Research Article

Reduced Water Use and Labor Cost and Increased Productivity of Direct Seeded Basmati Rice in Punjab, Pakistan

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Abstract | Rice (*Oryza sativa* L.) is a main staple food in Pakistan, after wheat and is generally cultivated through raising nursery seedlings and transplanting them in puddled soils. Declining surface water, high cost of pumped groundwater, high labor costs, and drudgery in manually transplanted rice (TPR) have motivated researchers to develop alternated technology such as direct seeded rice (DSR). About 30% of total water used in rice cultivation is consumed for puddling of soil (land preparation) and transplanting operations. Physical properties of soils are deteriorating due to continued puddling over the decades, resulting in structural breakdown leads to a compacted layer (the plough plate) that acts as a barrier to the infiltration of water and causes temporary waterlogging, which confines the penetration of roots and growth of a subsequent wheat crop after the harvesting of rice crop. DSR technology helps by eliminating the need for continuous ponding of water and thus lessens water use for rice production, resulting in saving of 15-20% of water over TPR. DSR is also a less labor-intensive and more farmers-friendly, time-saving and cost-effective technology than TPR. The Rice Research Institute, Kala Shah Kaku, has refined the DSR technology and production practices and conducted 20 field demonstrations of DSR with modified seed drills during 2017 in Gujranwala, Hafizabad, Narowal, Sheikhupura, and Sialkot districts. The super basmati rice variety was direct seeded in comparison with manually TPR. The DSR was carried out in well prepared dry seed bed with the help of tractor mounted rice drill. Irrigation was applied immediately after sowing and after 24 hours pendimethline was sprayed as pre-emergence weedicide. The irrigation was repeated about 4-5 days after pre-emergence weedicide application and afterwards about 3-5 days interval till tillering phase and then 5-7 days interval till crop maturity. The overall results indicated that paddy yield was 20% higher under DSR as compared to TPR. Moreover, during 2017 in Punjab Province, Pakistan, more than 2500 farmers cultivated rice using DSR on an area of about 10000 ha and found it more cost effective than manually TPR. Therefore, farmers can opt this technology to harvest maximum benefits.

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Introduction

After wheat (*Triticum aestivum*), rice (*Oryza sativa* L.) is the main staple food crop in South Asia (Ladha et al., 2000) and more than half of the world's population consumes rice as the major food (Khush, 2004) because a combination of energy enriched compounds are available in rice. Rice contributes about 30–75 % of calories consumed by more than 3 billion Asians (Khush, 2005) and in Pakistan per capita rice demand will increase from 36.2kg (in 2014) to 50.8kg for forecasted population of 258.4 million in 2035 (Ahmad et al., 2017).

Because rice is a semi-aquatic plant, it is usually cultivated by raising nursery seedlings and transplanting them into puddled soil. This practice is cumbersome and labor intensive, and demands continuous standing water for 20–30 days, requiring a large amount of water (Brar et al., 2012). On an average, 3000 liters of water are required for producing 1 kg of rice (Bouman, 2009) and mostly irrigation is done through pumping of groundwater, consuming 13% of total energy required for rice (Khan et al., 2009), due to the shortage of canal water, especially at the time of transplanting. This has resulted in the rapid decline of the water table in rice districts of Punjab, Pakistan. Similarly, careless transplanting by hired labor results in low planting densities in farmers' fields, which is a major cause of reduced yields. Because transplanting is done manually in the hot and humid season, and farm labor often does not transplant the required number of seedlings per hectare despite all efforts made to disseminate good production practices.

Conventional tillage such as transplanted rice (TPR) demands a huge quantity of labor and water, both of which are increasingly rare and expensive (Bhushan et al., 2007) Hence, manual transplanting has been achieving lower yields due to less plant populations. The timing of transplanting is important for getting the optimum yield of basmati rice but the window for transplanting is short and, due to the shortage of labor, it is very difficult to transplant the farm area within recommended transplanting season.

