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Research Article

# Optimizing Row Spacing for Direct Seeded Aerobic Rice under Dry and Moist Fields

**Muhammad Ishfaq[1*], Nadeem Akbar[1], Imran Khan[1], Shakeel Ahmad Anjum[1], Usman Zulfiqar[1], Muhammad Ahmad[1], Mumtaz Ahmad[2] and Muhammad Umer Chattha[1]**

*[1]Department of Agronomy, University of Agriculture, Faisalabad-38040, Pakistan; [2]Research and Development Officer, Engro Fertilizers, Seed Business, Pakistan.*

**Abstract** | Soil moisture status and row spacing at the time of sowing are important factors that can affect crop stand establishment, yield and yield-related attributes along with quality of direct seeded rice. Farmer field-based experiment comprised two soil moisture regimes at the time of sowing: ($M_1$ = Sowing in moist (field capacity) condition, $M_2$= Sowing in dry condition) in main plots, while three different row spacings ($S_1$: broadcasting, (no defined row spacing) $S_2$: 11.25 cm row spacing, $S_3$: 22.50 cm row spacing) were assigned to sub-plots. The experimental results revealed that treatment $S_3$ (22.50 cm row spacing) took minimum time to start emergence (3.7 days) and mean emergence time (9.6 days). In case of soil moisture condition at the time of sowing minimum time start to emergence and mean emergence time under moist field condition were (4.1 days) and (9.9 days) respectively. Final emergence count (177.3 $m^{-2}$), Plant height (71.6 cm) at physiological maturity, and opaque kernel (13.7%) were maximum while weed density and weed biomass was minimum in $S_2$ (11.25 cm row spacing) treatment. Statistically, maximum productive tillers (296.8 $m^{-2}$), numbers of grains per panicle (93.7), 1000-grain weight (19.4 g), paddy yield (3.5 t $ha^{-1}$) and harvest index (34.3%) were recorded in $S_3$ treatment. Percentage of sterile spikelet (9.5%), abortive kernel (9.7%) were highest in broadcasting treatments. Maximum net income (USD. 1097.2 $ha^{-1}$) was obtained from $S_3$ (22.50 cm row spacing) treatment under dry field conditions and BCR 1.5 was recorded in 22.50 cm spaced rows. In sum, 22.50 cm spaced rows are optimum for successful and economic rice productivity under direct seeded rice.

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***Correspondence** | Muhammad Ishfaq, Department of Agronomy, University of Agriculture, Faisalabad-38040, Pakistan; **Email:** Ishfaq2727@gmail.com
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## Introduction

Rice (*Oryza sativa* L.) is staple food for more than 50% of the world particularly in South Asia and Latin America (Kumar and Ladha, 2011). Most of the rice (75%) is grown and consumed in Asian countries (GOI, 2009). Rice is grown in many fragments of the world in diverse ways; transplanted flooded rice, alternate wetting and drying, rice on raised beds and aerobic rice (Bouman and Toung, 2003). The main cropping differences are between direct seeding and puddled rice (Pandey and Velasco, 2005). In case of Pakistan, rice is the second important staple food crop after wheat, it is the 3rd main crop after wheat and cotton and is also a significant exportable item in Pakistan (GOP, 2015). Major factors of farmer's choice of crop establishing technique are satisfactory water supply, rainfall pattern, field elevation and


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weed incidence (Pandey and Velasco, 1999). In Asia 90% of total fresh water is used in irrigated agriculture, and more than 50% of this is mandatory for rice.

Quantity of available water for irrigation is increasingly getting scarce (Gleick, 1993; Guerra et al., 1998). Traditional rice production system facing challenges of water, labor and energy crises and becoming less economic as conventional cultivation of rice is resource intensive (Rajkumara et al., 2003). Alarming water shortfall jeopardize food production in transplanting rice system (Cabangon et al., 2002). To combat with these problems and to ensure food security, direct seeded rice (DSR) might be promising solution, but the main reason behind the failure of DSR is heavy weed invasion, due to which 100% destruction of the rice crop may occurs (Rao et al., 2007). In this context to lessen the hardship and extra charges farmers are shifting to other methods like direct seeding of rice (Mehmood et al., 2002). In Asia area under DSR is increasing speedily with 21-22% of the total area under rice being dry seeded (Pandey and Velasco, 2002).

