood of the rural populations of these developing regions. Because of the large number of people subsisting on rice, its annual output should be increased by over 5×10^6 t a year just to keep pace with population growth (IRRI 1997). Moreover, its role in world trade seems to be certain and its demand in the international market would be well sustained for many years to come. The role of rice in the future will be more positive and conspicuous only if its quality and quantity is improved. Various techniques are in practice today to increase the yield of crops in response to increased consumption by using presowing seed or postemergence treatment (Perveen et al. 2011; Haq et al. 2012; Iqbal et al. 2012; Jamil et al. 2012; Naz et al. 2012; Shahzad et al. 2012; Shehzad et al. 2012a, 2012b). The quality of kernels can further be improved to attract the consumer and meet the international as well as the national requirements for good quality rice (Bhattacharyya and Singh 1992). Although the introduction of high yielding International Rice Research Institute (IRRI) rice varieties have revolutionized rice production in Pakistan, those varieties are no match for our conventional fine rice varieties, particularly Basmati, especially in quality. Transplanting and direct seeding are the 2 usual methods used for planting rice, transplanting being widely used. Direct seeding is practiced where water supply control is good. Advantages of direct seeding over transplanting include good stand establishment, higher tillering, and sometimes higher grain yield. Other advantages are stable growth and reduced lodging, better pest control, less risk due to drought and flooding damage, and low requirements for better water management practices (Farooq et al. 2007; Kang et al. 2012; Tohidi et al. 2012). In contrary, transplanting is more laborious, time-consuming, and expensive than direct seeding. This is because of difficulties in raising seedlings, high cost of labor, and labor shortage (Pandey et al. 2002).

Several reports have indicated that, besides lower labor involvement, there is no fundamental difference between direct seeding and transplanting if good management is

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practiced in rice culture (Akhgari and Kaviani 2011). Under proper cultural practices, however, direct seeding is significantly out-yielded by transplanted rice (Pandey et al. 2002). Effects of direct-seeded rice as compared to transplanting of fine rice on the growth, yield, and quality need to be investigated. The present study was therefore undertaken to determine and analyze the effect of different planting methods and nitrogen application rates on chlorophyll contents, quality, yield, and economic benefit of the fine rice Basmati-385.

2. Materials and methods

The cultivar Basmati-385, a commonly grown fine rice variety, was used as a test crop. The experiments were conducted at the Agronomic Research Area, University of Agriculture, Faisalabad (31°25′N, 73°09′E) for 2 seasons during 2010 and 2011. The soil was a sandy clay loam in texture. Before rice planting, a soil test showed a pH of 7.8 to 7.9, organic matter content varied from 0.69% to 0.73%, total nitrogen content from 0.063% to 0.069%, available P_2O_5 from 13.9 to 16.3 mg kg^{-1}, and extractable K_2O from 185 to 187 mg kg^{-1} in both years. The meteorological data regarding rainfall, relative humidity, and air temperature were recorded from a meteorological observatory in the immediate vicinity of the field during the phase of crop development as shown in Table 1. The experimental design for 2-year trials was a randomized complete block design in split plot arrangement with planting methods (i.e. direct seeding and transplanting through drilling) as the main factor and nitrogen rates (i.e. 0, 25, 50, 75, and 100 kg N ha^{-1}) for the layout of plots. The treatments with triplicate run were allocated in experimental units. Each plot consisted of 10 rows and 25-cm row spacing apart, for a net plot size of 6.0 m × 2.5 m.