In Pakistan, the area under rice is 2.72 million ha, producing 6.85 million tons of rice annually with an average yield of 2514 kg ha^{-1} (Anon., 2017). According to Crop Reporting Services, Punjab 2017, rice was cultivated on 1.842 million ha in Punjab and produced 3.85 million tons paddy. This average production is low due to the above-mentioned constraints and Aslam, 2016 reported 61 % lower yield nationally than average yield obtained internationally. However, it can be improved by adoption of good agriculture practices. Moreover, Traditional TPR is also a main source of greenhouse gas emissions, predominantly methane, which is also one of the contributing factor to global warming. Thus, there is a dire need to introduce technically practical and economically feasible techniques for growing paddy rice and to demonstrate standardized techniques on farmers' fields for their wider adaptability and acceptability.

To achieve the recommended plant population, the only alternative technologies to manually TPR are DSR or mechanized rice transplanted and these could be adopted to uplift the farm incomes as suggested by Olabode (2016) and Ullah et al. (2016). Mechanized transplanting is costly but has recently being introduced in Punjab. In the short term, the DSR method is a better option. In traditional rice cultivation, rice is sprouted in a nursery and sprouted seedlings are then transplanted into standing water. In DSR, rice seed is sown and sprouted directly in the field, eliminating the laborious process of planting seedlings by hand and greatly reducing the crop's water requirements. Therefore, direct seeding of rice under aerobic conditions is an alternative to replace the traditional TPR method. The DSR method not only saves irrigation water but also minimizes drudgery and helps reduce the cost of cultivation. Thus, DSR is a potential alternative to conventional TPR (Kumar and Ladha, 2011). DSR saves 13–15% of water use (Mann et al., 2004) and 50% of labor cost (Pandey and Velasco, 1999) compared to TPR. Although higher than recommended plant populations can be achieved through DSR. In South Asia, DSR is widely grown in Bangladesh and India, but suboptimal weed management practices can lead to a 50–91% reduction in yield (Fujita, 1996; Hussain et al., 2008). However, the use of pre-emergence and post-emergence herbicides has been explored to effectively control weeds (Moorthy and Mittra, 1992; Pellerin and Webster, 2004).

The objective of this study was to popularize the DSR technology through farmers' field days, seminars, and training focused on the problems of the farmers may face, and by raising demonstration plots on farmers' fields in five districts (Gujranwala, Hafizabad, Narrowal, Sheikhupura, and Sialkot) of Punjab. The present study was also designed to compare paddy productivity in DSR and traditional TPR.

Materials and Methods

In this study, the DSR technology was compared with manually transplanted rice at 20 sites: Mouza Ugo chack, Chack Ishaq, Manga Qadeem, Sokanwind, Gkharwali, Mangian, Panj Hatha, Pooran Pur, Budha

Rajadha, Rakh Boharoky, New Ghania Kalon, Chak Ramdas, Kot Harry Chand, Hardo Sehol Muslim, Roranwala Dera, Islam Pur, Gorian, Kot-Hadayat Ali, Manawala, and Lahorian in five districts Gujranwala, Hafizabad, Narrowal, Sialkot, and Sheikhupura. The range of physico-chemical characteristics of the soil at the 20 sites is given in Table 1. For the preparation of seed bed, irrigation was applied and during 1–20 June 2017, DSR was planted using a rice seed drill in already well-prepared laser-leveled dry soil at all the sites except two Kot Harry Chand and Kot Hadayat Ali where DSR was planted during 21–22 June. Certified seed of super basmati (*Oryza sativa* L.) was used, treated with Topsin M @ 2.5 g kg^{-1} and the seed rate was 24.5 kg ha^{-1}. The drill was transported from the Rice Research Institute, Kala Shah Kaku to the 20 destinations by truck on the day of seeding. At the time of seeding, urea (45 kg nitrogen ha^{-1}), diammonium phosphate (84 kg phosphorus ha^{-1}), and potassium sulphate (62 kg potassium ha^{-1}) were applied. The remaining nitrogen fertilizer was applied in two equal splits, and zinc sulphate 33% was applied with the 1st application of nitrogen 30–35 days after seeding (DAS).