The adoption of cultural approaches in integrated weed management (IWM) strategies has been increasing to reduce the dependence on herbicides and offer more effective weed control (Azmi et al., 2007). Among the factors involved in decreasing rice yield, the planting geometry is very crucial because plant population per unit area affects the yield. Hu et al. (2000) found that population dynamic exerts a significant effect on crop growth rate and economic yield, due to significant influence both on vegetative and reproductive development. Use of higher seed rate and altered plant spatial arrangement have been proposed and tested as a component of weed management strategies in cereals to improve competitiveness (Cousens, 1985; Kristensen et al., 2008). Singh et al. (1986) distinguished that 30cm spaced single row planting have maximum number of panicle (15.97) bearing tillers per hill that was similar to 60 cm spaced triple row strip planting. Optimum crop plant density and arrangement can reduce the impacts of weed competition. Comparison of three sowing techniques (normal transplanting, direct seeding in lines and broadcasting) in an experiment resulted that direct sowing in 20 cm apart lines gave best results (Mehmood et al., 2002). Iqbal (2014) concluded that narrow planting pattern in aerobic rice results comparatively improved growth and production due to more beneficially consumption of resources and environment, moreover heavy weeds infestation was suppressed which is most notorious factor for failure of aerobic rice. Lampayan et al. (2009) declared that row spacing from 25 to 35 cm have no significant effect on yield. Row spacing have no effect on lodging and bending resistant of stem, but row spacing of 35 cm can be used to manage weeds easily between the rows, moreover crop damage due to tyre tracks can be minimized in mechanized field operations. Jabbar et al. (2010) found that dry matter production of DSR was reduced when rice crop 75-cm spaced 4-rows strips (15/75) was intercropped with diverse forage legumes and non-legumes than sole crop of rice. In DSR narrow row spacing to control heavy weeds infestation could be one component of integrated weed management strategies. Chauhan and Johnson, (2011) reported that total weed biomass was affected by weed control timing and row spacing. Sridhara et al. (2011) conducted a field trail to evaluate the effect of planting geometry, genotype and method of establishment on roots traits and grain yield of DSR and declared that 30 cm row spacing under aerobic rice cultivation produced significantly maximum biological yield, number of panicles plant$^{-1}$ and test weight. Through studies it was deduced that, in general, in direct seeded rice too, in the presence of weeds the highest yields could be expected where crop plant densities and spatial uniformity were ensured to greater extent (Ni et al., 2004; Phuong et al., 2005).

This experiment was therefore conducted because direct seeded rice is dire need of hour as conventional method of sowing rice is water and labor intensive, deteriorating soil health and stagnant yield practice. Therefore, to optimize the row spacing for direct seeded aerobic rice and to distinguish the soil moisture level to attain maximum emergence and good stand establishment.

## Materials and Methods

*Experimental site and treatments*

The proposed field study was conducted at farmer's field in Jeevan Shah on Sargodha road Faisalabad, (31°."N latitude, 73°."E longitude), Pakistan during summer season, 2015. The experiment comprised of following two moisture regimes: ($M_1$ = Sowing in watter (field capacity) condition, $M_2$= Sowing in dry condition) that were assigned in main plot and three different rows spacing: **(**$S_1$ = Broadcast (No row spacing maintained), $S_2$ = Line sowing at 11.25 cm spaced rows, $S_3$ = Line sowing at 22.5 cm spaced rows) that were assigned to the subplots. The data regarding climatic conditions over the crop growing period are represented in Figure 1.

