Research Article

Growth, Yield and Economic Analysis of Dry-Seeded Basmati Rice

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Abstract | Planting method is an important aspect of production technology for the maximum resource utilization by crops per unit area. Dry-seeded rice (DSR) is a contemporary resource saving crop establishing technique, which enables farmers to harvest economical rice production. Field study was conducted at Rice Research Institute, Kala Shah Kaku, Pakistan in 2014 and in 2015 to evaluate the different planting methods. Three dry-seeded rice (DSR) planting methods viz. (i) DSR-broadcast, (ii) DSR-drill, (iii) DSR-ridges were compared with the conventional transplanting (TR) method in lines having row to row and plant to plant distance of 22.5cm distance, and farmer transplanting method. Experimental design was randomized complete block, replicated 3 times. Data were recorded on height (cm), tillers m^{-2}, filled and unfilled grains $panicle^{-1}$, thousand grain weight (g), grain and biomass yield (t ha^{-1}). Grain sterility (%) and harvest index (%) were also calculated. Highest grain yield (5.00 to 5.11 t ha^{-1}) with harvest index (30.00 to 31.50%) and relatively low grain sterility (12.00 to 12.01%) were observed in DSR-ridge and DSR-drill sowing method. Moreover, DSR (i.e. DSR-ridge and -drill) resulted in 104 and 76 % more profit over TR-farmer practice. The study concluded that DSR-ridge and DSR-drill proved to be the best to obtain the maximum paddy yield and net profit. Farmers can adopt these methods to harvest maximum benefit.

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Introduction

Rice (*Oryza sativa* L.) is a staple food crop of more than half of the inhabitants across the globe (Khush, 2004). In Pakistan, after wheat, it occupies 2nd position. Its cropped area was 3034 M ha and production was 7.410 M tons (Economic Survey of Pakistan, 2019). Among the cereal crops, rice is an important export commodity (Economic Survey of Pakistan, 2019). It contributes 3.1% in value addition to agriculture and 0.6% in the GDP (Economic Survey of Pakistan, 2019). The average yield of rice in Pakistan is about 2.44 t ha^{-1} (Economic Survey of Pakistan, 2019) which is low as compared to other rice producing countries due to many constraints including proper crop establishing techniques (Aslam, 2016).

In Asia rice is growing by transplanting, rice seedlings manually in puddled soil which is a widely adopted method. It consumes abundant water (Bouman and Tuong, 2001). Whereas, water resources are declining day by day. Its judicious use is gaining a pivotal importance to fulfil future water and food demand for the growing population (Mahajan *et al*., 2012). Shrinking water resources availability is a threat for the future rice production in Asia (Mahajan *et al*., 2012) and will adversely affect the sustainability of rice production (Chauhan *et al*., 2014). This calls for exploring water saving approach in rice farming e.g. dry-seeded rice (DSR). Bouman and Tuong (2001) reported that DSR on flat soil or on raised beds saves water considerably. DSR is planted in well prepared seed bed by drill or broadcast method, and after that irrigation is applied immediately. Irrigation is repeated after 3-4 days interval till the full germination of rice and afterwards irrigation is applied about 6-7 days interval. This DSR method as compared to transplanted rice saves huge quantities of water (Cabangon *et al*., 2002). DSR sown on dry seed bed and first irrigation applied immediately after sowing, and plots re-irrigated daily for 2 week after germination to maintain saturation. Subsequent irrigations were applied at hairline cracks appearance at surface of soil. This DSR crop resulted in saving water upto 40% as compared to puddled transplanted rice (Bhushan *et al*., 2007).