All transplanting or direct seeding was performed on puddled soil. Seeds for direct sowing were soaked for 24 h prior to sowing. All the direct-seeded plots were sown manually with the help of a single row hand drill on 4 July 2010 and 28 June 2011, using a seed rate of 60 kg ha^{-1}. Transplanting was done manually on 4 July 2010 and 2011 using 30-day-old seedlings in both years. Nitrogen fertilizers were applied at the time of transplanting/drilling as a basal dose of respective rate and incorporated in the soil prior to planting. Phosphorus (23 kg ha^{-1}) as single super phosphate and zinc (10 kg ha^{-1}) as zinc sulfate were also applied at the time of seedbed preparation. After transplanting or sowing, irrigation water was applied and maintained until mid-ripening phase (2 weeks before maturity). Weeds were controlled by hand pulling and plant protection measures following the standard recommendations. An area of 5 m^2 was harvested from each plot at random, avoiding the border effects. Paddy yields were weighed by using a triple beam balance at 14% moisture level. The yield of clean rough rice was expressed in tons per hectare. To investigate the level of sterility, abortiveness, opaqueness, and percentage of normal kernels, 20 primary panicles from each treatment were collected and information was recorded after having the panicle carefully sketched for differentiation of different categories of kernels/spikelets. A common electric lamp with a flexible stand and seed working board were used for this purpose (Nagato and Chaudhary 1969). Physical dimensions (length × width) were recorded on 100 healthy and normal kernels from each treatment with the help of a dial caliper and repeated 3 times (Ahmed and Khalid 1985). Rice kernels were ground in a Retsch Mill equipped with 60-mesh screen for the determination of amylose contents (Inayatullah-Awan et al. 1989). The intensity of blue color was read in a Spectronic-20 at 620 nm. The protein contents were determined by micro-Kjeldahl method (N × 5.95). The water absorption ratio was determined from the weight of cooked rice per weight of raw rice (Juliano et al. 1965). An area of 100 cm × 100 cm was harvested from each plot and threshed manually. Kernels (m^{-2}) were air dried up to 14% moisture contents, weighed for kernel yield, and then expressed as t ha^{-1}.

Table 1. The metrological conditions during the experimentation.

	Temperature			RH	Rainfall	Panevaporation	Sunshine	ETo	Wind speed
	Max.	Min.	Avg.						
2010	°C	°C	°C	%	mm	mm	hours	mm	km h^{-1}
10 Jul	36.0	27.9	31.9	63.6	277.8	06.8	09.0	04.8	08.1
10 Aug	34.9	26.1	30.5	74.6	226.6	04.9	06.0	03.4	06.5
10 Sep	33.9	23.3	28.6	66.8	86.5	04.8	07.9	03.4	05.7
10 Oct	32.9	19.7	26.3	59.6	00.0	03.5	07.6	03.0	03.3

In 2011, the difference in weather conditions was ±2%. RH = relative humidity, ETo = evapotranspiration.

Chlorophyll a and b contents were determined following the method of Iqbal et al. (2012). Fresh leaves (0.2 g) were chopped and extracted overnight with 80% acetone at 4 °C. The extracts were centrifuged at 10,000 rpm for 5 min. Absorbance of the supernatant was read at 645 and 663 nm using a double beam spectrophotometer (CE Cecil 7200, Germany) and the contents of chlorophylls a and b were calculated by the following formulas:

Chl a = $[12.7 (OD_{663}) - 2.69 (OD_{645})] \times V/1000 \times W$,

Chl b = $[22.9 (OD_{645}) - 4.68 (OD_{663})] \times V/1000 \times W$.

All the data from all the experiments were analyzed on a personal computer using the analysis of variance function of the MSTAT statistical package (Steel et al. 1997). When the F-test indicated statistical significance, the treatments' means were separated using the least significance different (LSD) test at a 5% probability level.

3. Results

The paddy yield was not significantly affected by the planting methods in 2010 and ranged from 3.20 to 3.42 t ha^{-1} in the direct-seeded and transplanted methods. In 2011, transplanting culture enhanced paddy yield (4.43 t ha^{-1}) as compared to direct seeding (3.58 t ha^{-1}). Generally, increasing nitrogen rates significantly enhanced the paddy yield over the control (N_0) in both of the seasons (Table 2). The pooled data for the paddy yield were positively and strongly correlated with the total leaf area duration. The common regression accounted for 68.7% of the variability in the data. There was a linear relationship between total dry matter and paddy yield in both of the seasons. The common regression accounted for 93.2% of the variance in yield. In general, paddy yield was significantly but differentially affected by the increasing rates of nitrogen application, irrespective of planting method (Table 2). The higher yield in these treatments may be due to increased growth resulting in improvement in yield components. This probably contributed to less sterility, less abortive kernels, and higher grain weight and thus higher yield. Higher paddy yield was seen in transplanted versus direct-seeded rice. The transplanting method increased the paddy yield up to 6.43% (2010) and 19.18% (2011) over direct-seeded rice, especially at the higher rates of N applications. Yield response to applied nitrogen was significant at the rate of 75 kg N ha^{-1} in both the planting methods. These results differ from those of Dingkuhn et al. (1992), who reported slightly higher yields in row-seeded rice compared to transplanting. However, in another study, higher paddy yield in transplanted rice than row-seeded at lower N rates of application was reported (Furuya et al. 2005). Transplanted rice enables the crop to make rapid early growth, especially with adequate supply of N to intercept more solar radiation and thus to produce and fill spikelets. Similar results have also been previously reported (IRRI 1985; Raghuwanshi et al. 1986).