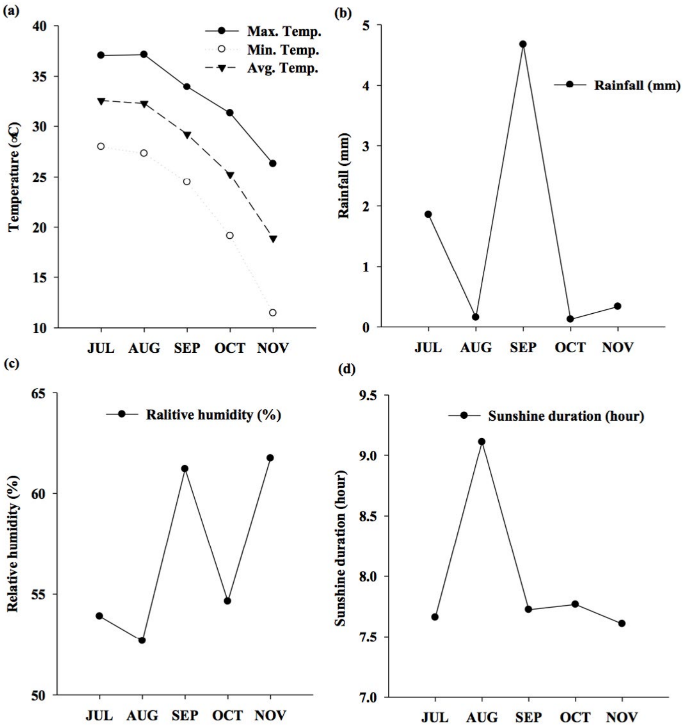



**Figure 1: a**) *Maximum, minimum and average temperature (°C),* **b**) *Rainfall (mm),* **c**) *Relative humidity (%) and* **d**) *sunshine duration (h) over the growing period of direct seeded rice.*

### *Soil analysis*

Soil sample were taken at the depth of 15 cm and 30 cm. The composite soil sample were analyzed for its various chemical properties by using the method of Homer et al. (1961). Percentage of sand, silt and clay in the soil sample was determined by hydrometer method (Moodie et al, 1959). Texture class was determined by using international textural triangle. The soil was sandy clay loam having pH 8.0, TSS 0.21%, organic matter 0.73%, total nitrogen 0.05%, available P 6.5 ppm and available K 186 ppm.

### *Crop husbandry*

The required seed bed was prepared and rice cultivar Super Basmati was sown on 7th July 2015 using seed rate of 30 kg $ha^{-1}$. Direct seeding was done by hand drill to maintain the line to line spacing. The crop was fertilized with 150 kg $ha^{-1}$ N, 70 kg $ha^{-1}$ P and 50 kg $ha^{-1}$ K and 12 kg $ha^{-1}$ Zn in the form of urea, DAP, Sulfate of potash and Zinc sulphate respectively. Half of nitrogen and whole of the phosphorus and potash fertilizers were applied at sowing, while remaining nitrogen was given in two equal splits, at tillering and panicle initiation stage of the crop. Zinc sulphate dose was applied 25 days after sowing. Under dry field condition field was irrigated immediately after the sowing, while, in case of moist (wattar condition) field was irrigated after one week of sowing. Weed management was practiced through combined cultural and chemical control. Pre-emergence herbicides (Top-star® Oxadiargyl 80% WP @ 40 g $acre^{-1}$) was applied just after sowing of crop in standing water.

### *Procedure to record the observations*

Time to start germination and final emergence count was counted on daily basis according to AOSA (1990) until a constant stand was achieved. Mean emergence time (MET) was calculated according to Ellis and Robert (1981). Data pertaining to plant height at maturity was measured from base to leaf tip of 15 plants from each plot with the help of a meter rod, grain yield and straw yield samples were recorded after harvesting and threshing the plants in 1 $m^2$ area. Harvesting was done manually and yield and yield components were recorded at the time of physiological maturity and harvesting.

