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SCREENING AND ADAPTABILITY OF RICE VARIETIES FOR YIELD, MILLING RECOVERIES, AND QUALITY TRAITS UNDER DRY DIRECT-SEEDED RICE

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The conventional rice production system of Pakistan is escalating due to the higher level of labor involved, shortage of water and higher cost of production due to the rapidly increasing cost of energy resources. Dry direct seeded aerobic rice (DDSAR) is a valuable option to ease the problem of labor, water, and energy resources. In this study, screening of four rice varieties of conventional transplanted rice was evaluated under DDSAR in terms of yield, milling recoveries, grain and cooking quality. Four rice cultivars, viz; Super Basmati; Basmati 2000; Basmati 515 and PS-2 were sown at the Research Station of the Engro Fertilizers, Sheikhupura, Pakistan during three consecutive summer seasons (2016 to 2018). The sowing was accomplished in well prepared dry fields. Each variety performed well in terms of yield and quality traits in DDSAR but in terms of yield, Basmati-515 outperformed the other varieties and showed consistency in yield for three consecutive years of cultivation. PS-2 also gave yield statistically similar to Basmati-515 but maximum cooked grain length (17.1-17.5 mm) and grain elongation ratio (1.69-1.7) was recorded for PS-2. In contrast to other varieties, the minimum head rice percentage (40.5-43.5%) was recorded in PS-2 cultivar besides having the second-highest total milled rice percentage (50.5-73.4%) after Basmati-515 (81.0-82.8%). DDSAR did not affect the cooking quality of rice except bursting. In crux, the cultivation of low land rice cultivars under DDSAR not only maintained or increased the grain yield but also the grain and cooking quality of rice.
Keywords: Aerobic rice, bursting, grain dimensions, head rice recovery, yield-related traits.

INTRODUCTION

Rice (*Oryza sativa* L.) is an important staple food for more than half of the world's population (Chauhan *et al*., 2017). About 90.2% of the world's rice is produced and consumed in Asia (Anonymous, 2018). Global warming, scarce water resources, limited availability of labor and climate change has threatened the rice productivity through the conventional method of cultivation (Sandhu *et al*., 2017) and inculcate that the need of the time is to adopt some possible motives to introduce alternate water and energy-efficient production system such as direct-seeded rice (Nie *et al*., 2012; Rasul, 2016; USGS, 2016). Being water and labor-saving, direct-seeded rice is an emerging technology in the rice-wheat cropping system that facilitates the sowing of seeds directly in the non-puddled and unflooded field (Wang *et al*., 2002; Belder *et al*., 2005).

Numerous advantages of direct-seeded rice over transplanted rice has been reported in the literature as require less water (49-55%) and labor requirement (Bhushan *et al*., 2007; Nawaz *et al*., 2017; Ishfaq *et al*., 2020), maintain yield and quality (Ishfaq *et al*., 2018; Ishfaq *et al*., 2021) and timely sowing of succeeding crop (Kumar and Ladha, 2011). According to estimation, it has been reported that water requirement is expected to be increase intensively for agriculture because to ensure food security 60% more production of food will be required (WWAP, 2016). The nutrition demand of an ever-increasing population requires that food production should be enhanced by 100% and 60% in developing countries and globally, respectively by 2050 (Alexandratos and Bruinsma, 2012). The scenario of increasing population and dwindling water resources, challenged the cultivation of conventional transplanted rice (Bouman *et al*., 2005). While, DDSAR cultivation seems to be potentially productive because it needs 49-55% less amount of water, 50% less labor, 32-88% higher crop productivity (Wang *et al*., 2002; Ishfaq *et al*., 2020), 50% fewer greenhouse gases emission (Weller *et al*., 2016). Instead of benefits as mentioned above, there are some serious challenges needed to be encountered for the successful cultivation of DDSAR. These are impaired kernel quality (Farooq *et al*., 2011), high weed infestation (Bajwa *et al*., 2019), panicle sterility (Kumar and Ladha, 2011), lack of suitable varieties, and water and disease management (Nguyen and Ferrero, 2006).

The lack of stable and well-adapted varieties under direct-seeded rice cultivation is a major drawback behind the failure to achieve a declared yield potential (Wang *et al*., 2002). So, one of the main reasons behind such a high yield gap among farmers is the cultivation of the contemporary cultivars of rice using an aerobic rice production system (Sandhu *et al*., 2019). According to Nie *et al*. (2012), the major constraint behind the poor yield and quality of aerobic rice is the absence of proper water and nutrients management.

