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Pakistan Journal of Agricultural Research

Research Article

Impact of Planting Methods on Performance of PK-386 and Super Basmati at Different Locations

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Abstract | Field trials were conducted at eight different locations in Gujranwala and Sheikhupura districts during summer season, 2020 to determine the most profitable and economical planting method for PK-386 and Super Basmati cultivars of rice. Three planting methods viz. direct seeded rice (DSR), mechanical transplanting of rice (MTR) and conventional transplanting of rice (CTR) were compared at various locations. Data on yield-contributing traits and paddy yield were recorded. An Economic analysis was also carried out to determine the cost-effective planting method. Rice cultivars PK-386 and Super Basmati produced the highest number of tillers (410 and 350 m^{-2}) under DSR, while the lowest number (276 m^{-2} and 253 m^{-2}) from CTR, respectively. Number of grains per panicle and 1000-grain weight remained unaffected from planting methods whereas paddy yield was significantly influenced by various planting methods. The highest paddy yield of PK-386 and Super Basmati (5.59 t/ha and 4.34 t/ha) was recorded from DSR followed by MTR (4.82 t/ha and 3.92 t/ha), while the lowest paddy yield (4.50 t/ha and 3.80 t/ha) was observed from CTR. Economic analyses exhibited the highest net income (Rs.132308 and 302684 ha^{-1}) from PK-386 and Super Basmati, respectively grown under DSR. Among all the three rice planting methods, DSR attained the highest paddy yield as well as net income therefore, it is advisable that farmers should adopt DSR technology for growing both varieties.

Received | May 05, 2023; **Accepted** | September 19, 2024; **Published** | December 26, 2024
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Citation | Hussain, S., A. Naeem, A. Ameen, M. Yousuf, I. Hussain and M. E. Safdar. 2024. Impact of planting methods on performance of pk-386 and super basmati at different locations. *Pakistan Journal of Agricultural Research,* 37(4): 411-420.
DOI | https://dx.doi.org/10.17582/journal.pjar/2024/37.4.411.420
Keywords | Direct seeded rice, Mechanical transplanting, Conventional transplanting, Paddy yield, Economic analysis

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Introduction

In Pakistan, following wheat, rice stands as the second most crucial staple crop (Mahmood *et al.*, 2002). Over half of the world's population relies on rice as a primary dietary staple (Khush, 2004). Presently, Pakistan's per capita consumption of rice sits at 18 kg, projected to rise to 50.8 kg by 2035 as the population is estimated to reach 258.4 million (Ahmad *et al.*, 2017). It has become a major source of income among grain crops, contributing 0.5 percent to the GDP of the country. In 2021-22, national rice production was 9.32 million tons that was 10.7 percent above last year's production of 8.42 million tons. In the last few years, rice acreage has witnessed an increasing trend (Anonymous, 2022). The efficiency and longevity of rice-centric systems face challenges due to inefficient input utilization, increasing water and labor shortages, the impacts of climate change, looming energy and fuel crises, rising cultivation costs, and the emergence of socio-economic changes such as urbanization and labor migration (Ladha *et al*., 2009). Addressing these problems requires agricultural management and technological innovations.

Normally, rice is grown in all provinces of Pakistan and conventional method is adopted to raise the crop. Conventional transplanting involves more labor, water, and fuel costs because puddling is imperative to create a hard pan that resists water infiltration (Sanchez, 1973). Repeated puddling leads to alterations in soil physical properties, including the disruption of soil aggregates, decreased permeability in lower soil layers, and the creation of compacted layers at shallow depths (Sharma and De Datta, 1985; Aggrawal et al., 1995; Sharma et al., 2003). These changes can have adverse effects on subsequent non-rice upland crops within the crop rotation (Hobbs and Gupta, 2000; Tripathi et al., 2005). Moreover, both puddling and transplanting processes demand substantial quantities of water and labor, both of which are progressively scarce and expensive, consequently reducing the profitability of rice production. At the time of transplanting rice nurseries, water shortage is usually observed in the canals, which is ultimately compelling farmers to pump groundwater. About 3000 liters of water are needed to produce 1 kg of rice (Bouman, 2009). This unstoppable pumping of fresh water has forced the water table to drop. In this scenario, farmers seek alternative methods of rice sowing.