Traditional method of transplanting rice seedlings in puddled soil not only consumes more water but also involves intensive labor (Saleem *et al*., 2020). About 25-50 man-days ha^{-1} are required for transplanting whereas in DSR only 5 man-days ha^{-1} are needed (Dawe, 2005). Labor scarcity and increasing wages are mounting a high production cost. This element is gradually replacing conventional transplanting with DSR. In Pakistan among other constraints, low plant population is an important factor of low production, which can be overcome by DSR. Moreover, DSR escapes time of nursery raising and transplanting which is strenuous and tedious in hot weather. Additionally, transplanting period is short and to adjust seedlings with environment DSR is a good alternative method for rice establishment (Laary *et al*., 2012), as it doesn't face transplanting shock, favors early crop establishment, accelerate growth and hasten maturity (Tuong, 2008). Furthermore, DSR plays a key role to achieve optimum plant population with water saving and improvement in the yield (Ladha *et al*., 2009; Farooq *et al*., 2011). Planting through DSR is being practiced successfully in USA, Italy, France, Russia, Cuba, Japan, Korea, India and Philippines including Iran (Akhgari, 2004).

Planting methods not only affect yield and quality of rice but also influence soil health. DSR produces more yield as compared to transplanting (Iqbal *et al*., 2019).

Site specific changes in method of land preparation and crop establishment should be applied in DSR to enhance yield (Farooq *et al*., 2008). This study was aimed to test economic impact of different planting techniques including DSR on yield and its components for Super Basmati rice which is planted on 80 % area in Pakistan.

Materials and Methods

Experiment was conducted at experimental farm of Rice Research Institute, Kala Shah Kaku, Pakistan (73°50'16E and 31°45'35N having altitude of 205 m) for two seasons (2014 and 2015). The soil under experimentation was clay loam and its physico-chemical properties of experimental field are given in Table 1. Soil analysis was carried out before sowing the experiment for pH_s, EC_e and SAR (U.S. Salinity Laboratory Staff, 1954). Soil organic matter was determined using Walkely method as reported by Walkely (1947). Nitrogen percentage from soil was examined by Kjheldhal distillation apparatus method (Kjeldahl, 1883). Available phosphorous was determined by using Spectrophotometer according to the method described by Olsen *et al*. (1954) and available potassium using Flame photometer described by Chapman and Pratt (1961). And Soil texture was determined using hydrometer method.

A portion of saturated paste was transferred to a tarred china dish. It was weighed, dried to constant weight at 105°C and weighed again. Saturation percentage (SP) was calculated by using formula. (U.S. Salinity Laboratory Staff, 1954).

$$SP = \frac{\text{Loss in weight on oven drying (g)}}{\text{Oven dried soil weight (g)}} \times 100$$

Meteorological data of crop seasons are shown in Figure 1. Four planting methods viz. (i) broadcast 24 h soaked seed in well prepared seedbed (i.e. DSR-broadcast), (ii) drilling of dry seed in well prepared dry soil followed by irrigation (i.e. DSR-drill), (iii) ridges made after broadcast 24 h soaked seed in well prepared seed bed (i.e. DSR-ridge) and (iv) departmental recommended transplanting (TR-recommended) were compared with (v) farmers transplanting (TR-farmer practice). Drill sowing was done with happy seeder using its inclined plate seed box system. Whereas for DSR-ridge, seed was broadcasted in the well-prepared seedbed and afterwards ridges were made with the help of a ridger.