Table 1: *Physico-chemical characteristics of the 20 demonstration sites.*

Parameters	Soil depth	
	0–6 Inch	6–12 Inch
Electrical Conductivity (dSm^{-1})	1.42-3.1	0.89-1.5
Soil pH	8.0-8.31	8.14-8.35
Organic Matter	0.35-0.40	0.15-0.25
Nitrogen (%)	0.4-0.47	0.20-0.26
Available Phosphorus (ppm)	5-5.5	4.5-5.2
Available Potassium (ppm)	90-94	75-78
Saturation (%)	40-43	33-36
Texture	Clay loam to loam	Clay loam

Immediately after planting the dry seed, the soil was irrigated, and pre-emergence weedicide was applied 24 hours after irrigation while the soil was in a saturated condition. Before pre-emergence weedicide application, the field must be without standing water because in Pakistan, pre-emergence weedicide is not available with rice safener and phyto-toxicity or low germination will result if the chemical comes in contact with the rice seed. Before applying the pre-emergence weedicide, the weather forecast was also checked for each site, because if there is rain after seeding, the pre-emergence weedicide is not applied. At Sokanwind and Islampur, pre-emergence weedicide was not applied due to rain after seeding.

Irrigation was applied 4–5 days after the application of pre-emergence weedicide, and then irrigation was applied at 3–5 day intervals to keep the soil saturated until the tillering phase was completed and then 5-7 days interval till crop maturity. The plots were then irrigated every 3 days interval. For comparison, near the demonstration site a nursery was sown for conventional transplanting in the farmers' fields. The nursery was sown by broadcasting sprouted seed in puddled soils, and which were then uprooted and transplanted manually during 1–20 July when the seedlings were 25–35 days old. DSR sowing and transplanting dates are given in Table 2.

Table 2: *DSR sowing dates and transplanting dates at the 20 locations.*

No.	Location	DSR sowing dates	Transplanting dates
1	Ugo Chak	08.06.2017	15.07.2017
2	ChakIshaq	08.06.2017	15.07.2017
3	Manga Qadeem	16.06.2017	19.07.2017
4	Sokanwind	05.06.2017	05.07.2017
5	Gakharwali	05.06.2017	05.07.2017
6	Mangian	06.06.2017	10.07.2017
7	Panj Hatha	13.06.2017	13.07.2017
8	Pooran Pur	09.06.2017	09.07.2017
9	Budha Rajadha	09.06.2017	09.07.2017
10	Rakh Bharokay	07.06.2017	20.07.2017
11	New Ghania Kalan	07.06.2017	07.07.2017
12	Chak Ramdas	12.06.2017	12.07.2017
13	Kot Harry Chand	21.06.2017	21.07.2017
14	Hardo Sehol Muslim	19.06.2017	20.07.2017
15	Roranwala Dera	15.06.2017	20.07.2017
16	Islam Pur	13.06.2017	15.07.2017
17	Gorian, Sidhanwali	15.06.2017	15.07.2017
18	Kot Hadayat Ali	22.06.2017	18.07.2017
19	Manawala	15.06.2017	17.07.2017
20	Loharian	19.06.2017	19.07.2017

The post-emergence herbicide (bispyribac-sodium + bensulfuron) at the rate of 247 g ha^{-1} was sprayed at 18–22 DAS in saturated soil conditions to control weeds in the DSR fields. The plots were irrigated 24 hours after post-emergence herbicide application and kept with standing water for 2–3 days after the weedicide application to increase its efficacy. The TPR fields were flooded continuously for 15–20 days after transplanting, then irrigated at 5-day intervals. DSR plots were irrigated at 3–4 day intervals until crop maturity. Two noxious weeds *Leptochloa chinensis* and *Dactyloctenium aegyptium* were found in two locations: New Ghania Kalan and Herdosehol Muslim. To control these weeds, a mixture of 865ml ha^{-1} of phenoxoprop-p-ethyl and 247 g ha^{-1} of bispyribac-sodium + bensulfuron was applied 18–22 DAS. Every location was visited at 5-day intervals to check the crop growth and apply the required inputs to the crop. Precautionary fungicides were applied to control bacterial leaf blight, brown leaf spot, and blast. Training programs, field seminars, and farmers' days were also conducted to disseminate the DSR technology among the farmers' community (Figure 3a, b, c, d) because "seeing is believing" and to train master trainers (Figure 4a, b).