Table 2. Effect of planting methods and nitrogen rates on paddy yield and yield attributes of rice (*Oryza sativa* L.).

Treatments	PY		AK		OK		NK	
	2010	2011	2010	2011	2010	2011	2010	2011
Planting methods								
P_1	3.20	3.58^b	2.19^a	1.85^a	2.16	2.16^a	99.64^b	114.43^b
P_2	3.42	4.43^a	1.86^b	1.71^b	2.22	1.84^b	129.82^a	133.70^a
LSD ($P \leq 0.05$)	NS	0.35	0.14	0.12	NS	0.23	6.68	8.89
Nitrogen rates								
N_0	2.40^d	3.26^d	2.42^a	2.22^a	2.34^a	2.34^a	96.37^b	104.75^d
N_1	3.00^{bc}	3.85^c	2.09^b	1.74^{bc}	2.40^a	2.23^a	107.77^c	114.87^c
N_2	3.26^{bc}	3.99^c	1.92^{bc}	1.57^{bc}	2.27^{ab}	1.85^b	188.31^b	127.12^b
N_3	3.50^b	4.23^b	1.91^{bc}	1.52^c	2.05b^c	1.85^b	123.56^a	134.15^a
N_4	4.39^a	4.67^a	1.78^c	1.85^b	1.89^c	1.75^b	127.62^a	139.41^a
LSD ($P \leq 0.05$)	0.28	0.20	0.27	0.32	0.29	0.30	4.88	6.64

Any 2 means not sharing a letter differ significantly at $P \leq 0.05$; NS = nonsignificant; P_1 = direct seeding, P_2 = transplanting; N_0 = 0, N_1 = 25, N_2 = 50, N_3 = 75, N_4 = 100 kg N ha^{-1}; PY = paddy yield (t ha^{-1}), AK = abortive kernels, OK = opaque kernels, NK = normal kernels.

Abortive kernels were considered, in which fertilization does take place but the development of the kernel starts taking place sluggishly, which finally discontinues at the early development stage of the kernel. The occurrence of abortive kernels was significantly different between the 2 planting methods in both years. In 2010, the number of abortive kernels in the transplanted method was 1.86 in comparison to 2.19 in the direct seeding method. In 2011, equivalent figures were observed: 1.71 and 1.86, respectively (Table 2). Maximum abortive kernels (2.42) were recorded in control plots (N_0) compared to N_1 (2.09), N_2 (1.92), N_3 (1.91), and N_4 (1.78) treatments. The lowest abortive kernels were recorded (1.78) with application of 100 kg N ha^{-1}, which was statistically on par with N_3 and N_2 treatments. In 2011, a similar trend was observed, where N_0 also enhanced the number of abortive kernels over all other rates of N application. The number of abortive kernels was 2.22 in N_0, 1.74 in N_1, 1.57 in N_2, 1.52 in N_3, and 1.85 in N_4, respectively, in 2011.