Alternate rice planting methods like direct seeded rice (DSR) and mechanical transplanting are feasible over conventional transplanting (Kumar and Ladha, 2011). These alternate methods ensure recommended plant population and can increase farm income (Ullah *et al*., 2016; Olabode, 2016). Mechanical Transplanting of Rice (MTR) is costly and involves the use of machines to transplant rice seedlings. This method is more efficient than conventional transplanting, as it can transplant seedlings at a much faster rate. In addition, it requires fewer laborers and can be done with less water, which can be an advantage in regions where water is scarce. Mechanical transplanting also ensures uniform spacing between seedlings, which can improve crop yields. It was preferred by farmers due to its ease of use and efficiency (Umar et al., 2022). In contrast to the conventional method of rice transplanting where seedlings are grown in a separate bed and then transplanted into water-filled fields, Direct Seeded Rice (DSR) involves sowing rice seeds directly into the field. This method eliminates the labor-intensive task of manually planting seedlings and significantly reduces the plants' water needs. DSR is extensively practiced in Pakistan, Bangladesh, and India within South Asia. However, insufficient weed management could lead to a substantial yield decrease of 50-91% (Hussain *et al*., 2008). Nonetheless, the effective control of weeds has been demonstrated through the utilization of pre and post-emergence herbicides (Moorthy and Mittra, 1992; Pellerin et al., 2004). The DSR reduces about 30% labor cost and saves 20% water compared with conventional transplanting (Saleem *et al*., 2020). In a previous study, effect of six planting methods of rice was compared and a higher tillers m^{-2} were recorded in DSR compared to conventional and mechanical transplanting (Ali *et al*., 2012). Saleem *et al*. (2020) reported 20% higher paddy yield in DSR over conventional transplanting. In short, each method of rice cultivation has its own advantages and disadvantages in the context of rice cultivation in Pakistan. Conventional transplanting is still widely practiced, however, it demands a substantial labor force and necessitates a considerable quantity of water. DSR is a viable alternative to conventional transplanting, but it requires careful management of weeds, pests, and diseases. Ultimately, the selection of cultivation method will depend on the certain conditions of each farm, and farmers should cautiously evaluate the pros and cons of each method before planting.

PK-386 and Super Basmati are two popular rice varieties grown in Pakistan. PK-386 is a high-yielding rice variety that was developed by Rice Research Institute (RRI), Kala Shah Kaku, Pakistan. It is known for its long grain length, fine cooking quality, and resistance to diseases and pests. PK-386 is popular for its export quality and is commonly exported to countries like China, Iran, and the United Arab Emirates (Akhtar *et al*., 2015). Super Basmati is another popular rice variety in Pakistan. It is known for its distinct aroma, flavor, and delicate texture. Super Basmati is grown mainly in the Punjab province of Pakistan and is considered one of the best types of basmati rice in the world (Akhtar and Haider, 2020). Both PK-386 and Super Basmati are important rice varieties for Pakistan's economy, as rice is a major export crop for the country. According to the Pakistan Bureau of Statistics, in 2021, Pakistan exported more than 4.2 million metric tons of rice of worth more than 2.2 billion USD (Anonymous, 2021). Both PK-386 and Super Basmati are popular rice varieties among farming community of the country. This research aimed to evaluate various rice planting methods to identify the most profitable, cost-effective, and suitable approach for establishment of PK-386 and Super Basmati.

Materials and Methods

Study Site

Field experiments were laid out at eight different locations of districts Gujranwala and Sheikhupura during the summer season, 2020. Farm locations are given in Table 1.

Table 1: *Details of eight selected Agriculture Farms.*

Variety	S.No.	Farm Name	Address
PK-386	1	Nasir Farm	Sher Pur, District Gujranwala
	2	Faisal Farm	Bhoma Bath, District Gujranwala
	3	Shahid Farm	Kot Ladha, District Gujranwala
	4	Naeem Farm	Nokhar, District Gujranwala
Super BasMATI	1	Azhar Farm	Moza Kalair, District Gujranwala
	2	Mirza Farm	Kot Baray Khan, District Gujranwala
	3	Anwar Farm	Hamboki, District Gujranwala
	4	PARC Farm	Kala Shah Kaku , District Sheikhupura

Experimental design and treatments

Two rice varieties PK-386 and Super Basmati were selected according to farmers' preferences. For the study, three rice stand establishment methods i.e. direct seeded rice (DSR), mechanical transplanting of rice (MTR) and conventional transplanting of rice (CTR) were compared at each location. The trials were conducted using a randomized complete block design (RCBD) comprising three replications. The plot size was 600 m^2.