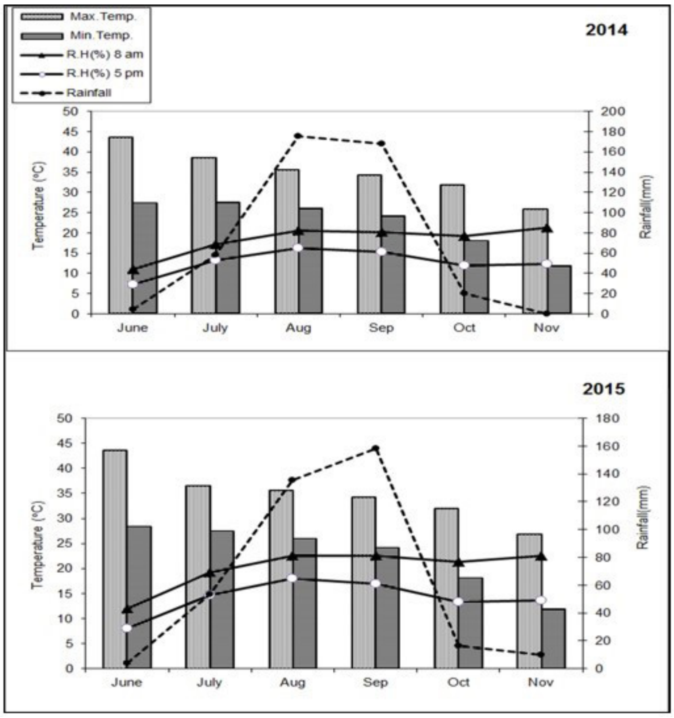

Figure 1: *Meteorological data for crop growth season during 2014 and 2015.*

Table 1: *Physico-chemical characteristics of experimental field.*

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

Experiment was a randomized complete block design (RCBD), treatments replicated thrice. Sowing was done in a net plot of size 600 m^2 (20m x 30m). Certified seed of Super Basmati (35 kg ha^{-1}) was used for all DSR methods. Direct seeded rice was sown on June 12th and 14th in 2014 and 2015, respectively. Before sowing, seeds were treated with fungicide (Topsin M at the rate of 2.5 g kg^{-1}). Drilling of dry seed with DSR-drill was done in a well-prepared dry seedbed following immediate irrigation and repeated water flooding whenever needed to enhance germination. In DSR-ridge, broadcast of soaked seed was done manually followed by formation of ridges using a potato ridger. Clover (Bispyribac sodium) 20% SC at the rate of 250 g ha^{-1} was sprayed at 20 and 39 days after seeding in saturated soil condition to control weeds. Manual transplanting of 35 days old rice seedlings was done on 14th July in TR-recommended and TR-farmer practice. In case of TR-recommended line to line and plant to plant distance was maintained 22.5 cm by using marked strings across the field. Rifit (Pretilachlor) at the rate of 2000 ml ha^{-1} used after 5 days of transplanting in standing water with shaker bottle to control weeds. Recommended fertilizer 133-85-62 kg N-P-K kg ha^{-1} was applied in all plots. All K and P with 1/3rd N was applied at seedbed preparation and remaining N was used in two equal splits at 40 and 60 days after transplantation (DAT). For transplanting methods continuous flooding was done for 30 DAT and thereafter irrigation was applied at weekly interval. Whereas, irrigation to DSR was applied at 5-7 days interval till maturity.

Data recording

The data recording and harvesting of all treatments was done on 12th and 18th November during 2014 and 2015, respectively. Five plants were randomly selected from a treatment and height was measured from base to tip including panicle. At harvest, panicles bearing tillers were counted from a m^2 area at three places in a treatment and averaged for number of tillers m^{-2}. Five panicles were randomly selected, measured its length from ear marked area to tip, grains separated manually to determine filled and unfilled grains panicle^{-1}. The paddy samples were sundried after harvesting and threshing, grain moisture content was determined by grain moisture meter (LKB-PRODUK TERAB-Stockholm-Sweden), and thousand grain weight was measured by using electrical balance. The paddy yield (t ha^{-1}) was adjusted at 14% moisture.

Economic analysis

The economic analysis was carried out as under:

Grand income = [(paddy yield × market price of paddy t^{-1}) + (straw yield × market price of straw t^{-1})]

Net profit= (grand income – total cost of production)

Benefit-cost ratio= net benefit / total cost of production

Statistical analysis

Data were analyzed statistically by statistical package (Statistix 8.0). For testing treatments' means significance, Fischer's Analysis of Variance Technique was used and Least Significance Difference Test ($P \leq$

0.05) was applied for comparing means (Steel *et al*., 1997).