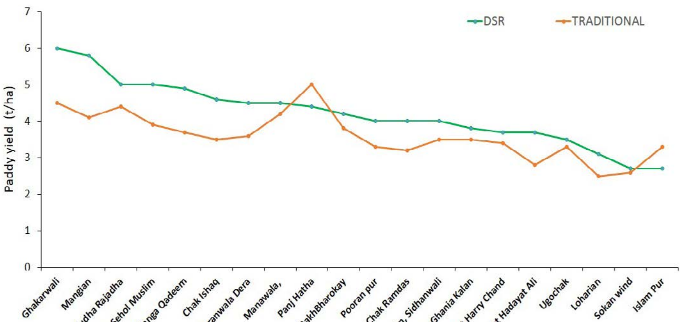

Figure 1: *Comparison of paddy yield (DSR and traditional transplanting) at different locations.*

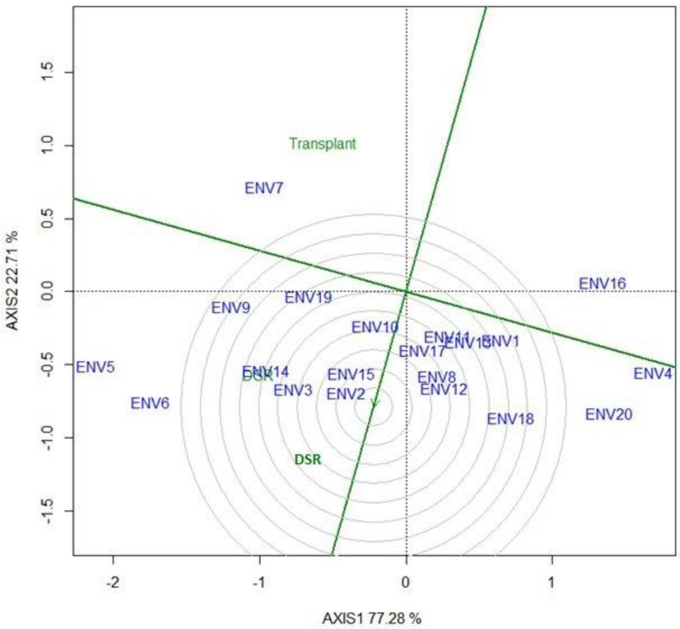

Figure 2: *GGE biplot analysis on the basis of paddy yield where X-axis shows principal component 1 (DSR) and Y-axis indicateds principal component 2 (transplanting). If the total variation is 100% then contribution due to DSR is 77.28% and owing to transplanting is 22.71%. The ENVI (environment), ENV2 correspond to location 1, Location 2, referred Table 3.*

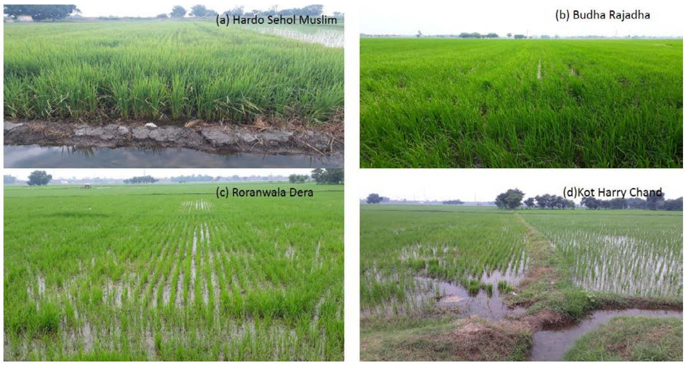

Figure 3: *Direct seeded rice plots at different locations.*

Figure 4: *Farmer training programe at Rice Research Institute, Kala Shah Kaku.*

Data recording

Data of paddy yield and yield components were recorded for all the field demonstrations. The number of grains per panicle and productive tillers m^{-2} were recorded by counting an average of three samples (1 m^2) taken randomly from each demonstration plot. Plant height was measured with a meter rod from the soil level to the tip of the flag leaf and then averaged. 1000 grain weight (g) was recorded by taking three samples (five plants per sample) randomly from each demonstration plot. Data for paddy yield were recorded by harvesting three samples selected randomly from each demonstration plot (Amanullah and Hidayatullah, 2016; Amanullah et al., 2016).

