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Effect Of Different Irrigation Intervals On Direct Seeded Rice In Salt Affected Soil

Muhammad Rizwan

Soil Salinity Research Institute, Pindi Bhattian, Pakistan

Email: ranarizwan744@yahoo.com

Khalil Ahmed

Soil Salinity Research Institute, Pindi Bhattian, Pakistan

Muhammad Nadeem Iqbal

Soil Salinity Research Institute, Pindi Bhattian, Pakistan

Ghulam Shabbir

Soil Salinity Research Institute, Pindi Bhattian, Pakistan

Muhammad Shakar

Soil Salinity Research Institute, Pindi Bhattian, Pakistan

Ghulam Qadir

Soil and Water Testing Laboratory for Research, Lahore, Pakistan

Muhammad Qaisar Nawaz

Soil Salinity Research Institute, Pindi Bhattian, Pakistan

Muhammad Faisal Nawaz

Soil Salinity Research Institute, Pindi Bhattian, Pakistan

Amar Iqbal Saqib

Soil and Water Testing Laboratory for Research, AARI, Faisalabad, Pakistan

Ijaz Hussain

Soil Salinity Research Institute, Pindi Bhattian, Pakistan

Zulfiqar Ali

School of Agro-Technology and Applied Sciences, Institute of Brunei Technical Education (IBTE), Brunei Darussalam

Hafiz Muhammad Ijaz

Statistical Section, Ayub Agricultural Research Institute, Faisalabad, Pakistan

ABSTRACT

Pakistan has been ranked one of the most water stressed countries due to the combined effects of escalating freshwater shortages, and severe alterations in weather patterns. Therefore, the water available for agriculture is facing enormous pressure, posing a serious threat to agricultural production and food security. Hence, the systematic investigation of sustainable and environment friendly irrigation approaches has become a vital research domain for optimizing water productivity, enhancing agricultural production, and ensuring food security. Consequently, a field experiment was conducted over two successive growing seasons in 2019, and 2020 to evaluate the effects of four irrigation intervals (4, 6, 8 and 10 days) on growth, yield and water use efficiency of the direct seeded rice cultivated in saline sodic soils. The results showed

that the maximum plant height, number of tillers, panicle length, grain/panicle, 1000-grain weight and straw yield were observed under 8 days irrigation interval. During the 2019 and 2020 growing seasons, the highest paddy yields (3.18 t ha^{-1} and 3.28 t ha^{-1} , respectively) and water use efficiency ($2.45 \text{ kg ha}^{-1} \text{ mm}^{-1}$ and $2.64 \text{ kg ha}^{-1} \text{ mm}^{-1}$, respectively) were achieved with an 8-day irrigation interval. In conclusion, 8-day irrigation interval is the optimal schedule for obtaining maximum rice grain yield, and water productivity, thereby representing a viable water-saving strategy for Pakistani cropping systems.

Keywords: Direct Seeded Rice, Irrigation Interval, Water Use Efficiency, Moderately Salt Affected Soil

INTRODUCTION

Global water scarcity presents a major challenge to agricultural production, necessitating a strategic focus on innovative irrigation technologies to enhance crop yields and achieve sustainable food security. In the same way, irrigated agriculture accounts for about 70% of the global water consumption, and this water demand could double by 2030 globally (Okasha et al., 2020). Agricultural systems of Pakistan with dense populations and limited freshwater resources is under increasing stress to reduce freshwater consumption for irrigation, in response to escalating demands from industrial and municipal sectors. This condition become worse under scenario of climate change, limited freshwater resources, high temperature and minimal precipitation. Addressing this dual challenge of increasing food production while conserving water resources is only achievable primarily through enhanced crop water productivity.

Rice (*Oryza sativa* L.) is an important cereal, nutritious and staple food for the half global population, and simultaneously represents the most water-intensive commodity in global agriculture (Thakur et al., 2014) Asia accounts for over 90% of global rice production and an equivalent share of its agricultural water use (Khepar et al., 2000). Projections indicate that by 2025, approximately 15 million hectares of Asia's irrigated rice systems will face physical water scarcity, with a further 22 million hectares of dry-season rice production susceptible to economic water scarcity (Tuong et al., 2003). In Pakistan, rice is also a major summer crop being cultivated on approximately 25% of the total cultivated area. Moreover, the area under rice cultivation in Pakistan is 10% of the total area being cultivated in summer season (Khan et al., 2006). In addition, rice growers have a perception that continuous flooding to rice crop results in enhanced crop yields, despite thinking that flooding results in substantial irrigation inefficiencies including poor field application efficiency, salinity, waterlogging, and unbalanced water distribution in the field. In this context, several studies have demonstrated that typical application of 13-18 cm per irrigation to rice crop is approximately 8 cm more than consumptive use (Kahlown et al., 2001). Kalwij, (1997) and Kahlown et al. (1998) reported that on-farm irrigation efficiencies through flooding to rice crop are about 23-70%.