Crop Husbandry

Seed of both varieties was used at the rate of 35 kg ha^{-1}, 30 kg ha^{-1} and 12.5 Kg/ha for DSR, MTR and CTR, respectively. Sowing and seedling transplanting dates of different planting methods are given in Table 2. Nursery for MTR was sown in plastic trays by involving service providing firm Chairman Sons, Gujranwala. To control the weeds in nursery, recommended herbicides were applied. The experimental plots were adequately prepared, utilizing NPK fertilizers at rates of 134 kilograms per hectare for nitrogen, 86 kilograms per hectare for phosphorus (in the form of di-ammonium phosphate), and 60 kilograms per hectare for potassium (as potassium sulfate).

In MTR and CTR, twenty-five to thirty days old seedlings were transplanted. The MTR was done with rice transplanter while conventional transplanting was done with the help of labor in the puddled field. Pre-emergence herbicides i.e. pendimethalin in case of DSR and butachlor in case of mechanical and conventional transplanting fields were applied at the rate of 2.5 L ha^{-1}. Additionally, Puma Super @ 625 ml ha^{-1} + Winsta @ 250g ha^{-1} was sprayed as post emergence herbicides to manage weeds complex in DSR. Other recommended agronomic practices were followed during the course of study.

Data recording and statistical analysis

Data regarding yield-related characteristics such as tiller count per square meter, panicle length (cm), number of grains per panicle, 1000-grain weight (g), and paddy yield per hectare (kg ha^{-1}) was gathered and subjected to statistical analysis using Statistix 8.1. Locations were treated as main factor and different planting methods were kept as sub-factor for analysis. The comparison of treatment means was conducted using the least significant difference test at a probability level of 0.05 (Steel *et al*., 1997). An economic analysis was also carried out to determine the cost-benefit ratio of various planting methods of rice.

Results and Discussion

Analysis of variance (ANOVA)

Statistically evaluated data are presented in Table 3 and Table 4. Planting methods showed a significant difference in number of tillers m^{-2}, panicle length and

Table 2: *Sowing and transplanting dates of PK-386 and Super Basmati in different planting methods.*

Variety	Planting Methods	Sowing date	Seedling transplanting date
PK-386	Direct Seeded Rice (DSR)	19-06-2020	-
	Mechanical Transplanting (MTR)	01-06-2020	01-07-2020
	Conventional Transplanting (CTR)	01-06-2020	02-07-2020
Super Basmati	Direct Seeded Rice (DSR)	22-06-2020	-
	Mechanical Transplanting (MTR)	20-06-2020	22-07-2020
	Conventional Transplanting (CTR)	20-06-2020	22-07-2020

Table 3: *Analysis of variance for yield contributing traits of PK-386 variety as affected by various planting methods (Mean Squares).*

SOV	DF	Tillers m^{-2}	Panicle length (cm)	Grains/Panicle	1000-grain weight (g)	Paddy Yield (t/ha)
Location	3	3690.9^{ns}	1.85618^{ns}	1963.88**	5.45889**	0.40833**
Error(a)	6	1305.5	0.6191	56.94	0.24694	0.02142
Planting Method	2	57232**	1.3819**	88.11^{ns}	0.24778^{ns}	3.80163**
L*PM	6	2050**	2.08679**	205.52^{ns}	0.21556^{ns}	0.24532**
Error(b)	16	429.4	0.21127	84.92	0.10653	0.0475
Total	35					

Table 4: *Analysis of variance for yield contributing traits of Super Basmati variety as affected by various planting methods (Mean Squares).*

SOV	DF	Tillers m^{-2}	Panicle length (cm)	Grains/Panicle	1000-grain weight (g)	Paddy Yield (t/ha)
Location	3	4612.8**	26.3669**	1905.56**	6.75741*	0.8112**
Error(a)	6	427.1	0.1011	24	0.7563	0.01661
Planting Method	2	28461.4**	6.9419**	30.53^{ns}	0.11694^{ns}	0.97425**
L*SM	6	1350.7**	3.3297**	46.31^{ns}	0.64435^{ns}	0.14406**
Error(b)	16	282.7	0.3882	66.07	1.43083	0.01577
Total	35	99.4	2.2544	149.78	1.02111	0.11192

** = Significant ($P \leq 0.01$)

paddy yield for both cultivars. All traits were influenced significantly by different locations except tillers number and panicle length of PK-386. The interaction of locations and planting methods was also significant for all parameters except number of grains per panicle and 1000-grains weight (g) in both cultivars.