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 and Discussion

The results showed that significant difference was found in yield, yield components, and planting methods between DSR and traditional TPR (Table 3). DSR resulted in a 16.64% higher average yield (42.05 t ha^{-1}) than traditional TPR (36.05 t ha^{-1}). Similarly, DSR produced the maximum number of productive tillers (411 m^{-2}). Plant height (134.36 cm), number of grains per panicle (110.51), whereas, 1000 grain weight (20.27 g) were higher in the TPR. But DSR maintained its yield advantage owing to its number of productive tillers being 13.43% higher than in the TPR fields.

Plant height

The maximum plant height achieved was 144.83 cm in TPR at Mouza Panj Hatha, district Hafizabad. The second highest, 144.45 cm was also noted in TPR, at Mouza BudhaRajadha, district Gujranwala. In DSR, the maximum plant height of 143.40 cm was observed at Mouza Panj Hatha, district Hafizabad and the minimum plant height of 115cm was found in DSR at Mouza Islampur, district Gujranwala. The average data of the 20 locations showed that the maximum plant height attained was 134.36 cm in TPR and 130.22 cm in DSR. The results are quite in agreement with those of Hidaytullah and Amanullah, 2015. The results are also quite in line with those of Laary et al. (2012) who reported more plant height in transplanting rice over other DSR crop establishment techniques.

Productive tillers

The highest number of productive tillers m^{-2} (473) was found in DSR at Mouza ChakIshaq, Sialkot district. Similar results were observed at Mouza Ghakar Wali, Hafizabad district and Mouza Pooranpur, Gujranwala district, which had productive tillers of 471 m^{-2} and 470 m^2, respectively. The minimum tillers, 314 m^{-2}, was found at Mouza Kot Hadayat Ali, Sheikhupura district under the TPR technique. The average of the 20 locations revealed that DSR produced more productive tillers (411 m^{-2}) than traditional TPR (362 m^{-2}). The results are in agreement with those of Rashid et al. (2009) who found that drum-seeded rice produced more tillers m^{-2} than transplanted rice. Findings are also in conformity to those Ali et al. (2012) who evaluated six planting methods including farmer conventional transplanting, mechanized transplanting, dry direct seeding in lines and broadcasting, dry direct seeding on raised beds by machine and wet direct seeding (broadcasting of pre-germinated seed in puddled soil) and observed highest number of tillers m^{-2} in dry direct seeding in lines as compared to other methods including transplanted rice.

Number of grains panicle^{-1}

The maximum grains panicle^{-1} produced by transplanting was 120 at Mouza Panj Hatha, Hafizabad district. The average of the 20 locations showed that highest number of grains per panicle, 111, was in TPR, whereas number of grains per panicle in DSR was 103. The results are in conformity with Iqbal et al. (2019) who reported more number of filled grains panicle $^{-1}$ in DSR-ridge and DSR-drill sowing over transplanted rice. Ali et al. (2012) also reported that DSR (line sowing) produced more grains per panicle than TPR.

1000 grain weight

Data regarding 1000 grain weight for the 20 locations are given in Table 3, which shows that the highest value (23.33 g) was achieved in TPR at Mouza Panj Hatha, Hafizabad district and the highest weight (21.78 g) in DSR was also observed at the same location. The average data (Table 4) showed that the maximum 1000 grain weight was 20.27 g in TPR and of 19.13 g in DSR. This might be attributed to better root development in TPR, which produced healthy panicles with more grains. Similar results were observed by Sudhir et al. (2007) who investigated four methods viz. broadcast in puddled plots, direct drilling in puddled plots, direct drilling in compacted plots and direct drilling under unpuddled and uncompacted conditions and found that direct drilling with compaction resulted in higher grain weight.

Paddy yield

The paddy yield was highest in DSR at all locations (Figure 1) except at Mouza Panj Hatha and Islampur, where it was 12 and 18.18 % lower than TPR. Non-application of pre-emergence weedicide and less germination due to heavy rain were the main factors of the low yield at Mouza Islampur. Similarly, germination of last year dropped paddy in DSR and suboptimal plant population as well were major factors of low yield at Mouza Panjhatha. The highest paddy yields, 6.0 t ha^{-1} and 5.8 t ha^{-1}, were obtained by DSR at Mouza Ghakarwali and Mangian, respectively, and the lowest paddy yields of 2.7 t ha^{-1} in DSR and 2.6 t ha^{-1} in TPR at Mouza Sokan for the two planting techniques, respectively. The paddy yield was highest in DSR because of the higher number of productive tillers than in traditional TPR. The maximum paddy yield (4.20 t ha^{-1}) was obtained in DSR, which was 16.64% higher than from TPR and this increment was mainly due more number of productive tillers per unit area. These research outcomes are quite in line to those of Sudhir et al. (2007) who investigated four methods viz. broadcast in puddled plots,