### *Experimental design and statistical analysis*

The experiment was conducted in a randomized complete block design (RCBD-Split plot arrangement) with three replications. The collected data were analyzed using the Fisher's analysis of variance technique. Then treatment means were compared using Least Significant Difference (LSD) test at 5% probability level (Steel et al., 1997). Economic analysis was made by calculating the adjusted paddy and straw yields, cost of production and benefit-cost ratio.

## Results and Discussion

### *Stand establishment parameters*

Soil moisture conditions at the time of sowing had a substantial impact on time start to emergence, time taken to 50% emergence and mean emergence time, while, no significant effect of soil moisture condition was observed on final emergence count. Moist field condition at the time of sowing plants took minimum time to start emergence (4.1 days), 50% emergence (8.1 days) and mean emergence time (9.9 days) (Figure 2. a, c and e). Row spacing significantly affected all the stand establishment attributes (Figure 2. b, d, f and h). In $S_3$ (22.50 cm apart rows) treatment direct seeded Super Basmati took minimum time (3.7

days) to start emergence, 50% emergence time (7.5 days) and mean emergence time (9.5 days) followed by 11.25 cm row spacing, while, maximum time for all these stand establishment parameters were taken by broadcasting treatment. Moreover, in case of final emergence count (FEC) 11.25 cm spaced rows showed maximum FEC (177.3 $m^{-2}$) followed by 22.50 cm spaced rows (156.2 $m^{-2}$) and least FEC (143.5 $m^{-2}$) was observed under broadcasting treatment. Interactive effect between soil moisture regimes and row spacing was found non-significant for these parameters. Moreover, non-significant (*$p \leq 0.05$*) interactive effect of field moisture condition at the time of sowing and row spacing was observed (Figure 2).

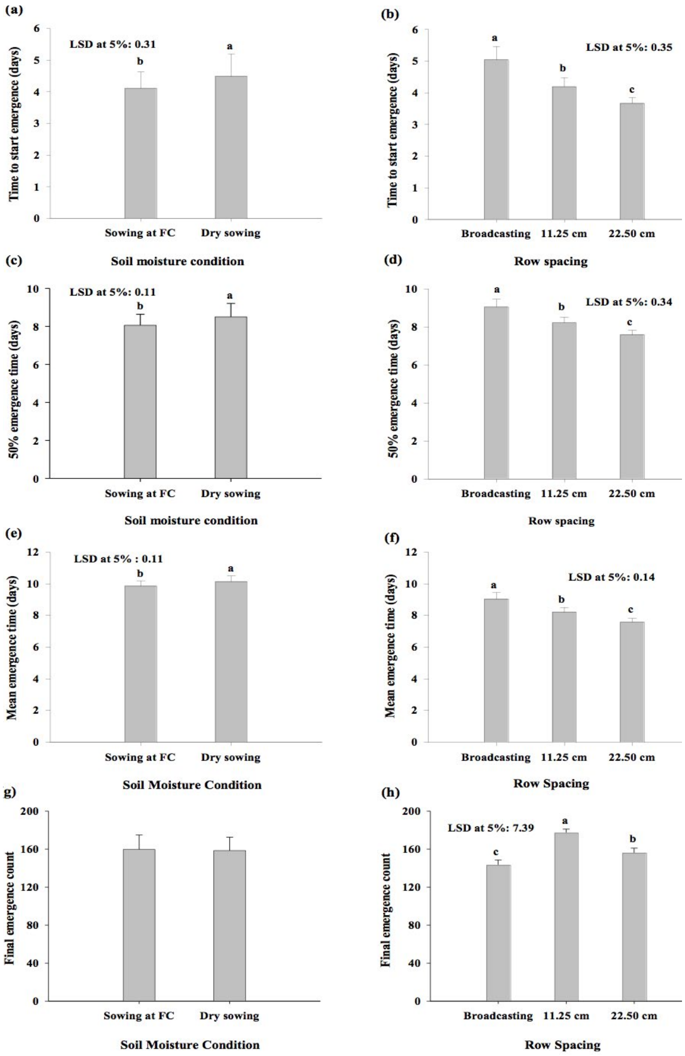



**Figure 2:** *Effect of soil moisture conditions at sowing and row spacing on (a, b) time to start emergence, (c, d) 50% emergence time, (e, f) mean emergence time and (g, h) final emergence count.*