Tillers per square meter

The highest number of tillers (m^{-2}) was observed in direct seeded rice (DSR) and the lowest tillers (m^{-2}) were showed by conventional transplanted rice (CTR) for both cultivars; PK-386 and Super Basmati (Table 5). Relatively higher average number of tillers per unit area were observed from PK-386. It showed the highest tillers m^{-2} (445) at Naeem Farm sown under DSR and the lowest number of tillers m^{-2} (248 tillers m^{-2}) at Faisal Farm when sown under CTR (Figure 1). While the Super Basmati showed the highest value of tillers m^{-2} (377) in DSR at PARC Farm, and the lowest value of 240 tillers m^{-2} at Mirza Farm under CTR system (Figure 1). The average across locations showed that PK-386 and Super Basmati sown under DSR produced more tillers (410 m^{-2} and 350 m^{-2}, respectively) than sown under CTR (276 & 253 m^{-2}, respectively). Mechanical Transplanting also improved the tillers number compared with CTR, however, it was below DSR in both varieties and at all locations. These findings are consistent with the results of Rashid *et al.* (2009), who suggested that DSR sown through drum produced more tiller m^{-2} than transplanted rice. This argument also agrees with the results of Ehsanullah *et al.*, (2007), Ali *et al.*, (2012) and Saleem *et al.* (2020) who evaluated various establishment methods and found the highest number of tillers