Pakistan ranked 4th in rice export and exports premium quality rice to over 100 countries of the world due to the special aroma. It is difficult to define rice quality with precision because each part of the world has its preference for quality. Moreover, the concept of rice quality for consumers, millers, ethnic groups and growers may vary due to emphasis on different quality traits. For instance, according to consumer preference, grain shape, size, appearance, cooking characteristics, and aroma are more important. While, for millers, more head rice recovery with less broken and brown rice are important quality traits. Milling recoveries are also the most important quality traits from a marketing point of view (Pandey *et al*., 2014). It is the need of the hour to increase rice productivity as well as its quality to ensure the rice export and national food security. So, screening of ecologically sound, and cost-efficient rice cultivars with maximum attainable yield and better quality is necessary for the successful cultivation of DDSAR in the rice belt of Pakistan. Therefore, the current study was assumed for the screening of high yielding varieties having better quality traits in the ecological condition of rice belt and water-limited production system like DDSAR.

MATERIALS AND METHODS

This experimental study was conducted at Research Station of the Engro Fertilizers, Crop Science Division, Dera Balam, Sheikhupura, Pakistan from 2016 to 2018 during the Summer season (June to November). This farm is situated at 74.24° E longitude, 31.81° N Latitude, and 214 meters' altitude above the sea level in the rice core belt (kallar tract) of Punjab, Pakistan. Map of experimental location is represented in Figure 1**.** Before the execution of the experiment, the soil samples up to 30 cm (0-15 cm and 15-30 cm) depth were collected using a soil auger following the zig-zag pattern of soil sampling from different locations and a composite sample was prepared (Fortunati *et al*., 1994). The soil samples were analyzed for various soil properties (Table 1) by following method of Estefan *et al.* (2013). The soil of the experimental site was classified as loamy.

Four approved varieties of rice viz; V_1= Basmati Super, V_2= Basmati-2000, V_3= Basmati-515, and V_4= PS-2 were used for screening under DDSAR. The characteristics of each variety are elaborated in Table 2. The treatments were randomly

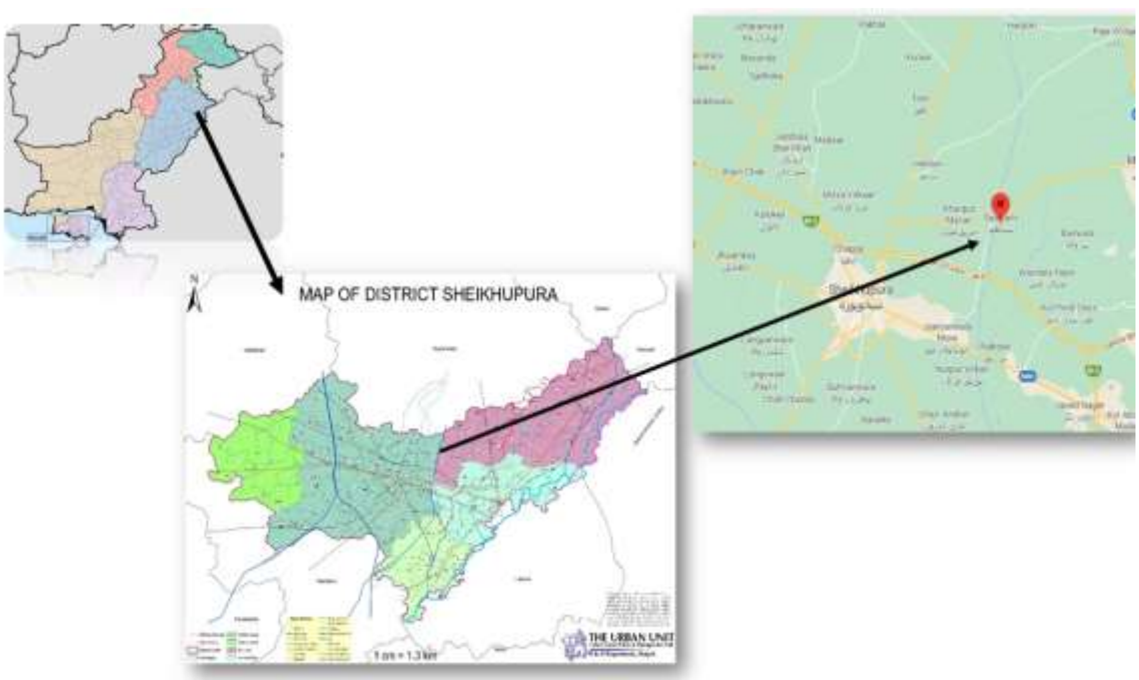

Figure 1. Map of experimental location.

assigned to the experimental unit using a randomized complete block design while, assuring that each treatment must be present in each plot of one acre. In each growing season, each acre was divided into four equal plots (200 m × 4.95 m) and randomly each variety was assigned to the experimental unit. The experimental treatments were replicated thrice in three adjacent paddy fields.