**Plant height (cm):** Soil moisture condition at the time of sowing had no outstanding impact on plant height while, Row spacing considerably affected the plant height (Table 1). The plants that were grown under 11.25 cm spaced rows gave maximum height (71.6 cm) while, broadcasting treatments gave minimum plant height (66.98 cm). Moreover, interactive effect of field moisture condition at the time of sowing and row spacing was non-significant.

**Weed density and biomass (g) $m^{-2}$:** Hasty weed emergence was observed in watter (field capacity) ($M_1$) condition as compared to sowing in dry condition, but soil moisture condition and interactive effect of soil moisture condition and row spacing did not affect significantly the density of broad leaves as well as narrow leaves weeds and biomass production of weeds (Figure 3, 4 and 5) at 30, 45 and 60 days after sowing (DAS). Row spacing affect significantly the weeds density as well as weed biomass per unit area. Highest density of narrow leaves (22.2, 33.5 and 44.5 broad leaves (11, 17.7 and 23.7) and weeds biomass (22.7, 72.9 and 146.9 g $m^{-2}$) was recorded in broadcasted treatments at 30, 45 and 60 DAS respectively. While, lowest density of narrow leaves (11.3, 21 and 29.8), broad leaves (5.2, 10.2 and 16.2) weed and minimum weed biomass production g $m^{-2}$ (9.6, 46.9 and 119.5) at 30, 45 and 60 DAS respectively.

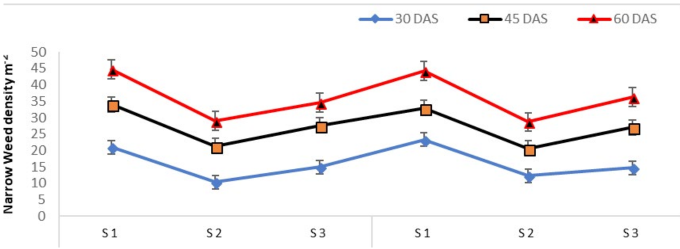
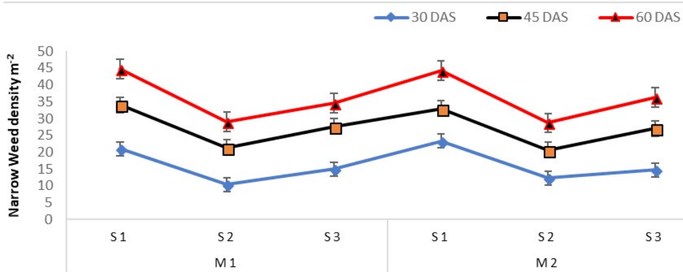
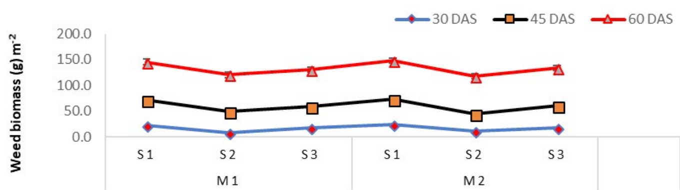



**Figure 3:** *Effect of row spacing under dry and moist field conditions on broad leaves weed density $m^{-2}$*




($M_1$ = Sowing in moist (field capacity) condition, $M_2$= sowing in dry condition, $S_1$: broadcasting, $S_2$: 11.25 cm row spacing, $S_3$: 22.50 cm row spacing)

**Figure 4:** *Effect of row spacing under dry and moist field conditions on narrow leaves weed density $m^{-2}$*




(M1 = Sowing in moist (field capacity) condition, M2= Sowing in dry condition, S1: Broadcasting, S2: 11.25 cm row spacing, S3: 22.50 cm row spacing)