Table 3: *Yield and yield component data of the 20 locations.*

Sr. No.	Location / Environments	Sowing method	Plant height (cm)	Productive tiller m^{-2}	No. of grains $Panicle^{-1}$	1000 grain weight (g)	Paddy yield (t ha^{-1})	Percent increase in yield in DSR over TPR
1	Ugo Chak	DSR	124.80	375.00	101.00	19.28	3.5	6.06
		Transplanting	134.16	326.25	105.70	20.40	3.3	
2	Chak Ishaq	DSR	126.80	473.33	102.00	19.42	4.6	31.43
		Transplanting	136.31	419.63	98.50	20.55	3.5	
3	Manga Qadeem	DSR	129.20	395.33	111.20	19.66	4.9	32.43
		Transplanting	138.89	343.94	110.00	20.80	3.7	
4	Sokan wind	DSR	132.20	388.33	97.50	17.53	2.7	3.85
		Transplanting	136.89	337.85	95.00	18.55	2.6	
5	Ghakarwali	DSR	127.40	470.63	103.26	20.11	6.0	33.33
		Transplanting	131.92	409.19	105.60	21.03	4.5	
6	Mangian	DSR	128.60	416.67	110.39	19.75	5.8	41.46
		Transplanting	133.17	354.17	116.50	20.90	4.1	
7	Panj Hatha	DSR	143.40	437.00	112.00	21.78	4.4	-12.00
		Transplanting	144.83	455.35	120.00	23.33	5.0	
8	Pooranpur	DSR	134.60	470.00	100.25	19.43	4.0	21.21
		Transplanting	137.70	403.00	108.00	20.56	3.3	
9	BudhaRajadha	DSR	141.20	457.33	111.95	19.85	5.0	13.64
		Transplanting	144.45	397.88	113.30	21.00	4.4	
10	RakhBharokay	DSR	131.80	434.67	100.33	18.76	4.2	10.53
		Transplanting	134.83	378.16	103.50	19.85	3.8	
11	New Ghania Kalan	DSR	128.80	378.33	99.00	18.89	3.8	8.57
		Transplanting	131.76	329.15	100.52	19.99	3.5	
12	ChakRamdas	DSR	127.40	418.00	103.00	18.62	4.0	25.00
		Transplanting	130.33	355.30	102.56	19.70	3.2	
13	Kot Harry Chand	DSR	126.40	407.00	102.25	18.45	3.7	8.82
		Transplanting	129.31	354.09	106.66	20.00	3.4	
14	Hardo Sehol Muslim	DSR	129.40	374.33	105.00	19.56	5.0	28.21
		Transplanting	133.28	318.18	102.57	20.70	3.9	
15	Roranwala Dera	DSR	133.20	427.67	100.00	18.76	4.5	25.00
		Transplanting	137.20	363.52	113.50	19.85	3.6	
16	Islam Pur	DSR	115.00	363.00	90.65	18.47	2.7	-18.18
		Transplanting	123.25	389.50	98.75	19.54	3.3	
17	Gorian, Sidhanwali	DSR	129.60	365.00	101.53	18.83	4.0	14.29
		Transplanting	133.49	317.55	106.65	19.93	3.5	
18	Kot Hadayat Ali	DSR	130.60	369.67	102.35	17.62	3.7	32.14
		Transplanting	132.00	314.22	97.59	18.65	2.8	
19	Manawala	DSR	136.80	395.67	106.00	20.55	4.5	7.14
		Transplanting	133.00	344.23	108.90	21.75	4.2	
20	Loharian	DSR	127.20	395.00	94.75	17.31	3.1	24.00
		Transplanting	130.40	335.75	106.45	18.32	2.5	