Table 1. Physico-chemical properties of the soil.

Characteristics	Values	Units	Status
Physical analysis			
Soil Texture	Loam		
Chemical analysis			
pH	7.9	-	Medium alkaline
EC	1.4	dSm^{-1}	Sodic soils
Saturation %age	38	%	Partially saturated
Organic Matter (OM)	1.03	%	Low
Available P	6.7	mg kg^{-1}	Low
Available K	134	mg kg^{-1}	Medium

After the soaking irrigation field was cultivated at field capacity moisture content (-40 kPa soil moisture tension) with cultivator and immediately planking was done. Weeds were allowed to emerge for ten days and then a rotavator was used to cut the weeds, and bury them under the soil. To prepare the seedbed for DDSAR, dry cultivation along with planking was done. Line sowing of each variety was accomplished using the multi-crop zero-till planter-2016 (locally modified multi-crop zero-till planters manufactured by Green land engineers, Daska) on 10th June 2016, 12th June 2017 and 8th June 2018 in dry soil. The crop was cultivated in lines (25 cm apart) using the seed rate of each variety @ 25 kg ha^{-1}.

Nitrogen (170 kg ha^{-1}), Phosphorus (85 kg ha^{-1}), Potash (60 kg ha^{-1}), and Zinc (15 kg ha^{-1}) were applied according to the recommendation in the form of Urea, DAP, SOP, and Zinc sulfate 33%, respectively. Phosphorus and Potash were applied as a basal dose along with 20% of total N at the time of sowing. The remaining 80% N (Urea) was applied in two splits. The second dose of nitrogenous fertilizer and Zn was applied at the active tillering stage (BBCH code 24 at 25 DAS), while the third split of nitrogenous fertilizer was applied at the panicle initiation stage (BBCH code 30 at 55-60 DAS) (Lancashire *et al*., 1991).

The first two weeks after the sowing, field was remained under the muddy condition to ensure the better stand establishment and weed control while irrigation management for the rest of the crop growth period was according to crop need as detailed in Ishfaq *et al*. (2020) for direct seeded rice under aerobic conditions. Total water input during the crop season is represented in Figure 2. During critical growth stages: two weeks after sowing, active tillering, panicle initiation, and flowering stages, irrigation were assured to avoid the water stress. Aside from the pre-irrigation, the DSR crop received on an average 14 irrigations. Last irrigation was applied in the third week of October in 2016, 2017, and 2018. Weeds were controlled by the application of pendimethalin @ 2000 $mLha^{-1}$within 24 hours of sowing in muddy conditions as pre-emergence and bispyribac sodium + bensulfuron methyl @ 200 g ha^{-1} as a post-emergence at 20 DAS. Cartap (Cartap hydrochloride) was applied at 22.5 kg ha^{-1} in the third week of August in each experimental year and the second application was done in the first week of September to control the rice stem borer and rice leaf folder. During the 1st week of October, Actara 25 WG (a.i. Thiamethoxam 25%) and Score 250 EC (a.i. Difenaconazole) were sprayed to prevent the planthopper. In the second week of September Nativo (trifloxystrobin and tebuconazole) was sprayed to cure a fungal attack (brown leaf spot) of the crop.

The crop was harvested on the 13th, 10th, and 8th of November in 2016, 2017, and 2018, respectively when the grain moisture content was ~19%. Grain moisture content was found by using grain moisture meter (MC-7825G, Swastik Scientific Co.).

Two locations from each experimental unit having an area of 1 m × 1 m were selected to count the total number of tillers in DDSAR and averaged. Plant height (from soil level to the tip of flag leaf or panicle) of randomly selected panicle (20) was measured using a wooden meter rod and average plant height was calculated for each variety (Yoshida, 1981). Similarly, the average of selected tillers (20) for plant height was used to measure panicle length, filled, unfilled and total numbers of grains $panicle^{-1}$(Ishfaq *et al*., 2020). Filled and unfilled grains $panicle^{-1}$ were differentiated by dipping the grains of each panicle in the water bucket. Floated grains were categorized as unfilled while; sunken as filled one and finally

Table 2. Characteristic of rice varieties used in the experiment.