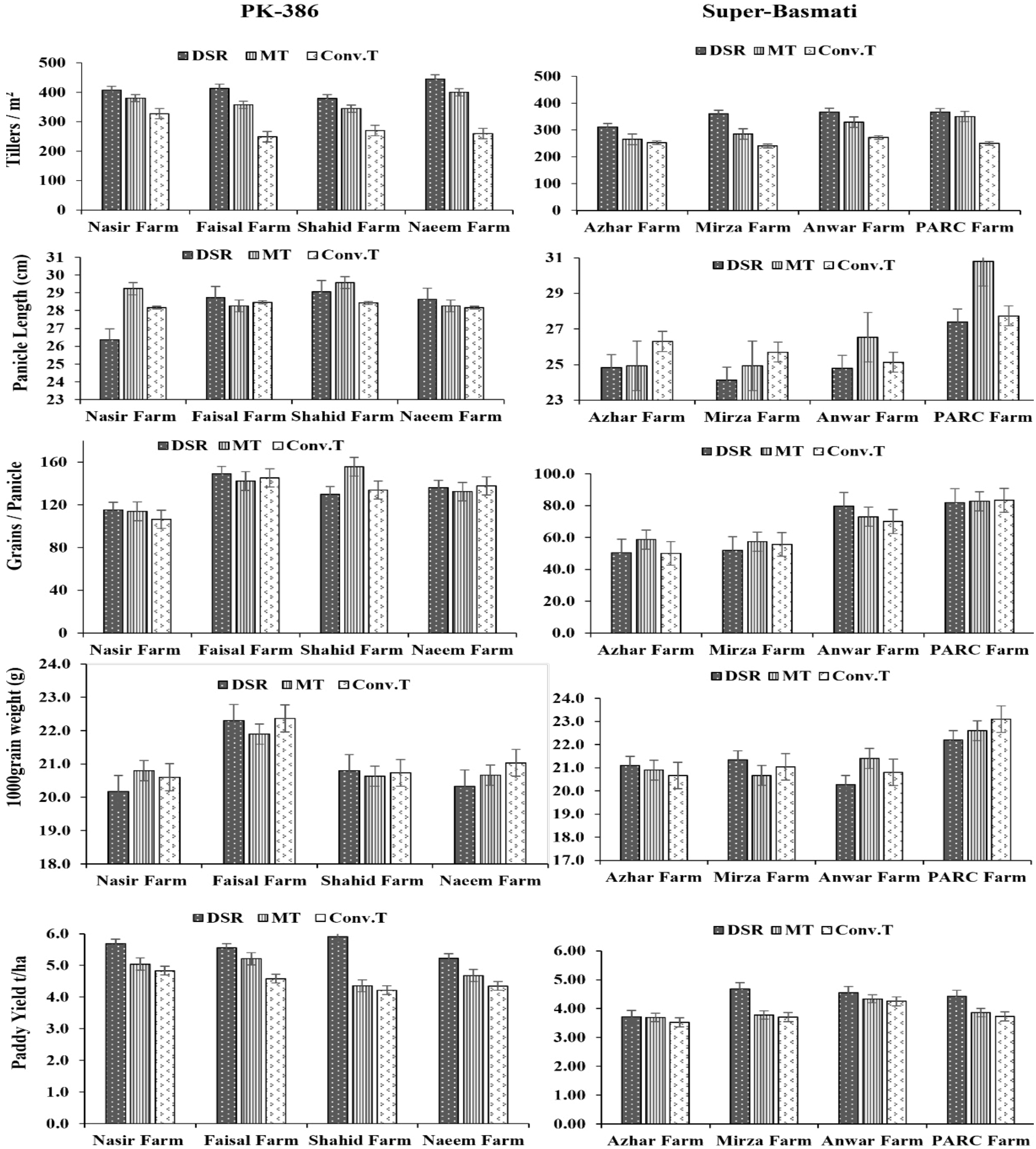

Figure 1: *Yield contributing traits of two rice varieties PK-386 and Super Basmati with three planting methods; direct seeded rice DSR, mechanical transplanting rice (MTR) and conventional transplanting rice (CTR) at different locations.*

in DSR as compared to other planting methods. Direct seeding was found as the appropriate technique to obtain proper plant population and number of tillers which can ensure optimum crop cover and ultimately the higher paddy yields.

Panicle Length (cm)

The maximum average panicle length was observed from both rice varieties planted under MTR system while the lowest panicle length of these varieties was recorded when sowing under DSR. Generally,

Table 5: *Average values of yield contributing traits of 8 different locations (4 locations for each variety)/ planting methods.*

Variety	Planting Methods	Tillers m^{-2}	Panicle length (cm)	Grains/Panicle	1000grain weight (g)	Paddy Yield (t/ha)
PK-386	Direct Seeded Rice (DSR)	410 a	28.19 b	132	20.90	5.59 a
	Mechanical Transplanting	370 a	28.83 a	136	21.18	4.82 b
	Conventional Transplanting	276 b	28.30 b	130	21.00	4.49 c
LSD (0.05)		41.67	0.39	NS	NS	0.16
Super Basmati	Direct Seeded Rice (DSR)	350 a	25.29 c	66	21.20	4.34 a
	Mechanical Transplanting	306 b	26.80 a	67	21.40	3.91 b
	Conventional Transplanting	253 c	26.21 b	64	21.38	3.80 b
LSD (0.05)		23.83	0.36	NS	NS	0.14

longer panicles were produced by PK-386 compared with Super Basmati (Table 5). The maximum panicle length of PK-386 (28.83 cm) was recorded from MTR at Shahid Farm and the shortest panicles of 25.29 cm length were observed from DSR at Nasir Farm. Longest panicles of Super Basmati were found from MTR at PARC Farm while the shortest were noted from DSR at Mirza Farm. The results are consistent with the observations of Hussain *et al.* (2013), who found shorter panicles in DSR compared to CTR. Shorter panicles recorded from DSR may be ascribed to dense plant population which offered more competition for panicle growth.

Number of grains panicle^{-1}

Various locations influenced grains per panicle of both rice varieties significantly while the effect of planting methods as well as their interaction with locations remained non-significant on grains/panicle (Tables 3 and 4). PK-386 produced higher average number of grains per panicle as compared with Super Basmati. Significant impact of locations on grains number may be attributed to different growth environment at various locations. These results are in congruence with those of Hussain *et al.* (2013) who concluded that different locations may affect the grains per panicle due to variable environmental conditions. Awan *et al.* (1989); Majid *et al.* (1989); Song *et al.* (2009) observed minimal variations in the number of grains per panicle across various methods. Our findings also confirm these observations in which method of planting had no bigger impact on number of grains per panicle. Conversely, Ali *et al.* (2012); Iqbal *et al.* (2019) documented a higher count of grains per panicle in DSR compared to CTR.

1000-grain weight (g)

The thousand grain weight was significantly influenced by different locations, while the effects of different planting methods and their interaction with locations were not significant. (Tables 3 and 4). Although heavier grains were recorded from transplanted rice compared with direct seeded yet the impact was not significant in both varieties. Various locations influenced 1000 grain weight significantly due to variations in growing environments. Luzes (1991), Gitsopanlos and Willams (2004); Sudhir *et al.* (2007); Farooq *et al.* (2011) documented reduced 1000 grain weight in DSR compared with conventional. Our results suggest that there is no significant impact of different planting methods on 1000 grain weight of rice.