Table 4: *Averages of the 20 locations for the two planting techniques.*

Sowing methods	Plant height (cm)	Productive tillers m^{-2}	Number of grains $panicle^{-1}$	1000 grain weight (g)	Paddy yield (t ha^{-1})	Percent Increase in Yield in DSR over TPR
DSR	130.22	411.03	102.72	19.13	4.20	16.64
Transplanting	134.36	362.34	110.51	20.27	3.65	

direct drilling in puddled plots, direct drilling in compacted plots and direct drilling under unpuddled and uncompacted conditions and found that direct drilling with compaction resulted in higher grain yield. Similarly, Iqbal et al. (2019) and Ali et al. (2012) also reported more grain yield in DSR-ridge and DSR- drill sowing over PTR.

Genotype and genotype by environment (GGE) biplot analysis

The term "GGE biplot" refers to a biplot that displays the genotype (G) and genotype by environment (GE) data. The baisc property of a GGE biplot is that it is based on tester centered data, whereby the tester (environment) main effects (E) are removed, and the entry main effect (G) and the entry by tester interaction (GE) are retained and combined. Therefore, a biplot based on tester-centered data contains only G + GE, shortened as GGE (Yan et al., 2000).

GGE biplot analysis of average grain yields in all the environments (loactions) against both the methods showed the interaction of environments and cultivation methods was significant (Figure 2). The conventional TPR method performed better in only two environments, whereas DSR performed better in all the other studied environments. The biplot showed that the DSR method was a better option and provided a higher yielded in almost all the environments, except in two locations Panj Hatha (designated as Env. 7 in the biplot) and Islampur (Env. 16) where TPR resulted in higher grain yields than DSR and this was mainly due to more number of tillers, grains per panicle and thousand grain weight. This might be attributed to better soil conditions that favored healthier TPR crop establishment than DSR at these two sites.

Conclusions and Recommendations

Based on demonstrations of DSR at 20 sites using super basmati variety, paddy yield is higher from DSR than from TPR. All farmers at the 20 sites were enthralled with the performance of DSR and its potential benefits. DSR is also very attractive as it mitigates issues of greenhouse gas emissions, water shortage, and labor scarcity. DSR technology is attracting rice growers because it is less expensive than TPR. DSR is cost-effective and famer-friendly, but to achieve its full potential requires precise land leveling, correct seeding depth and timing of sowing, and effective weed management. The field experiences clearly showed that the most challenging task in DSR is weed control and thus attaining optimum weed control is a key to DSR's success. Poor crop establishment at two sites was due to rainfall during the crop establishment stage. Water saving in DSR varied among locations based on land leveling and efficient irrigation practices, but on average, a 15% water saving was observed in DSR without any loss in yield. Adoption of DSR on a larger scale is possible by prioritizing resources and the adequate availability of services and supplies from private sector service providers to attain the maximum benefit of DSR. Further refinement of good practices is required for including essential elements such as laser land leveling and application of the right weedicides at the right times. If these two components are integrated in the good practices for DSR, the technology will be adopted by the farmers. Further systematic research is needed for control of noxious weeds (*Leptochloa chinensis*, *Dactyloctenium aegyptium,* etc.), which affect rice production in DSR.

Novelty Statement

Direct seeded rice (DSR) is gaining momentum owing to less labor-intensive and more farmers-friendly, time-saving and cost-effective technology than traditional transplanted tice (TPR). DSR technology eliminates the need for continuous ponding of water and thus lessens water use for rice production, resulting in saving of 15-20% of water over TPR. The results of current study demonstrated at different localities indicated that paddy yield was 20% higher under DSR than TPR. So, farmers can opt this resource saving technology for their income uplifting.

Author's Contribution

Mr. Muhammad Usman Saleem conducted the trial and drafted the result and discussion and Dr. Nadeem Iqbal drafted the introduction part. Whereas, Mr. Shawaiz Iqbal conducted and collected the data at farmer's field and also compiled the data, Mr. Usama Bin Khalid wrote material and methods, Mrs. Adila Iram did the statistical analysis, Dr. Muhammad Akhter supervised the trials at farmer's field, Mr. Tahir Latif compiled the data and Dr. Tahir Hussain Awan conducted and supervised the trials at farmer's field.

Conflict of interest

The authors declare that there is no conflict of interests regarding the publication of this article.

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