Variety	Year of release	Crop duration	Plant height (cm)	Yield potential (t ha^{-1})	Salient features
Basmati Super	1996	150	120	3.2	Extra-long (7.45 mm) and strong aromatic.
Basmati-2000	2000	145	132	4.5	Stiff stem, high yielding, extra-long (7.68 mm) and strong aromatic.
Basmati-515	2011	154	125	4.5	Extra-long (7.56 mm), strong aromatic, moderately resistant to bakanae disease/foot rot and blast
PS-2	2013	145	120	3.5	Non-basmati, better tillering, lodging resistant, extra-long grain rice

Data source: https://aari.punjab.gov.pk/crop_varities_rice average was taken. The electronic automatic grain counter was used to count the grains panicle^{-1} and then 1000-grains from each experimental unit to measure the 1000-grains weight. Then digital electronic weighing balance was used to determine the weight of 1000-grains and expressed in grams. From each experimental unit harvesting of 2 m × 2 m area was done manually by using a sickle. The harvested rice crop from each respective plot of 2 m × 2 m size was tied into bundles and sun-dried for 3-4 days to lower down the moisture content ~14% before being threshed manually by beating against the metal drum and expressed in tonnes ha^{-1}.

Rice quality parameters are further categorized into milling recoveries, grain measurements, and cooking quality parameters. Total milled rice contains whole grains or head rice and broken grains; the total milled rice %age was calculated by using a digital weighing balance. A sample of 500 g was taken for each variety from each experimental unit. After the milling operation, the obtained sample was again weighed and total milled rice %age was calculated. For calculating brown rice %age a sample of about 50 grains of each variety after milling was taken and brown rice %age was calculated. Head rice %age was also found out from the same sample that was taken for calculating total milled rice %age. A digital seed grader was used for grading the grains on their size bases and head rice %age was taken.

Grain dimensions (length, width, and thickness) of 50 normal grains from each experimental unit were measured and expressed in mm. Milled grains were taken to measure grain length, width, and thickness. Grain length and width of randomly selected grains were measured by using a digital Vernier caliper (0-150 mm) and then average values were taken. However, the thickness of grain was measured by using a Screw gauge.

To determine cooked grain length (mm), the length of 10 whole rice grains of each experimental variety after cooking was measured by using the micro-scale, and the average length of cooked grain was compared with the average length of the uncooked grains. Bursting %age was calculated by counting the burst grains after cooking. The elongation ratio length of cooked grain was divided by the length of uncooked grain which was already measured for each variety (Ishfaq *et al*., 2021).

The computer software statistics 10 student version was used to analyses the data using the Fischer analysis of variance (ANOVA) technique. One-way ANOVA was constructed by taking fine-grain varieties as a factor under rice production system DSR. For post-ANOVA mean separation, for a parameter, the Tuckey test at 5% probability level was used (Steel *et al*., 1997).

RESULTS

Statistical analysis indicated that Basmati-515 took more water inputs as compared to other all varieties while within year's the highest water inputs were received in 2016 and 2018 than year 2017. Total water inputs in DDSR were with range of 1200 mm to 1490 mm (Figure 2).Varieties exhibited substantial differences in plant height; however, they exhibited significant effects in comparison (Table 3). In the year 2016 and 2018, Basmati-2000 and Basmati-515 comparatively had no significant plant height difference as compared to 2017 when both varieties had substantial plant height differences (Table 3). Statistically, the maximum plant height (148.0 cm) was observed in Basmati-2000 (Table 3) while Super Basmati gave minimum plant height (123.0 cm). On an average, maximum plant height was recorded in 2017 while the minimum in 2016 (Table 3). Maximum total numbers of tillers m^{-2} were counted in Basmati-515 (345, 313 and 311) in successive 3 growing years followed by PS-2 (305, 296 and 295), showing that there was a significant difference between rice varieties for maximum total tillers m^{-2} (Table 3). The minimum number of tillers was found in Basmati-2000 (275.0). On the average, maximum number of tillers was observed in 2016 while, minimum in 2018 (Table 1b). The maximum panicle length was measured in Basmati-515 (30.5 cm) in three growing years (Table 3) while, Basmati-2000 gave minimum panicle length (26.9 cm). This indicates that the four fine rice varieties were significantly different for panicle length. On an average, the maximum panicle length was measured in 2016 while, minimum in 2018 (Table 3). The highest number of filled grains panicle^{-1} was counted in Basmati-515 (105.0 panicle^{-1}) followed by PS-2 (97.0 panicle^{-1}) and Super Basmati (94.0 panicle^{-1}) with slight variation in three growing years (Table 3). On an average, the

Table 3. Morphological traits for the screening of basmati varieties in direct-seeded rice system.