Opaque kernels were considered as those that had stopped gaining weight at a little later stage of kernel development. These kernels do not get translucent or clear and have an overall chalky and porous structure due to shortage of filling material. The planting method did not significantly affect the number of opaque kernels $panicle^{-1}$ in 2010, and it varied from 2.16 to 2.22 opaque kernels $panicle^{-1}$ in both practices. However, in 2011 the number of opaque kernels $panicle^{-1}$ was significantly affected by the 2 culture methods. The direct seeding showed a higher number of opaque kernels of (2.16 vs. 1.84) over transplanting during the year 2011 (Table 2). The lower rate of opaque kernels in the transplanting method may be due to the availability of a sufficient amount of moisture at the dough and later kernel development stages, which facilitated the translocation of carbohydrates to the kernel at these stages (Nagato and Chaudhary 1969). In the case of the direct-seeding method, restricted moisture was available for translocation of already lower carbohydrates, and thus more opaque kernels were produced. Nitrogen rates also significantly affected the number of opaque kernels $panicle^{-1}$ in both seasons (Table 2). More opaque kernels were recorded in the control and N_1 (25 kg N ha^{-1}) treatments (2.34 and 2.40) as compared to higher rates of nitrogen application. In 2011, the average numbers of opaque kernels were also on par between N_2, N_3, and N_4 treatments and varied from 1.75 to 1.85 $panicle^{-1}$. Overall, opaque kernels varied from 2.05 to 2.40 $panicle^{-1}$ in both the seasons.

In 2010, the transplanting method increased normal kernels by 23.24% (129.82 vs. 99.64) over direct seeding. In 2011, transplanting also enhanced the normal kernels by 14.41% over direct seeding (133.70 vs. 114.43). Increasing rates of nitrogen significantly increased the number of normal kernels with lower rates of nitrogen application. However, N_3 and N_4 did not differ significantly in this respect. A similar study regarding the number of grains $panicle^{-1}$ was also reported previously for the transplanting method (Singh et al. 1981). These differential effects of planting methods or nitrogen rates affect the number of abortive and opaque kernels, which may be large enough to cause significant differences in the normal kernels.

The average kernel length varied from 6.6 to 6.7 mm in both of the planting methods. However, application of various nitrogen rates significantly affected kernel length in both years. In 2010, increasing rates of nitrogen increased kernel length over the control. However, kernel length was statistically on par in all of the nitrogen rates (N_1 to N_4) (Table 3). In 2011, the same trend was observed. The increasing rate of nitrogen from N_2 to N_4 enhanced kernel length over N_0 or N_1 (25 kg N ha^{-1}) treatments. Both N_0 and N_1 (25 kg N ha^{-1}) treatments were on par in kernel length in 2011. Overall, kernel lengths varied from 6.4 to 6.9 mm in various nitrogen treatments in both seasons. Nitrogen rates also did not affect the kernel width in the 2010 season. However, there were significant differences in kernel width among nitrogen rates during 2011. Maximum kernel width of 1.7 mm was recorded with the application of 100 kg N ha^{-1} (N_4 compared to N_0 and other nitrogen rates, except N_2, 50 kg N ha^{-1}), where the kernel width was on par with that of the N_4 treatment. Overall, the kernel width varied from 1.5 to 1.7 mm among various treatments in both the seasons (Table 3). Sidhu et al. (1989) reported kernel length of 7.15 mm and kernel width of 1.65 mm in Basmati-385, which is on par with that recorded in the present study.

Kernel length width ratio was not significantly affected by either planting method or nitrogen rates and varied from 4.0 to 4.2 among various treatments (Table 3). Under normal conditions, the kernel dimensions (length × width) are genetically determined in rice plants. In accordance with our results, a similar study was also reported previously for Basmati-385 rice (Sidhu et al. 1989).

The water absorption ratio was significantly higher in transplanting as compared to direct seeding in both seasons. The N_4 (100 kg N ha^{-1}) treatment showed a higher water absorption rate of 4.35% as compared to all other nitrogen rates in both seasons (Table 3). In 2011, both N_4 and N_3 rates were on par with each other in water absorption rate. On the average, water absorption rates were 3.76%, 4.01%, 4.17%, 4.31%, and 4.36% in N_0, N_1, N_2, N_3, and N_4, respectively (Table 3). These results are in line with those of Khan (1993), who also noted increased water absorption of rice kernels in transplanted rice and with higher rates of N application.