**Figure 5:** *Effect of row spacing under dry and moist field conditions on biomass production (g) of weeds $m^{-2}$*

**Table 1:** *Effect of row spacing under dry and moist field conditions on yield and related attributes of direct seeded aerobic rice.*

| Treatment | Plant height(cm) | Total tillers ($m^{-2}$) | Productive tillers ($m^{-2}$) | Kernels per panicle | 1000- kernels wt. (g) | Paddy yield (t $ha^{-1}$) | Straw yield (t $ha^{-1}$) | Harvest index (%) |
|---|---|---|---|---|---|---|---|---|
| Row Spacing (RS) | | | | | | | | |
| $S_1$ | 66.9[c] | 220.8[c] | 180.2[c] | 45.8[c] | 13.7[c] | 1.8[c] | 3.7[c] | 32.8[b] |
| $S_2$ | 71.6[a] | 346.7[a] | 280.0[b] | 74.0[b] | 16.7[b] | 2.7[b] | 9.7[a] | 21.9[c] |
| $S_3$ | 68.1[b] | 310.0[b] | 296.8[a] | 93.7[a] | 19.4[a] | 3.5[a] | 6.7[b] | 34.3[a] |
| LSD($p \leq 0.05$) | 0.4 | 14.5 | 11.2 | 3.2 | 0.9 | 0.1 | 0.2 | 1.3 |

**$S_1$:** *Broadcast (No spacing maintained);* **$S_2$:** *Line sowing at 11.25 cm distance;* **$S_3$:** *Line sowing at 22.50 cm distance; **: highly significant;* **NS:** *Non-significant.*

**Table 2:** *Effect of row spacing under dry and moist field conditions on quality parameters, net income and benefit cost ratio (BCR) of direct seeded aerobic rice.*

| Treatment | Sterile spikelet (%) | Opaque kernels (%) | Abortive kernels (%) | Normal kernels (%) | Total expenditure (USD) | Gross income (USD) | Net income (USD) | BCR |
|---|---|---|---|---|---|---|---|---|
| Row Spacing (RS) | | | | | | | | |
| $S_1$ | 9.5[a] | 11.7[b] | 9.7[a] | 15.3[c] | 713.4 | 576.0 | -137.4 | 0.8 |
| $S_2$ | 8.2[b] | 13.7[a] | 7.8[b] | 44.3[b] | 731.9 | 1025.5 | 291.6 | 1.4 |
| $S_3$ | 5.2[c] | 10.2[c] | 6.2[c] | 72.2[a] | 743.2 | 1097.2 | 353.9 | 1.5 |
| LSD($p \leq 0.05$) | 1.1 | 1.7 | 1.4 | 3.7 | | | | |

**$S_1$:** *Broadcast (No spacing maintained);* **$S_2$:** *Line sowing at 11.25 cm distance;* **$S_3$:** *Line sowing at 22.50 cm distance; **: highly significant;* **NS:** *Non-significant.*

*Yield and yield related attributes*

Soil moisture condition at the time of sowing and interactive effect (of soil moisture condition and row spacing) showed non-significant ($p \leq 0.05$) results about yield and yield related attributes while, row spacing effected the yield and yield related attributes significantly (Table 1).

**Total numbers of tillers, productive tillers $m^{-2}$:** Maximum total numbers of tillers $m^{-2}$ were counted in those treatments where rice was sown in 11.25 cm spaced rows and productive tillers $m^{-2}$ (296.8) were maximum in 22.50 cm spaced rows. Whereas more spacing and broadcasting treatments discouraged the ability of tillering (Table 1).

**Kernels per panicle and 1000-kernel weight (g):** Row spacing considerably affected the number of grains per panicle and 1000-kernel weight (g). The row spacing of $S_3$ (22.50 cm) produced maximum number of grains per panicle (93.7) and 1000-kernels weight (19.4 g) followed by row spacing of 11.25 cm (74.0), (16.7 g) respectively and least kernels per panicle (45.8) and 1000-kernels weight (13.7 g) were found in $S_1$ (broadcasted) treatment (Table 1).