Treatment	Total tillers m^{-2}			Plant height (cm)			Panicle length (cm)			Filled grains panicle^{-1}		
	2016	**2017**	**2018**	**2016**	**2017**	**2018**	**2016**	**2017**	**2018**	**2016**	**2017**	**2018**
Super Basmati	301.0^{b}	285.0^{c}	282.0^{bc}	123.0^{b}	128.0^{c}	126.0^{b}	28.5^{b}	28.4^{ab}	27.9^{bc}	87.0^{b}	94.0^{b}	91.0^{c}
Basmati-2000	275.0^{c}	276.0^{d}	275.0^{c}	143.0^{a}	148.0^{a}	139.0^{a}	27.7^{b}	27.5^{b}	26.9^{c}	79.0^{c}	83.0^{d}	86.0^{d}
Basmati-515	345.0^{a}	313.0^{a}	311.0^{a}	137.0^{a}	138.0^{b}	140.0^{a}	30.0^{a}	30.5^{a}	30.6^{a}	100.0^{a}	105.0^{a}	103.0^{a}
PS-2	305.0^{b}	296.0^{b}	295.0^{b}	127.0^{b}	133.0^{bc}	130.0^{b}	28.9^{ab}	28.5^{ab}	29.1^{ab}	89.0^{b}	91.0^{c}	97.0^{b}
HSD ($p \leq 0.05$)	*25.4*	*6.5*	*13.6*	*7.5*	*6.1*	*4.8*	*1.5*	*2.3*	*1.8*	*2.7*	*2.4*	*3.4*

HSD= Honestly significant difference; Values sharing different lettering for a parameter are different significantly ($p \leq 0.05$) by the Tukey's HSD test.

Table 4. Yield and yield-related traits for the screening of basmati varieties in direct-seeded rice system.

Treatment	Unfilled grains panicle^{-1}			Total grains panicle^{-1}			1000-grain weight (g)			Grain yield (t ha^{-1})		
	2016	2017	2018	2016	2017	2018	2016	2017	2018	2016	2017	2018
Super Basmati	12.0^{b}	12.0^{b}	11.0^{b}	96.0^{bc}	105.0^{b}	100.0^{c}	22.1^{c}	22.9^{bc}	22.6^{b}	4.2^{b}	4.0^{bc}	4.0^{bc}
Basmati-2000	15.0^{a}	17.0^{a}	13.0^{a}	94.0^{c}	100.0^{c}	96.0^{d}	21.4^{c}	21.7^{c}	21.8^{c}	3.2^{c}	3.5^{c}	3.4^{c}
Basmati-515	10.0^{c}	7.0^{c}	9.0^{c}	109.0^{a}	115.0^{a}	115.0^{a}	25.1^{a}	24.6^{a}	25.8^{a}	5.1^{a}	5.1^{a}	5.0^{a}
PS-2	11.0^{bc}	11.0^{b}	10.0^{bc}	99.0^{b}	106.0^{b}	105.0^{b}	23.7^{c}	23.9^{ab}	24.1^{b}	4.6^{b}	4.4^{ab}	4.4^{ab}
HSD ($p \leq 0.05$)	*1.4*	*1.4*	*1.4*	*3.2*	*1.6*	*2.7*	*1.2*	*1.7*	*1.7*	*0.5*	*0.6*	*0.7*

HSD= Honestly significant difference; Values sharing different lettering for a parameter are different significantly ($p \leq 0.05$) by the Tukey's HSD test

maximum numbers of filled grains were recorded in 2018 while, minimum in 2016 (Table 3).

However, the lowest numbers of unfilled grains were found in Basmati-515 (7.0 panicle^{-1}) while Super Basmati (12.0 panicle^{-1}) and Basmati-2000 (17.0 panicle^{-1}) possessed the maximum number of unfilled grains respectively (Table 4). On average, in 2016 the maximum number of unfilled grains was observed while the minimum number of unfilled grains was observed in 2018 (Table 4). All yield contributing characters and yield were noticeably influenced by variety (Table 4). Different varieties considerably affected the number of grains per panicle and 1000-grain weight. Basmati-515 produced the maximum number of total grains (115.0 panicle^{-1}) followed by PS-2 (106.0 panicle^{-1}) in three growing years (Table 4). On an average, the maximum number of total grains panicle^{-1} was found in 2017 while, the minimum was found in 2016 (Table 4). Maximum 1000-grain weight was observed in Basmati-515 (25.8g) with a significant difference in the 1000-grain weight of the other three varieties under the same growing conditions (Table 4). Minimum 1000-grain weight was recorded in PS-2 (23.7g). On an average bases, a maximum of 1000-grain weight was observed in 2018 while, the minimum was observed in 2016 (Table 4).

Overall, Basmati-515 produced the highest grains yield (5.1 t ha^{-1}) in three successive growing years, while Basmati-2000 gave the minimum grain yield (3.2 t ha^{-1}) (Table 4). On an average, the maximum grain yield was observed in 2017 while the minimum grain yield was observed in 2016 (Table 4).