Additionally, flood irrigation promotes the significant leaching of essential and soluble plant nutrients, reducing the fertilizer use efficiency (FUE), and contributing to

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groundwater pollution (FAO, 2010). Moreover, the processes of mineralization and subsequent release of mineral nutrients in soil is limited due to the suppression of microbial activities under continuous flooding practices (Wassmann, 2010). For that reason, the development of innovative, sustainable and environment friendly irrigation strategies for high water demanding crops, and evaluating their efficacy is quite challenging for researchers. However, major water-saving approaches include maintaining saturated soil conditions, reducing irrigation depth, adopting irrigation scheduling, alternate wetting and drying, and intermittent irrigation (Arora, 2006). Among these water saving approaches, intermittent irrigation is the controlled application of water to crops in interchanging intervals to allow the soil to dry for specified period of time (Keiser et al., 2002). This practice of water application to crops involves applying water at set intervals by making intermittent non-flooded conditions. However, depending on the type of soil, prevailing climatic conditions, and crop management practices, the duration of non flooded periods can range from one to ten days (Fonteh et al., 2013). Therefore, by adapting this approach, a significant amount of irrigation water can be conserved and allocated for the cultivation of additional area of land for ensuring food security. Hence, under water deficit regimes, the method of intermittent irrigation offers a viable approach for the rice cultivation in Pakistan. Moreover, this approach has been extensively appraised globally, and benchmarked against continuous flooding to the crops under water deficit conditions (Van der Hoek et al., 2001; Ndenecho, 2009; Mostafazadeh-Fard et al., 2010). However, the efficacy of intermittent irrigation application remains quite understudied, and limited knowledge within the specific agro climatic conditions of Pakistan.

Studies under salt-stress field conditions ($EC = 8.0 \text{ dS m}^{-1}$) have shown that rice yield is highly dependent on water depth. A water depth of 7.5 cm produced the highest rice grain and straw yields whereas a depth of 2.5 cm yielded the lowest value of grain and straw yields (Moursi, 2001; El-Hadidi et al., 2002). The study by Morsi and Abdelkhalek (2015) reported that irrigation requirements for several Egyptian rice varieties were 1176.1 mm for Sakha 102, 1208.4 mm for Giza 178 and 1233.6 mm for Sakha 104. Okasha et al. (2020) investigated the effects of different irrigation management practices (drip, gated pipe, flood) and intervals (7, 9, 11 days) on growth and yield performance of squash. Similarly, it has been demonstrated in several studies that different irrigation systems, and irrigation intervals markedly influenced the agronomic, phenological, and physiological attributes of squash. Additionally, a study reported that the application of water through combining drip irrigation with a 7 days irrigation interval produced the most potential impacts including the highest water productivity, and application efficiency. It also improved the soil nutritional profile, crop growth, yield, and fruit quality parameters.

Therefore, this water application approach is highly commended for exploiting the crop productivity, and conserving the water resources in the prevailing agro-climatic conditions of Pakistan. Moreover, Abdelhalim et al. (2017) evaluated the impact of continuous flooding, and intermittent irrigation application on the growth and productivity of two rice cultivars viz. Giza 178 and Oraby2. The results of this study demonstrated that Giza 178 revealed the highest water productivity (WP), concluding that intermittent irrigation at a depth of 3 cm following the interval of 12 days can be