Results and Discussion

Effect of planting methods was non-significant ($P \leq 0.05$) on plant height during 2014 and 2015. However, various planting methods significantly ($P \leq 0.05$) influenced productive tiller number m^{-2} in first and second year (Table 2). The maximum productive tiller number (416 and 409 m^{-2} during 2014 and 2015, respectively) were recorded in DSR-ridge. However, it remained statistically at par with DSR-drill and DSR-broadcast. All methods produced 26-61 % (2014) and 23-49 % (2015) higher productive tiller number m^{-2} when compared with TR-farm practice. Additionally, an increase of 18-24 % (2014) and 12-21% (2015) was recorded in tiller number per unit area in all DSR vs. TR-recommended practice. Two years averages data depicted that varying planting methods had a non-significant ($P \leq 0.05$) effect on panicle length. All the rice establishing methods indicated an increase of 18-26 % (2014) and 1-9 % (2015) in panicle length (cm) against TR-farmer practice, except the TR-recommended practice during 2015 (Table 2).

Number of filled grains panicle^{-1} showed a significant response for planting methods (Table 2). The maximum number of filled grains panicle^{-1} was observed in DSR-ridge (90 and 72) followed by DSR-drill (79 and 58) and DSR-broadcast (77 and 50) in first and second year, respectively. DSR-ridge produced 38 and 55 %, DSR-drill resulted in 20 and 25 %, DSR-broadcast recorded 19 and 8 %, and TR-recommended practice caused 5 and 6 % more number of filled grains per panicle over TR-farmer practice during 2014 and 2015, respectively (Table 2). Different planting methods significantly ($P \leq 0.05$) affected the unfilled grains number panicle^{-1} during both years. The lowest unfilled grains number panicle^{-1} (12) was observed in DSR-ridge (Table 2) that was followed by TR-recommended practice (13). All the treatments produced 12-31% and 8-23 % less unfilled grains per panicle than TR-farmer practice during 2014 and 2015, respectively (Table 2). Results indicated that different planting methods during 2014 and 2015 significantly ($P \leq 0.05$) altered grain sterility. The lowest sterility percentage (12 %) was recorded in DSR-ridge (Table 3) and it was followed by DSR-drill (16 %),

Table 2: *Effect of planting methods on plant height (cm), number of productive tillers m^{-2}, panicle length (cm) and number of filled and unfilled grains panicle during 2014 and 2015.*

Planting methods	Plant height (cm)		Number of productive tillers m^{-2}		Panicle length (cm)		Number of filled grains panicle^{-1}		Number of unfilled grains panicle^{-1}	
	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015
DSR-broadcast	117.21	117.92	384 ab	379 ab	26.54	25.77	77.41 abc	49.92 b	15.70 ab	21.31 a
DSR-ridge	120.01	120.06	416 a	409 a	28.30	26.34	89.73 a	71.81 a	12.31 c	18.13 b
DSR-drill	118.92	119.04	403 ab	388 ab	27.16	24.45	78.10 ab	57.71 b	14.91 b	21.50 a
TR-farmer practice	114.50	110.47	259 c	275 c	22.52	24.14	65.12 c	46.23 b	17.92 a	23.53 a
TR-recommended practice	117.53	108.05	326 bc	337 bc	27.35	23.66	68.71 bc	49.10 b	13.30 bc	20.81 ab
LSD	ns	ns	77.4	69.1	ns	ns	12.525	12.190	2.559	3.017

Table 3: *Effect of planting methods on grain sterility %, 1000-grain weight, grain yield (t ha^{-1}), straw yield (t ha^{-1}) and harvest index (%) of rice crop during 2014 and 2015.*