Milling recoveries which included the total milled rice %age, brown rice %age, and head rice %age had a significant effect on the various quality characters of a variety. The higher %age of total milled rice was recorded in Basmati-515 (82.8%) followed by PS-2 (73.4%) while, the lower total milled rice %age was in Super Basmati (63.4%) as given in (Table 5). On an average, the maximum total milled rice %age was remarked in 2016 while, the minimum %age of total milled rice was remarked in 2018 (Table 5). Brown rice %age greatly affects the quality characters of a variety. The maximum brown rice %age was calculated in Basmati-2000 (84.0%) while Basmati-515 had minimum brown rice %age (80.1%). It presents a significant difference in brown rice %age in these varieties (Table 5). As reflected by the mean of these varieties that brown rice %age was comparatively almost same in three successive growing years (Table 5). Head rice %age was calculated; that was maximum in Basmati-515 (55%) followed by Super Basmati (52%), while, Basmati-2000 and PS-2 had a minimum (48% and 40.5%, respectively) head rice %age (Table 5). The mean value of three successive growing years indicates that maximum head rice %age was observed in 2017 while comparatively minimum head rice %age was observed in 2016 and 2018 (Table 5). Grain dimensions were found to have a significant effect on various quality parameters. The longest grain length was measured in Basmati-515 (9.1 mm) in three growing years (Table 5) followed by PS-2 (8.2 mm) while, minimum grain length was measured in Basmati-2000 (6.1 mm). On an average, the maximum grain length was observed in 2016 while, the minimum grain length was observed in 2018 (Table 5).

The greater grain width was measured in Basmati-515 (1.7 mm) as minimum grain width was measured in Basmati-2000

Table 5. Milling recoveries and rice grain quality traits for the screening of basmati varieties in direct-seeded rice system.

Treatment	Total milled rice %age			Head rice %age			Brown rice %age			Grain length (mm)		
	2016	2017	2018	2016	2017	2018	2016	2017	2018	2016	2017	2018
Super Basmati	68.5^{c}	67.0^{bc}	66.0^{bc}	51.0^{b}	52.0^{b}	50.0^{b}	82.3^{ab}	82.6^{ab}	82.7^{ab}	7.3^{c}	6.8^{bc}	6.8^{bc}
Basmati-2000	67.1^{c}	64.4^{c}	63.4^{c}	47.0^{c}	50.5^{c}	47.0^{c}	83.9^{a}	83.9^{a}	84.0^{a}	6.5^{c}	6.1^{c}	6.2^{c}
Basmati-515	82.8^{a}	81.0^{a}	81.4^{a}	55.0^{a}	53.5^{a}	54.0^{a}	80.1^{b}	80.3^{b}	80.2^{b}	9.1^{a}	8.9^{a}	8.1^{a}
PS-2	73.4^{b}	70.5^{b}	71.4^{b}	40.5^{d}	43.5^{d}	43.4^{d}	81.8^{ab}	81.9^{ab}	82.0^{ab}	8.2^{b}	7.4^{b}	7.4^{ab}
HSD ($p \leq 0.05$)	*2.8*	*4.5*	*5.4*	*1.5*	*1.5*	*2.7*	*2.7*	*2.8*	*2.5*	*0.8*	*0.8*	*0.9*

HSD= Honestly significant difference; Values sharing different lettering for a parameter are different significantly ($p \leq 0.05$) by the Tukey's HSD test

Table 6. Rice grain quality and cooking quality traits for the screening of basmati varieties in direct-seeded rice system.

Treatment	Grain width (mm)			Grain thickness (mm)			Cooked grain length (mm)			Bursting %age			Elongation ratio		
	2016	**2017**	**2018**	**2016**	**2017**	**2018**	**2016**	**2017**	**2018**	**2016**	**2017**	**2018**	**2016**	**2017**	**2018**
Super Basmati	1.3^{ab}	1.3^{b}	1.3^{ab}	1.4^{ab}	1.5^{ab}	1.4^{ab}	13.9^{bc}	14.0^{bc}	13.8^{bc}	7.0^{b}	5.0^{b}	7.0^{b}	1.57^{bc}	1.6^{ab}	1.56^{b}
Basmati-2000	1.2^{b}	1.3^{b}	1.2^{b}	1.4^{b}	1.3^{b}	1.4^{b}	12.8^{c}	12.1^{c}	12.3c	11.0^{a}	13.0^{a}	15.0^{a}	1.54^{c}	1.5^{b}	1.55^{b}
Basmati-515	1.7^{a}	1.7^{a}	1.7^{a}	1.5^{a}	1.7^{a}	1.5^{a}	15.1^{b}	15.4^{ab}	15.5^{ab}	3.0^{d}	2.0^{c}	2.0^{c}	1.62^{ab}	1.6^{ab}	1.63^{ab}
PS-2	1.36^{ab}	1.4^{ab}	1.4^{ab}	1.46^{ab}	1.5^{ab}	1.5^{ab}	17.1^{a}	17.3^{a}	17.5^{a}	4.0^{c}	4.0^{bc}	4.0^{c}	1.69^{a}	1.7^{a}	1.69^{a}
HSD ($p \leq 0.05$)	*0.4*	*0.4*	*0.4*	*0.1*	*0.3*	*0.1*	*1.9*	*2.7*	*2.5*	*0.9*	*2.1*	*2.2*	*0.1*	*0.1*	*0.09*