The transplanting method increased amylose content (24.33%) as compared to direct seeding (23.53%). Regarding nitrogen levels, a significant effect on the amylose content was observed during 2011, where

Table 3. Effect of planting methods and nitrogen rates on quality attributes of rice (*Oryza sativa* L.).

Treatments	KL (mm)		KW (mm)		KLWR		WAR (%)		AC (%)		PC (%)	
	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011
Planting methods												
P_1	6.6	6.7	1.6	1.6	4.1	4.1	4.00[b]	4.03[b]	24.51	23.53[b]	8.00	7.56[b]
P_2	6.7	6.7	1.6	1.6	4.1	4.0	4.19[a]	4.20[a]	24.74	24.33[a]	7.80	8.11[a]
LSD ($P \leq 0.05$)	NS	NS	NS	NS	NS	NS	0.08	0.07	NS	0.82	NS	0.08
Nitrogen rates												
N_0	6.4[b]	6.5[c]	1.6	1.5[b]	4.0	4.1	3.83[d]	3.76[d]	24.35	23.55[d]	7.12[e]	7.10[e]
N_1	6.8[a]	6.6[bc]	1.6	1.6[b]	4.2	4.1	3.95[c]	4.01[c]	24.36	23.69[d]	7.56[d]	7.60[d]
N_2	6.7[a]	6.8[ab]	1.7	1.7[a]	4.0	4.1	4.14[b]	4.17[b]	24.59	23.91[c]	7.95[c]	8.00[c]
N_3	6.7[a]	6.7[ab]	1.6	1.6[b]	4.1	4.1	4.21[b]	4.31[a]	24.65	24.15[b]	8.22[b]	8.41[b]
N_4	6.7[a]	6.9[ab]	1.7	1.7[a]	4.1	4.0	4.35[a]	4.36[a]	24.26	24.35[a]	8.65[a]	8.56[a]
LSD ($P \leq 0.05$)	0.2	0.30	NS	0.1	NS	NS	0.16	0.12	NS	0.15	0.18	0.11

Any 2 means not sharing a letter differ significantly at $P \leq 0.05$; NS = nonsignificant; P_1 = direct seeding, P_2 = transplanting; $N_0 = 0$, $N_1 = 25$, $N_2 = 50$, $N_3 = 75$, $N_4 = 100$ kg N ha^{-1}; KL = kernel length, KW = kernel width, KLWR = kernel length width ratio, WAR = water absorption ratio, AC = amylose content, PC = protein content.

amylose contents of 24.35% were recorded with the application of 100 kg N ha^{-1} (N_4) as compared to all other rates of nitrogen application. The lowest amylose contents were recorded in N_0 (23.55%) and N_1 (23.69%) treatments, respectively. The lowest amylose contents were noted in direct-seeded rice at N_0 or lower rates of N application (Table 3). Both the transplanting methods and increased rates of N application were at a greater advantage in terms of increased growth. This increased growth probably resulted in higher interception of radiation and thus greater production of photosynthate. Stimulation of growth could provide increased assimilates and metabolites resulting in increased amylose content. The average amylose contents varied from 23.93% to 24.44%, similar to results reported by Sidhu et al. (1989) for Basmati-385 rice (23.52%).

The transplanted rice showed higher protein contents (8.11%) as compared to the direct-seeded rice (7.56%). Application of nitrogen significantly and linearly increased protein contents in both seasons (Table 3). Application of 100 N ha^{-1} enhanced protein content up to 8.65% compared to all other nitrogen applications. The lowest protein contents of 7.12% in 2010 and 7.10% in 2011 were recorded in N_0 plots. In 2011, the average protein contents were 7.10%, 7.60%, 8.00%, 8.41%, and 8.56% with N_0, N_1, N_2, N_3, and N_4 treatments, respectively. Protein content in rice ranging from 6.0% to 8.0% in different agronomic treatments was also reported previously for the same cultivar (Khan 1993).