Planting methods	Grain sterility (%)		1000-grain weight (g)		Paddy yield (t ha^{-1})		Straw yield (t ha^{-1})		Harvest index (%)	
	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015
DSR-broadcast	16.89 b	29.95 b	20.11 b	26.85	4.30 abc	3.81 bc	11.35 a	9.17 ab	27.48 c	29.35 b
DSR-ridge	12.01 d	20.13 d	23.89 a	28.10	5.11 a	4.95 a	11.11 a	10.07 a	31.50 a	32.96 a
DSR-drill	16.02 c	27.19 c	20.86 b	27.56	4.70 ab	4.30 ab	11.67 a	10.60 a	28.71 bc	28.86 c
TR-farmer practice	21.55 a	33.80 a	20.52 b	25.40	3.52 c	3.11 c	8.73 b	8.37 b	28.73 bc	27.09 d
TR-recommended practice	16.18 c	29.83 b	21.05 b	27.10	3.90 bc	3.50 c	9.18 b	9.03 b	29.82 b	27.93 c
LSD	0.447	2.046	2.443	ns	0.908	0.703	1.156	2.423	2.300	0.630

TR-recommended practice (16 %), and DSR-broadcast (17 %), whereas, the highest sterility (21%) was recorded in TR-farmer practice during first year with a similar trend in the second year (Table 3). Results demonstrated that during 2014, 1000-grain weight was significantly affected with planting methods whereas in 2015 it showed a non-significant ($P \leq 0.05$) behavior. All the planting methods resulted in 2-16 % and 6-11 % more grain weight over TR-farmer practice in first and second year, respectively (Table 3). However, the highest 1000-grain weight was achieved with DSR-ridge (23.89 g) while, the lowest was recorded in TR-farmer practices (20.52 g).

Paddy yield varied significantly ($P \leq 0.05$) among different planting methods during first and second year (Table 3). The maximum paddy yield during 2014 was achieved with the DSR-ridge (5.11 t ha^{-1}) followed by DSR-drill (4.70 t ha^{-1}), DSR-broadcast (4.30 t ha^{-1}) and TR-recommended practice (3.90 t ha^{-1}) as compared to TR-farmer practice (3.52 t ha^{-1}). Similar trend was observed in 2015. All the methods resulted in 10-45 % and 13-59 % more paddy yield over TR-farmer practice during first and second year, respectively. Moreover, all the DSR-planting methods produced 10-31 % and 8-41 % more paddy yield over TR-recommended practice during 2014 and 2015, respectively (Table 3). As far as TR-recommended practice and TR-farmer practice is concerned, TR-recommended practice produced 10 and 11 % more paddy yield than TR-farmer practice in first and second year, respectively (Table 3). Significant ($P \leq 0.05$) effect of planting methods was observed on straw yield of rice crop during 2014 and 2015 (Table 3). The highest straw yield (11.67 t ha^{-1}) during first year was achieved with DSR-drill that was followed DSR-broadcast and DSR-ridge, whereas, lowest straw yield (8.73 t ha^{-1}) was recorded in TR-farmer practice. During 2015, the maximum straw yield (10.67 t ha^{-1}) was found in DSR-drill that was followed by DSR-broadcast, DSR-ridge and TR-recommended practice, respectively. The TR-farmer practice again occupied the bottom rank by producing straw yield of 8.37 t ha^{-1}. Planting methods influenced harvest index significantly ($P \leq 0.05$) during both the years (Table 3). DSR-ridge and TR-recommended practice produced 10 and 22 %, 4 and 3 % more harvest index (%) over TR-farmer practice during 2014 and 2015, respectively. The maximum harvest index (31.50 %) was observed with DSR-ridge that was followed TR-recommended practice whereas, the lowest harvest index of 27.48 % was noted in DSR-broadcast having a similar trend during the second year (Table 3).

The lowest production cost was observed in DSR-broadcast, ridge and drill sowing and highest was in TR-recommended practice followed by TR-farmer practice (Table 4). Economic analysis revealed that during first year the highest net benefit ($ 800.46 ha^{-1}) was obtained in DSR-ridge sowing followed by DSR-drill sowing ($ 692.51 ha^{-1}) while, minimum net benefit ($ 333.56 ha^{-1}) was observed in farmer transplanted rice. Benefit-cost ratio was also highest in DSR-ridge (1.54) and -drill (1.31) whereas, lowest (0.58) in TR-farmer practice. Similar trend was noted in the second year of study (Table 5).