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recommended under water scarce conditions. In addition, Elsadek et al. (2023) studied the water balance for the direct seeded rice cultivar (Giza 178) in arid conditions of Egypt. This study involved four irrigation regimes including continuous flooding, 3 days interval, 6 days interval, and 10 days interval of irrigation application. The results of this study showed that irrigation application at a 3 days interval produced the highest rice grain (9.8 t ha^{-1}) and biomass (21.0 t ha^{-1}) yield, while, the application of irrigation at a interval of 6 days provided significant amount of water savings (18.3–22.4%) with only a marginal reductions in crop yields. Thus, under the Egyptian arid conditions, both 3 days, and 6 days irrigation intervals are recommended as an important approach for balancing high rice productivity and water conservation. In the same way, Bazkiaee et al. (2023) studied the effects of irrigation intervals and transplanting dates on the rice crop (Hashemi cultivar) in Iran. This study found that the highest paddy yield (4271 kg ha^{-1}) was achieved with the continuous flooding, while the 5 day irrigation interval maintained the higher crop yield (3844 kg ha^{-1}) combined with the improved water savings. The earliest transplanting date (April 21st) resulted in the highest water productivity. The optimal combination for balancing grain yield and water use efficiency was the 5-day irrigation interval with the April 21st transplanting date, supporting its recommendation as a water-conserving practice for the region. This research aimed to evaluate the impact of the conventional practice (continuous flooding) versus intermittent irrigation on the yield, yield attributes, and water productivity of direct-seeded rice grown under salt stress conditions.

MATERIAL AND METHODS

Experimental site

The field experiment was conducted during the Kharif season of 2015, and 2016 at the research farm of the Soil Salinity Research Institute, Pindi Bhattian (31.8950°N , 73.2706°E ; 184 m altitude). The prevailing meteorological conditions during the study period are presented in figure 1-3.

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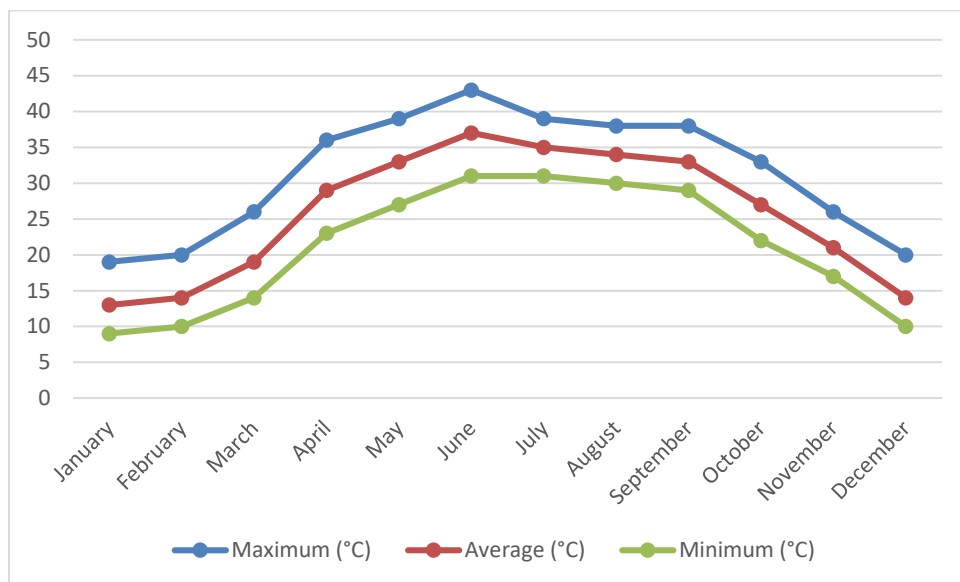


Figure 1. Temperature (°C) patterns during the growing seasons of 2019.

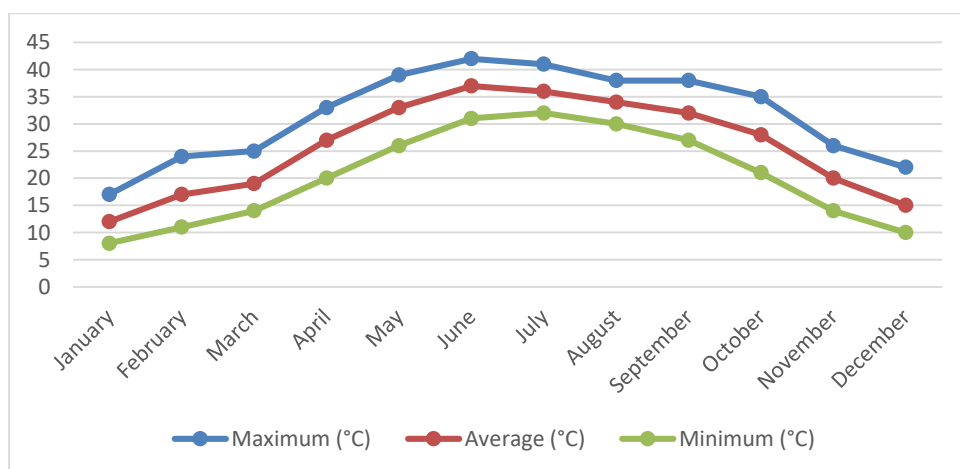


Figure 2. Temperature (°C) patterns during the growing seasons of 2020.