Paddy yield (t ha^{-1})

Paddy yield data were presented in Table 5 and Figure 1. It was found that the paddy yield was significantly influenced by different planting methods. The highest paddy yield was observed in DSR followed by MTR, and the lowest paddy yield was recorded in CTR for both PK-386 and Super Basmati. The higher paddy yield in DSR and lower with CTR may be ascribed to larger number of tillers in DSR method. Number of productive tillers played a major role towards increasing Paddy yields in both rice varieties. Zheng *et al.* (2004) reported that paddy yield differed by different planting methods and depended upon plant population and number of productive tillers. Zhou-Han-Liang (2011) also got higher paddy yield with DSR in their experiments. Our results are in line with previous findings of higher paddy yields with higher number of productive tillers which can be achieved through direct seeding of rice.

Variety PK-386 exhibited its highest paddy yield (5.5 t ha^{-1}) from DSR at Shahid Farm, while its lowest yield (4.4 t ha^{-1}) was also observed at the same lo

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Table 6: *Economic analysis of different crop establishment techniques in PK-386 and Super Basmati cultivars.*

Inputs/Activity	PK-386			Super Basmati		
	DSR	MTR	CTR	DSR	MTR	CTR
Land preparation	4100	8000	8000	4100	8000	8000
Sowing/Transplanting	3300	11500	7750	3100	6700	6700
Fertilizer	23500	24000	24000	17000	17900	17900
Plant Protection	5500	4800	2850	5500	4800	2850
Irrigation	14250	11400	11400	14250	11400	11400
Harvesting	6000	6000	6000	6000	6000	6000
Total production cost	56650	65700	60000	49950	54800	52850
Average Yield (Maunds/acre)	55	48	45	43	39	38
Gross Income @Rs. 2000/40 kg for PK-386 @Rs. 4000/40 kg for Super. Basmati	110000	96000	90000	172000	156000	152000
Net Income (Rs.)/acre	53350	30300	37200	122050	101200	99150
Net Income (Rs.)/ha	132308	75144	92256	302684	250976	245892
BCR (GI/C)	1.94	1.46	1.50	3.44	2.85	2.88

cation when transplanted conventionally. Regarding Super Basmati, the maximum paddy yield (4.3 t/ha) was recorded from DSR at Mirza Farm, while its lowest paddy yield (3.8 t/ha) was obtained from CTR at Anwar Farm. Variation in paddy yield at different locations may be attributed to variation in fertility status and other growth environment which influenced number of grains and 1000 grain weight ultimately changing paddy yield.

Economic analysis

The economic evaluation demonstrated the greatest net income (Rs.132308 ha^{-1}) from DSR, followed by CTR (Rs.92256 ha^{-1}) for PK-386 variety (Table 6). Although MTR depicted higher gross income than conventional, yet the net income was less due to higher costs involved. DSR also showed the highest net income (Rs.302684 ha^{-1}) followed by MTR method for Super Basmati variety. The highest benefit cost ratio was obtained from DSR method in both varieties (1.94 and 3.44, respectively). MTR showed the highest production costs, while DSR showed the lowest production costs for both cultivars. Previous studies also proved DSR to be the most profitable method (Von Braun and Bos, 2004; Singh and Singh, 2007; Kumar *et al*., 2009).

Conclusion and Recommendations

The study concluded that direct seeded rice gave higher paddy yield (5.5 and 4.3 t ha^{-1}) with the highest cost-benefit ratio (1.94 and 3.44) from PK-386 and Super Basmati rice varieties, respectively. Conventional rice transplanting produced the lowest paddy yield (3.8 t ha^{-1}) due to less productive tillers and low plant population. DSR is a viable option to conventional transplanting, but it requires careful management of weeds, pests, and diseases. Farmers can save their inputs and achieve the best results in terms of rice yield and net income by adopting DSR technology.

Acknowledgments

The experiments of this study were financially supported by PSDP Project "*Productivity Enhancement of Rice*" funded by Federal Government of Pakistan. We are thankful to all staff members who conducted the trials at the farmers' field and helped to record the data. We are also thankful to the farmers who cooperated with the scientist during the study.

Novelty Statement

Aerobic rice production is a new technique having economic benefits over conventional system of rice crop establishment. It presents an effective weeds management strategy in different methods of rice production.

Author's Contribution

Shahbaz Hussain: Conceived the idea, conducted experiments, collected data and wrote up the manuscript.

Atif Naeem: Analyzed the data and drafted the manuscript.

Asif Ameen: Reviewed and improved the manuscript.

Muhammad Yousuf: Supervised the study, provided budget for carrying out the study and provided technical guidance at every step.

Imtiaz Hussain: Supervised the study, and gave technical suggestions during course of study and manuscript preparation.

Conflict of interest

The authors have declared no conflict of interest.

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