Planting techniques have paramount role on growth and grain yield contributing parameters e.g. like plant height, population density, filled or unfilled grains per panicle, panicle length and 1000-grain weight and grain yield. Our research findings revealed a non-significant behavior among planting methods on plant height (Das *et al*., 2015; Iqbal *et al*., 2019). However, this study indicated more height in all DSR methods with maximum in DSR-ridge, which might be attributed to better growth of the plants on ridges (Jamil *et al*., 2017). Similarly, all the DSR methods resulted in maximum productive tillers m^{-2} than transplanting method either TR-famer or -recommended practice. This is owed mainly because of optimum seed rate directly applying in the field that leads to recruitment of ideally required plant population, as it evades nursery raising, and then it's transplanting which is a strenuous job due to scorching and inhospitable weather condition in which laborers transplant hurriedly without fulfilling the optimum planting density. Some of earlier studies carried in past also reported more number of tillers m^{-2} achieved in DSR methods as compared to transplanting in puddled fields (Rashid *et al*., 2009; Sudhir *et al*., 2007). However, among these varying methods, maximum tiller number was observed in DSR-ridge and it might be ascribed to enhanced surface area availability with more porous and loose soil, eventually enabling the rice crop to absorb and uptake mineral nutrients in sufficient quantity along with water more effectively and efficiently (Zhang *et al*., 2003).

Panicle length showed a non-significant behavior under different planting methods. Some of previously

Table 4: *Production cost (US $ ha^{-1}) of different planting methods.*

Treatments	Production cost (US $ ha^{-1})											
Planting techniques	Land preparation charges (a)	Sowing/ transplanting charges (b)	Seed cost (c)	Nursery raising cost (d)	Plant Protection charges (e)	Irrigation charges (f)	Total variable cost (A= a+b+c+d +e+f)	Fertilizer cost (g)	Management cost (h)	Harvesting charges (i)	Total fixed cost (B= g+h+i)	Total production cost= A + B
DSR-broadcast	53.2	2.14	15.2	0	85.5	153.9	309.94	126.14	13.68	57	196.82	506.76
DSR-ridge	53.2	15.2	15.2	0	85.5	153.9	323.00	126.14	13.68	57	196.82	519.82
DSR-drill	53.2	22.8	15.2	0	85.5	153.9	330.60	126.14	13.68	57	196.82	527.42
TR-farmer practice	64.6	81.7	6.08	6.65	47.5	176.7	383.23	126.14	13.68	57	196.82	580.05
TR-recommended practice	64.6	119.7	6.08	6.65	47.5	176.7	421.23	126.14	13.68	57	196.82	618.05

PKR is Pakistan's currency. US$1=PKR 130.

Table 5: *Economics of different planting methods and their impact on grand income, net profit and benefit cost ratio for 2014 and 2015.*

Treatments	Total	2014					2015				
Planting methods	cost (US $ ha^{-1})	Paddy income ($ ha^{-1})	Straw income ($ ha^{-1})	Grand income ($ ha^{-1})	Net profit ($ ha^{-1})	Benefit-cost ratio	Paddy income ($ ha^{-1})	Straw income ($ ha^{-1})	Grand Income ($ ha^{-1})	Net profit ($ ha^{-1})	Benefit-cost ratio
DSR-broadcast	506.76	1075.00	43.70	1118.70	611.94	1.21	952.50	35.30	987.80	481.05	0.95
DSR-ridge	519.82	1277.50	42.77	1320.27	800.46	1.54	1237.50	38.77	1276.27	756.45	1.46
DSR-drill	527.42	1175.00	44.93	1219.93	692.51	1.31	1075.00	40.81	1115.81	588.39	1.12
TR-farmer practice	580.05	880.00	33.61	913.61	333.56	0.58	777.50	32.22	809.72	229.68	0.40
TR-recommended practice	618.05	975.00	35.34	1010.34	392.29	0.63	875.00	34.77	909.77	291.72	0.47