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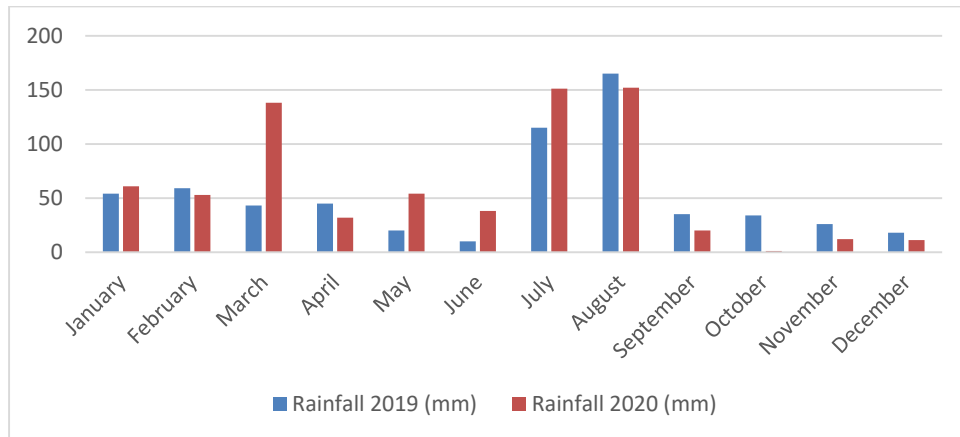


Figure 3. Rainfall (mm) patterns during the growing seasons of 2019 and 2020. A site with pre-existing salt-affected soil was selected for the experiment; the initial soil chemical characteristics are summarized in Table 1.

Table 01: Soil analysis before crop sowing

Soil Parameter	Soil Depth (0-15) cm
pH _s	8.80
EC _e (dS m ⁻¹)	4.33
SAR (mmol L ⁻¹) ^{1/2}	30.15

Experimental design, and treatment details

The present field study was conducted in a randomized complete block design (RCBD), having three replications of each experimental treatment. The net plot size for each experimental unit was kept 6m x 8m. The experimental treatments consisted of 4-irrigation intervals including 4, 6, 8 and 10 days. Irrigations were applied using a cut-throat flume. During the first week of June in both 2019 and 2020, rice (cv. Shaheen Basmati) was sown at a rate of 30 kg ha⁻¹. Fertilizer applications were uniform across all plots and consisted of urea (110 kg N ha⁻¹), single super phosphate (90 kg P₂O₅ ha⁻¹), and sulphate of potash (60 kg K₂O ha⁻¹). All other agronomic and crop management practices were maintained homogeneously.

Data collection and statistical analysis

At physiological maturity, the crop was harvested, and data on the plant height, number of tillers, panicle length, grain/panicle, 1000-grains weight, straw yield and paddy yield were recorded. Composite soil samples were collected from the upper soil layer (0-15 cm depth) prior to sowing and after harvest. These samples were air-dried, homogenized, passed through a 2-mm sieve, and subsequently analyzed for pH, electrical conductivity of the saturation extract (EC_e), and sodium adsorption ratio (SAR) following the standard methods (US Salinity Laboratory Staff, 1954). Moreover, the crop water use efficiency (WUE) was measured by following the scientific procedures given by Meng et al. (2025);

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$WUE (kg\ ha^{-1}\ mm^{-1}) = \text{grain yield } (kg\ ha^{-1}) / \text{the amount of irrigation water } (mm)$
The collected data on the crop growth and yield attributes were subjected to the analysis of variance (ANOVA) using the STATISTIX 8.1 software package. Moreover, the treatment means were separated using Least Significant Difference (LSD) test at 5% level of probability (Steel et al., 1997).