HSD= Honestly significant difference; Values sharing different lettering for a parameter are different significantly ($p \leq 0.05$) by the Tukey's HSD test

(1.2 mm) which indicates a significant difference in grain width of different fine grain rice varieties (Table 6). On an average, almost the same grain width was observed in four varieties in three successive growing years (Table 6). The maximum grain thickness was measured in Basmati-515 (1.7 mm) while, the minimum was measured in Basmati-2000 (1.3 mm) that is indicative of significant grain thickness difference in rice varieties studied for screening (Table 6)

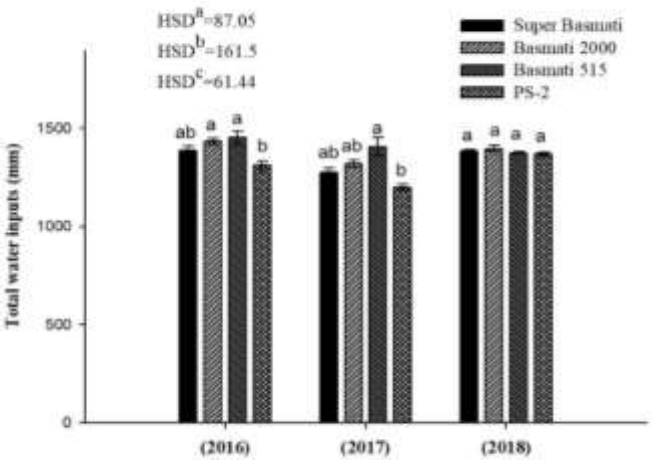

Figure 2. Total water inputs during rice season of 2016, 2017 and 2018; HSD= Honestly significant difference; HSD[a]= HSD value for 2016; HSD[b]= HSD value for 2017; HSD[c] = HSD value for 2018; Similar lettering on bar graphs within year are statistically similar ($p \leq 0.05$) by the Tukey's HSD test.

A maximum grain thickness was observed in 2017 while; minimum grain thickness was observed in 2016 (Table 6).The current experiment presented that, cooking quality parameters like cooked grain length (mm), bursting %age, and elongation ratio had a great impact on quality traits of a variety. Statistical analysis indicated that a significant difference exists for cooked grain length in rice varieties under experimentation. The maximum cooked grain length was calculated in PS-2 (17.5 mm) while, the minimum cooked grain length (12.1 mm) was calculated in Basmati-2000 (Table 6). The average cooked grain length was observed comparatively the same in three successive growing years. The maximum bursting %age (13%) after cooking was calculated in Basmati-2000, as the minimum bursting %age (2%) was calculated in Basmati-515 (Table 6). The mean value reflected that maximum bursting 2-15% was observed in 2018 as compared to the 2-13% bursting percentage in 2017(Table 6). In our study, it was observed that the maximum elongation ratio was measured in PS-2 (1.7) and the minimum value (1.5) was measured in Basmati-2000 (Table 6). The mean data of three years present that; elongation ratio remained non-significant each year.

DISCUSSION

The higher water inputs in 2016 and 2018 reflected that more evaporative demand of water inputs was due to increased temperature (Ishfaq *et al*., 2020). The lower amount of total water inputs in DDSAR could be attributed to devoid of continuous flooded condition and absence of heavy initial irrigation to create puddled condition (Kaur and Singh, 2017). Moreover, DDSAR crop matures earlier in comparison to transplanted rice (Farooq *et al.*, 2011; Ishfaq *et al*., 2020). In the water and labor scarcity scenario, DDSAR is not only an economic but an efficient, resourceful, and mechanized rice cultivation system. Research studies indicated that DDSAR pertains to improve soil physical health (Buresh and Haefele, 2010), labor, water, and energy-saving (Tuong *et al*., 2005), abridged GHG emission, ensure timely sowing of succeeding upland crop (Weller *et al*., 2016), enhanced environmental sustainability and agricultural productivity (Bouman *et al*., 2005). But, success in the DDSAR system is only possible when we have suitable crop management techniques along with some suitable rice genotypes that can thrive and maintain yield under water-limited conditions. Currently, DDSAR is getting momentum not only in Pakistan but also in other Asian countries (Kumar and Ladha, 2011). Up till now development of genotypes for upland rice is negligible and when genotypes of the TPR environment are cultivated in DDSAR they behave differently because of genotype × environment interaction (Dou *et al*., 2016).