**Paddy, straw yield (t $ha^{-1}$) and Harvest index (%):** Different row spacing had a significant effect on paddy, straw and biological yield; however, these parameters were not considerably affected by soil moisture regimes at the time of sowing. The highest straw yield (9.7 t $ha^{-1}$) and least harvest index (21.9%) were recorded in 11.25cm apart rows treatment. The highest paddy yield and harvest index (3.5 t $ha^{-1}$), (34.3%) respectively were observed in 22.50 cm apart rows and least straw yield (3.7 t $ha^{-1}$) and paddy yield (1.8 t $ha^{-1}$) were recorded under $S_1$ (broadcasted) treatment (Table 1). Data indicated that the treatments where row spacing 22.5 cm was maintained gave maximum net income of USD 353.9 $ha^{-1}$ and BCR 1.5, followed by, USD 291.6 $ha^{-1}$ and BCR 1.4 treatments where $S_2$ row spacing was maintained. Least BCR and net returns were attained from $S_1$ (broadcasting) treatments (Table 2).

*Quality parameter*

**Sterile spikelets, opaque kernels, abortive kernels and normal kernels (%):** Different row spacing affected the quality parameters noticeably while, soil moisture condition at the time of sowing and interactive affect between row spacing and soil moisture condition did not affect significantly the quality parameters of direct seeded Super Basmati rice. Highest sterile spikelet (9.5%), opaque kernel (11.7%) and abortive kernel (9.7%) were recorded in broadcasting treatment followed by $S_2$ (11.25 cm spaced rows) while, lowest percentages of sterile spikelet, opaque kernel and abortive kernel were observed in $S_3$ (22.50 cm spaced rows). Maximum normal kernel percentage (72.2%) was recorded in $S_3$ (22.50 cm row spacing) while, least percentage of normal kernel was recorded (15.3%) under $S_1$ (broadcasted) treatment (Table 2).

Stand establishment parameters in current experiment indicated that 22.50 cm spaced crop took minimum time to start emergence, 50% emergence time and mean emergence time, while final emergence count was maximum in 11.25 spaced rows. These results are supported by Ali et al. (1990) and Baloch et al. (2007), they reported that due to fluctuating moisture absorption or nutrient mobilization in different planting methods time to start emergence fluctuates significantly. Moreover, Fuki (2002) also predicted that sowing method also had influence on time to start emergence. Wang et al. (2002) reported that by using appropriate method of plantation mean emergence time could be reduced at significant level as in our results of broader row spacing were more efficient than broadcasting because in broader row spacing competition among seedling for space, moisture and nutrients was less as compared to narrow row spacing. Final emergence count was found to be higher in 11.25 cm spaced rows because more number of lines per unit area. Hence, more final emergence counts under 11.25 cm spaced rows. Moreover, soil moisture status at the time of sowing did not affect the final emergence count because after sowing the crop irrigation was applied immediately under dry field condition and availability of moisture was made equally after one week of sowing. Our results are also similar to the finding of Baloch et al. (2007) who reported that final emergence count significantly affected by different planting method.

In our experiment, higher plant height under narrow row spacing (11.25 cm spaced rows) could be attributed to increased intra-specific competition among rice plants. These results are similar to Mann et al. (2007) who reported that maximum plant height in narrows row spacing where no weed-crop completion exist but, more intra crop plant competition ensued. These results are correlating with Akbar and Ehsanullah (2004) they reported that plant height reduced in broadcast method than the line sowing.