The transplanted rice showed considerably higher chlorophyll a and b contents as compared to the direct-seeded rice. The chlorophyll a and b contents of 1.99 mg g^{-1} and 0.67 mg g^{-1} in 2010 and 1.97 mg g^{-1} and 0.66 mg g^{-1} in 2011 were recorded, respectively, while these were 1.75 mg g^{-1} and 0.59 mg g^{-1} in 2010 and 1.76 mg g^{-1} and 0.58 mg g^{-1} in 2011 in direct-seeded plants. Application of nitrogen significantly and linearly increased chlorophyll contents in both seasons (Table 4). Application of N at the dose of 100 kg ha^{-1} also enhanced the chlorophyll a and b contents significantly. Lowest chlorophyll a and b contents of 1.13 mg g^{-1} and 0.38 mg g^{-1} in 2010 and 1.12 mg g^{-1} and 0.37 mg g^{-1} in 2011 were observed in N_0, which increased linearly with the nitrogen rate.

The data indicated higher net benefit in transplanting than in the direct seeding method by about 22.27% (3.41 vs. 4.10 t ha^{-1}). Application of different N levels markedly increased the net benefit over N_0. Maximum net return was obtained at 100 kg N ha^{-1} by Rs 17,205 (US$191) in 2010 and Rs 19,615 (US$218) in 2011, respectively (Table 5). The results showed that under climatic conditions of Faisalabad, Pakistan, transplanted rice produced higher yield and thus higher economic benefit with nitrogen application at the rate of 100 kg N ha^{-1}. There was no interaction between the culture method and nitrogen application. Both culture methods showed maximum response at a higher level of nitrogen application.

Table 4. Effect of planting methods and nitrogen rates on chlorophyll contents of rice (*Oryza sativa* L.).

Treatments	Chlorophyll content			
	Chl a (mg g^{-1})		Chl b (mg g^{-1})	
	2010	2011	2010	2011
Planting methods				
P_1	1.99	1.97	0.67	0.66
P_2	1.75	1.76	0.59	0.58
LSD ($P \leq 0.05$)	0.17	0.18	0.06	0.07
Nitrogen rates				
N_0	1.13	1.12	0.38	0.37
N_1	1.48	1.47	0.50	0.49
N_2	1.55	1.56	0.52	0.53
N_3	1.69	1.71	0.57	0.57
N_4	1.98	1.96	0.67	0.65
LSD ($P \leq 0.05$)	0.16	0.14	0.07	0.04

P_1 = direct seeding, P_2 = transplanting; N_0 = 0, N_1 = 25, N_2 = 50, N_3 = 75, N_4 = 100 kg N ha^{-1}.

Table 5. Economic analysis of rice (*Oryza sativa* L.) as affected by different planting methods and nitrogen rates during 2010 and 2011.

Treatments	Total variable cost (Rs ha^{-1})	Gross income* (Rs ha^{-1})	Total expenditures (Rs ha^{-1})	Net income (Rs ha^{-1})	BCR (%)
			2010		
Planting methods					
P_1	415.00	16,800	4499.00	12,301.00	2.73
P_2	741.25	17,955	4820.75	13,134.25	2.72
Nitrogen rates					
N_0	0	12,600	4820.75	7779.25	1.61
N_1	255.39	15,855	5076.14	10,778.86	2.12
N_2	511.36	17,115	5332.11	11,782.89	2.21
N_3	766.19	18,375	5586.94	12,788.06	2.29
N_4	1021.59	23,047.5	5842.34	17,205.16	2.94
			2011		
Planting methods					
P_1	433.00	19,869.00	4509.50	15,359.50	3.41
P_2	745.75	24,586.50	4825.25	19,761.25	4.10
Nitrogen rates					
N_0	0	18,093.00	4825.25	13,267.75	2.74
N_1	369.51	21,367.50	5194.76	16,172.72	3.11
N_2	739.02	22,144.50	5564.27	16,580.23	2.98
N_3	1108.54	23,476.50	5933.79	17,542.71	2.96
N_4	1478.05	25,918.50	6303.30	19,615.20	3.11

P_1 = direct seeding, P_2 = transplanting; N_0 = 0, N_1 = 25, N_2 = 50, N_3 = 75, N_4 = 100 kg N ha^{-1}.
*In 2010, 1 US dollar was equal to 90.08 rupees. In 2011, 1 US dollar was equal to 89.98 rupees.