Table 2: Effect of Irrigation Frequencies on plant height, number of tillers, and panicle length of the direct seeded rice in salt affected soil during 2019

Irrigation Interval	Plant height (cm)	Number of tiller/m ²	Panicle length (cm)
4 Days	99.33 BC	286.67 B	16.16 B
6 Days	103.00 AB	296.67 B	18.30 A
8 Days	103.67 A	311.67 A	18.73 A
10 Days	96.67 C	263.33 C	15.50 B
LSD	4.2643	14.419	0.7795

Table 3: Effect of Irrigation Frequencies on plant height, number of tillers, panicle length of direct seeded rice in salt affected soil during 2020

Irrigation Interval	Plant height (cm)	Number of tiller/m ²	Panicle length (cm)
4 Days	101.33 BC	294.33 B	18.00 B
6 Days	104.00 AB	300.67 B	18.83 AB
8 Days	105.33 A	318.33 A	19.06 A
10 Days	97.67 C	287.33 B	16.50 C
LSD	3.9399	17.225	0.9576

The effects of irrigation frequencies on growth performance of direct-seed rice in salt-affected soil during two consecutive seasons (2019 and 2020) are presented in Tables 2 and 3. Plant height was significantly affected ($P \leq 0.05$) by irrigation intervals during both seasons, maximum plant height of 103.67 cm and 105.33 cm was recorded with an 8-day irrigation interval during 2019 and 2020 respectively. The lowest values for plant height were 96.67 cm and 97.67 cm under 10-day interval irrigation treatment during 2019 and 2020 respectively. Similarly, this study findings described that the number of tillers in the direct seeded rice crop were considerably influenced with the irrigation intervals. The 8-day irrigation interval produced maximum number of tiller (311.67 and 318.33), while the minimum number of tillers (263.33 and 287.33) were observed with 10-day irrigation intervals in both seasons. The 8-day irrigation interval during 2019 and 2020 recorded maximum panicle length of 18.73 cm and 19.06 cm respectively which was significantly shorter ($P \leq 0.05$) than under other irrigation intervals. The shortest panicle length of 15.50 cm and 16.50 cm were observed with the 10-day irrigation intervals.

Table 4: Effect of irrigation frequencies on grain/panicle, 1000- grain weight, straw yield of direct seeded rice in salt affected soil during 2019

irrigation interval	grain/panicle	1000- grain weight (gm)	straw yield (t ha ⁻¹)
4 Days	37.33 A	27.43 C	5.32 B
6 Days	38.00 A	29.76 B	5.54 AB
8 Days	39.00 A	31.60 A	5.87 A
10 Days	34.33 B	25.13 D	5.17 B
LSD	1.8540	1.0050	0.4038

Table 5: Effect of irrigation frequencies on grain/panicle, 1000- grain weight, straw yield of direct seeded rice in salt affected soil during 2020

Irrigation Interval	Grain/panicle	1000- grain weight (gm)	Straw yield (t ha ⁻¹)
4 Days	37.66 BC	28.33 B	6.31 B
6 Days	40.00 AB	30.66 A	6.81 A
8 Days	41.33 A	32.06 A	6.69 AB
10 Days	36.00 C	25.43 C	5.45 C
LSD	2.4241	1.7325	0.3840

The results presented in Tables 4 and 5 demonstrate that irrigation intervals had a significant effect on reproductive growth of rice in terms of grain/panicle, 1000- grain weight and straw yield. The highest grain/panicle (39 and 41.33) were recorded for the 8-day irrigation interval during 2019 and 2020 respectively. Conversely, irrigation with a 10-day interval produced the minimum grain/panicle (34.33 and 36) in both growing seasons. The significantly ($P \leq 0.05$) maximum 1000 grain weight of 31.60 g and 32.06 g were achieved with the 8-day irrigation interval during both growing seasons as compared with other irrigation intervals. The lowest 1000 grain weight of 25.13 g and 25.43 g was obtained with the 10-day irrigation interval. Irrigation intervals also showed significant ($P \leq 0.05$) effect on straw yield during both seasons. Irrigating the rice field every 8-days resulted in the highest straw yield of 5.87 t ha⁻¹ and 6.69 t ha⁻¹. Vice- versa, irrigation every 10 days recorded the lowest straw yield of 5.17 t ha⁻¹ and 5.45 t ha⁻¹.