For screening of genotypes, analysis of variance was employed to select the superior genotype for yield, quality, and adaptability. There was a significant effect of genotype on morphological, yield, milling, and quality traits due to different genetic potential or genotype × environment interaction. The prevailing variability in all traits might be due to reduced water regimes, nutrient uptake, availability, and irrigation cycle under the DDSAR system (Kreye *et al*., 2009).

Plant height was not affected in this study because water deficit was not reduced to such limitations that can reduce the stem growth, cell division, and cell length but, in aerobic rice when water stress gain severity inbred as well as hybrid genotypes showed a reduction in plant height and total tiller per unit area and ultimately reduction in final yield (Lu *et al*., 2002). Severe water stress at panicle initiation (PI) or after panicle emergence resulted in more spikelet sterility and reduction in the number of spikelets and assimilates translocation (Kato *et al*., 2009). Furthermore, contrary to our findings severe water stress would dehydrate the panicle, diminish the endosperm cells, and hampered the sink capacity (Xue *et al*., 2008). Similarly, in previously several studies a severe yield reduction was recorded under the aerobic condition when high yielding genotypes of lowland rice were cultivated (Bouman *et al*., 2005; Peng *et al*., 2006; Patel *et al*., 2010).

On the other hand, Zhang *et al*. (2012) concluded that soil drying after anthesis increased the test weight by 28.6% due to the increased grain filling rate of inferior spikelets. That was attributed to, improved activities of four key enzymes that are responsible for sucrose to starch conversion and abscisic acid role. Basmati-515 showed a stable and higher yield in all three years as compared to others due to having more tillers per unit area, the number of kernels per panicle, and the highest test weight. Moreover, basmati-515 is genetically moderately resistant to blast disease. Genotype PS-2 also represented a comparable yield to basmati-515 because of its higher genetic yield potential.

The suitable genotypes for higher yield were identified as Basmati-515 and PS-2, but in the case of milling recoveries, basmati-515 was found to be better due to less broken and more intact grains percentage. As compared to PS-2 and other genotypes, Basmati-515 attained higher head rice recovery which might be due to less chalky endosperm. According to Krishnan and Rao (2005), genetic potential and prevailing environment govern the quality of paddy. The most important environmental factor: soil moisture status at the post-anthesis stage influences the rice grain quality dramatically (Dingkuhn and Gal, 1996). Reduced soil moisture content curtailed the amylose content and percentage of un-ripened grains but, augmented the protein content of brown rice, milling recovery of rice (Renmin and Yuanshu, 1989). Thus, water stress at the post-anthesis stage could be applied as a useful factor to hamper the broken grains and to enhance the head rice percentage. Cooking qualities besides the aroma of Basmati rice are adversely affected under poor irrigation water supply specifically at the grain filling stage (Pandey *et al*., 2014). Reduced soil moisture condition at the post-anthesis stage induces; greater grain volume expansion upon cooking, physico-chemical difference in rice grain, higher milling recovery, more protein content, and head rice ratio (Fofana *et al*., 2010).

Previous studies (Xiaoguang *et al*., 2005; Kombali *et al*., 2017) and current study confer that economic and sustainable paddy yield and quality produce can be attained by applying irrigation according to the sensitivity of a genotype toward stress. Water-saving in aerobic rice cultivation could also be attained by decreasing irrigation cycles, called dry saving (Jalota *et al*., 2009). Water-saving from the dry cycle not only reduces production cost but can also be utilized to increase the area under production and to increase water productivity.

Conclusion**:** In crux, DDSAR is a viable alternative option under water limiting condition as it has potential to reduce total water inputs. DDSAR not only maintained the higher yields but also maintained the milling recovery and cooking quality of low land rice varieties except bursting. Among the tested varieties, Basmati-515 performed best due to more panicle bearing tillers per unit area, heavier kernel weight, and the number of grains per panicle. Whereas, PS-2 gave comparable yield and higher kernel length but lower milling recoveries. In terms of cooking quality more bursting of cooked grains was observed in Basmati-2000 but Basmati-515 and PS-2 gave the least.

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