Current experiment presented that, yield and its attributes such as productive tillers, kernel per panicle, 1000-kernel weight, and paddy yield as well as harvest index (Table 2) of DSR under 22.50 cm row spacing were appreciably higher than those of broadcasting and 11.25 cm spaced rows-row spacing. The reasons might be less shading effect, low intra crop competition for nutrients, radiation and better photosynthates translocation to grains which resulted in higher paddy yield. In our study, it was observed that number of lines $m^{-2}$ were almost doubled in 11.25 cm spaced rows as compared to 22.50 cm row spacing due to that total number of tillers were more in 11.25 cm row spacing treatments as compared to broadcasting and 22.50 cm spaced rows row spacing but number of healthy plants were more in $S_3$ (22.50 cm row spacing) treatment as compared to $S_1$ (broadcasted) and $S_2$ (11.25 cm row spacing). Our results are supported by Kondo et al. (2001) who reported that plant density significantly influenced by using different planting methods and drill sowing produced more tillers as compared to broadcasting method. Phuong et al. (2005) also showed an increase in tillers and panicle density by decreasing row spacing. Under narrow row spacing (11.25 cm apart rows), Although number of tiller per unit area was more yet number of tillers per plant were definitely less due to dilution effect and limited space available for rice plant to thrive. Previous studies of Phuong et al. (2005) and Chauhan and Johnson (2011) also support our results regarding productive tillers of DSR. At the experimental site weed flora consist of *Cyperus rotundus*, *Echinochloa crus-galli*, *Cyperus iria*, *Echinochloa colona*, and *Trianthema portulacastrum*. Weed density and weed biomass production was more in broadcasted treatment and 22.5 cm row spacing due to more space for weeds as compared to 11.25 cm row spacing (Figure 3,4 and 5). Our results are supported by the finding of Chauhan and Johnson (2011) and khaliq et al. (2014) who conclude that narrow row spacing controlled weeds as compared to broader row spacing. In narrow rows spacing intra plant competition is more as compared to weed-crop competition than in broader row spacing where weed-crop competition is more as compared to intra crop competition.

Less number of grains per panicle and 1000-kernel weight in 11.25 cm spaced rows was possibly due to dilution effect. The increased numbers of grain per panicles and 1000-kernel weight might be an outcome of better nutrient acquisition, fertilization and translocation of photo assimilates under the influence of broader row spacing and better weed management. Results are in line with Akbar et al. (2011) and Jaya-Suria et al. (2011). In case of line sowing, rice yield and harvest index in $S_3$ (22.50 cm row spacing) were higher as compared to broadcasting because in line sowing weed management was easy and crop lodging chance was minimum hence resulted in healthy plant. Harvest index in our study was higher in 22.50 cm spaced rows because weed-crop competition was less as weeds were managed easily and efficiently. While in broadcasting treatments harvest index were least because weed-crop interaction was more as it was difficult to eradicate the weeds easily. These outcomes are similar to finding of Phuong et al. (2005) and khaliq et al. (2011). Moreover, Khan et al. (2009) and Ganajaxi and Rajkumara (2000) reported that by changing the planting methods harvest index affected significantly.

Quality attributes of DSR in current study were affected significantly due to different row spacing, 22.50 cm apart rows gave lower percentage of abortive kernels, opaque kernel and sterile spikelet, while, higher percentage of normal kernel due to proper photosynthates translocation, less intra-crop competition and low weed-crop competition, because of which translocation system remained active and fully functional up to physiological maturity and normal kernel ratio increased. BCR was higher in $S_3$ (22.50 cm row spacing) treatment along with all other components. Nevertheless, minimum BCR (0.81) was realized for those plots where sowing was done through broadcasting method under moist field condition as well as dry field condition at sowing time.

## Conclusions

In conclusion, it was declared that direct sowing of rice in well prepared dry field is best practice to attain good crop stand, as compared to sowing in watter (field capacity) condition, while, 22.5 cm apart rows in direct seeded rice was found to be the best compared with other row spacing for stand establishment attributes, weed management in case of cultural operation, quality and yield of Basmati rice under direct seeded rice production system.

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## Author's Contribution

N. Akbar, S.A. Anjum and U. Chattha conceived the awareness of the study. M. Ahmad provided the material and technical input. I. Khan performed statistical analysis and data arrangement. M. Ishfaq wrote the manuscript and M. Ishfaq, U. Zulfiqar and M. Ahmed collected data from field.

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