PKR is currency of Pakistan, PKR 130= US$1, market price of paddy= 250 $ t^{-1}, market price of straw = 3.85 $ t^{-1}, grand income = [(paddy yield × market price of paddy t^{-1}) + (straw yield × market price of straw t^{-1})], net profit= (grand income – total cost of production). benefit-cost ratio = net benefit / total cost of production).

conducted studies also concluded that DSR-ridge planting, DSR flat planting either line or broadcast and puddled transplanting showed non-significant behavior on panicle length, with DSR-ridge having highest panicle length (Iqbal *et al*., 2019). Almost similar findings were reported by Naresh *et al.* (2013) while comparing three DSR methods with transplanted rice that supports our results. Highest number of filled grains per panicle was achieved with DSR-ridge and this enhanced number of filled grains might be attributed to better vegetative growth on ridges that promoted higher assimilates translocation during the grain filling stage (Song *et al*., 2009). Maximum sterility (%) was recorded in TR-farmer practice, and one of the previous research also reported higher sterility percentage in transplanted rice as compared to DSR planting methods (Javaid *et al*., 2012). 1000-grain weight was maximum in DSR-ridge and it might be owing to better root growth and development on ridges which produced healthier panicles with thick grains. Comparatively heavier grains recorded in this method might be due to more water retention in ridges for nutrient transportation during physiological maturity (Yuan-zhi, 2015). Zhang *et al.* (2003) also concluded higher grain weight in ridge sowing over conventional rice transplanting.

Paddy yield and HI (%) are the most vital parameters greatly affected by various crop establishment methods and are directly linked to other allometric components like plant population, filled grains $panicle^{-1}$, 1000 grain weight and sterility. In current study all these traits were higher in DSR-ridge and this might be due to higher chlorophyll content of flag leaf, slowing of leaf senescence, higher photosynthetic efficiency (Ting *et al*., 2013), more root biomass development and more root vitality (Dan-Ying *et al*., 2008), increased tillering, enhanced leaf area index and eventually resulting in higher paddy yield and HI (Feng *et al*., 2010). Lower paddy yield in TR methods might be affected by subsurface hard pan hindering and impeding root growth and development, and ultimately affect the crop growth and grain yield.

Yuan-zhi (2015) and Iqbal *et al.* (2019) also concluded higher paddy yield in ridge sowing over transplanted rice, drill and broadcast sowing techniques. All types of DSR methods were more profitable, due to low input cost and higher yield, as compared to puddled TR-planting methods. Some of the earlier studies also reported more profits extracted from DSR as compared to transplanting methods in Pakistan and other countries (Iqbal *et al*., 2019; Singh *et al*., 2004).

Conclusions and Recommendations

On the basis of current study it may be concluded that among all the treatments, DSR-ridge and DSR-drill proved to be the best to obtain the maximum paddy yield and net profit. Thus, to harvest maximum economical paddy yield a farmer may opt any of these two dry seeding planting methods depending upon the type of available farm machinery, equipment and soil.

Novelty Statement

Dry-seeded rice (DSR) is contemporary rice production technology which escapes the strenuous job of rice seedling transplanting in puddled soil. Refinement of DSR production technology especially planting techniques is an important aspect addressed in current study, and it was concluded that DSR–ridge and –drill sowing are best alternative options that can be adopted by rice growers across the globe to harvest maximum benefits.

Author's Contribution

SI and UBK conducted the experiments in field, recorded data and drafted the manuscript. NI drafted introduction. Whereas, MUS compiled the data and AI wrote material and methods. MR did statistical analysis. MS supervised the trials, and THA revised and improved the language of the manuscript.

Conflict of interest

The authors have declared no conflict of interest.

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