4. Discussion

Maximum paddy yield was obtained in the transplanted method at higher rates of N application. The average paddy yield of the present study at 331 g m^{-2} (2010) to 400 g m^{-2} (2011) was similar to earlier experimental yields of cv. Basmati-385 (Sidhu et al. 1989). Generally, there is severe competition among spikelets for nutrients after fertilization, and formation of abortive kernel competition was reduced slightly in the transplanting method as compared to direct seeding with high nitrogen rate applications. Therefore, where occurrence of abortive kernels was high, opaque kernels were reduced, and vice versa. Ahmad et al. (2009) also reported similar effects of different planting methods on abortive kernels in rice crops and reported that fertilized plants efficiently utilize the micronutrients during their growth and development, resulting in increased synthesis of proteins and other biological molecules. Regarding seeding method, a number of authors have suggested the direct seeding method due to cost effectiveness and labor savings; however, the yield that they obtained was lower than that of the transplanting method (Naklang et al. 1997; Farooq et al. 2009). Bhuiyan et al. (1995) revealed that the rice growth duration decreased for 7 to 10 days by direct cultivation and also that land occupation can be decreased; thus, it saves water and labor by 25%–30%. Field experiments showed water savings of 12%–60% for the direct seeding method with lower yields for the transplanted method (Balasubramanian et al. 2003; Gupta et al. 2003). Other researchers also proposed the direct seeding method as compared to transplanting for increasing production and release of early cultivars and suggested the adaptation of the cultivation method according to factors such as workers, labor, and water savings (Pandey et al. 2002; Dawe 2005).

The main objective of rice planting is yield, which ultimately depends on the cost-to-benefit ratio and the marginal rate of return. In the present study, it was found that the transplanting method was better as compared to direct seedling regarding the quality, yield, and cost-to-benefit ratio. Various researchers suggested the use of the direct seeding method on the basis of labor, water utility, and time savings; however, they did not study the cost-to-benefit ratio, on the basis of which we can suggest the culture method. In other regions of the worlds, some other researchers also suggested the use of the direct method for rice cultivation. This difference might be attributed to the agroclimatic conditions, the soil, and rice cultivar differences. The results obtained in the transplanting method were found to be contrary in different reports (Pandey et al. 2002; Akhgari and Kaviani 2011). Furthermore, Farooq et al. (2009) recorded a higher number of sterile spikelets and abortive, opaque, and chalky kernels in direct seeding as compared to the transplanting method. Akhgari and Kaviani (2011) detected no significant difference between direct and transplanting methods in the case of number/panicle and differentiated both methods on the basis of environmental conditions. This difference might be attributed to the cultivar difference as well as the agroclimatic difference. In this regard, Pantuwan et al. (2002) revealed that the yield of early genotype cultivars was low because of their shorter growth duration, and seeding method was also a limiting factor. However, in conformity to results of the transplanting method, Nourbakhshian (2000) showed that the grain yield was very low in the direct method versus the transplanting method. Kukal and Aggrawal's (2002) views were neutral toward the direct and transplanting methods with respect to yield. However, the economic analysis of the direct and transplanting methods is the more reliable approach for generalizing the results.

In conclusion, we found that the transplanting method was superior regarding yield and other yield attributes under the agroclimatic condition of Faisalabad, Pakistan. The rice yield and quality were significantly affected by the seeding method. The photosynthetic rate was also affected by the seeding method positively and the significantly higher yield and other yield components may be due to the accelerated photosynthetic rate. The Basmati-385 fine rice responded to nitrogen application differentially in the case of the transplanting and direct seeded methods. However, there was no interaction between the seeding method and nitrogen application rate. Both culture methods showed higher yield at the highest level of nitrogen. The transplanting method was found better than the direct seeding method for the enhancement in yield and yield components at the same level of nitrogen application. The transplanting method showed a significantly higher cost-to-benefit ratio and marginal rate of return as compared to the direct method, and on the basis of the marginal rate of return, the adaptation of the transplanting method is suggested under agroclimatic conditions similar to those of Faisalabad, Pakistan.

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