Table 6: Influence of the irrigation frequencies on the paddy yield (t ha⁻¹), and water use efficiency of the direct seeded rice in salt affected soil during 2019

Irrigation Interval	Paddy Yield (t ha ⁻¹)	No. of Irrigations Applied	Delta of water (mm)	Water use Efficiency (kg ha ⁻¹ mm ⁻¹)
4 Days	2.82 BC	24	2209	1.28
6 Days	2.88 B	16	1600	1.80
8 Days	3.18 A	12	1295	2.45
10 Days	2.60 C	09	1066	2.44
LSD	0.228			

Note: Rainfall (381 mm) occurred during kharif-2019 is included in delta of water.

Table 7: Influence of the irrigation frequencies on the paddy yield (t ha^{-1}) and water use efficiency of the direct seeded rice in the salt affected soils during 2020

Irrigation Interval	Paddy Yield (t ha^{-1})	No. of Irrigations Applied	Delta of water (mm)	Water use Efficiency ($\text{kg ha}^{-1}\text{mm}^{-1}$)
4 Days	3.14 B	24	2155	1.46
6 Days	3.39 A	15	1469	2.31
8 Days	3.28 AB	12	1240	2.64
10 Days	2.45 C	8	935.99	2.62
LSD	0.2294			

Note: Rainfall (326.39 mm) occurred during kharif-2020 is included in delta of water.

The data in Tables 6 and 7 depicted that there were significant differences ($P \leq 0.05$) due to irrigation frequencies on the paddy yield of direct-seeded rice during both growing seasons. The rice crop yielded a maximum of 3.18 t ha^{-1} and 3.28 t ha^{-1} in response to an 8-day interval irrigation during 2019 and 2020 respectively. Furthermore, the minimum paddy yield of 2.60 t ha^{-1} and 2.45 t ha^{-1} was observed under the 10-day interval irrigation treatment during both seasons. Similarly, a higher water use efficiency of $2.45 \text{ kg ha}^{-1}\text{mm}^{-1}$ and $2.64 \text{ kg ha}^{-1}\text{mm}^{-1}$ was obtained with water applied at an 8-day interval during 2019 and 2020, respectively, whereas the lowest value for water use efficiency of $1.28 \text{ kg ha}^{-1}\text{mm}^{-1}$ and $1.46 \text{ kg ha}^{-1}\text{mm}^{-1}$ was achieved under the 4-day interval treatment during both seasons.

Soil properties

Table 8: Effect of irrigation frequencies on soil properties after harvest of rice 2019

Irrigation Interval	pH _s	% Decrease over initial value	EC _e (dS m^{-1})	% Decrease over initial value	SAR ($\text{mmol L}^{-1})^{1/2}$	% Decrease over initial value
4 Days	8.77	0.34	4.01	7.98	29.50	2.20
6 Days	8.78	0.22	4.06	6.65	29.43	2.44
8 Days	8.78	0.22	4.09	5.86	29.22	3.18
10 Days	8.79	0.11	4.23	2.36	29.65	1.68

Irrigation frequencies also influenced the chemical properties of salt-affected soil after the harvest of the rice crop in each growing season. Regarding soil pH, a maximum decrease of 0.34% was observed with the 4-day interval irrigation compared to the initial value (Table 8), while a reduction of 0.22%, 0.22%, and 0.11% was recorded with the 6-, 8-, and 10-day interval irrigations, respectively, during 2019. Similarly, soil

ECe was also ameliorated, and a steady decrease was observed across irrigation treatments. The 4-day interval irrigation exhibited a maximum decrease of 7.98% compared to the initial value. At the same time, a reduction of 6.65%, 5.86%, and 2.36% was observed with the 6-, 8-, and 10-day interval irrigations, respectively. A similar trend was observed for SAR, with a reduction of 9.75%, 8.10%, 6.34%, and 3.04% recorded under the 4-, 6-, 8-, and 10-day interval irrigations, respectively.

Table 9: Effect of irrigation frequencies on soil properties after harvest of rice 2020

Irrigation Interval	pH _s	% Decrease over initial value	EC _e (dS m ⁻¹)	% Decrease over initial value	SAR (mmol L ⁻¹) ^{1/2}	% Decrease over initial value
4 Days	8.76	0.45	3.74	15.77	27.47	9.75
6 Days	8.76	0.45	3.89	11.31	27.89	8.10
8 Days	8.77	0.34	3.96	9.34	28.35	6.34
10 Days	8.78	0.22	4.04	7.17	29.26	3.04

At the end of the study in 2020, a more pronounced ameliorating effect was observed on soil pH, ECe, and SAR. Reductions of 0.45%, 0.45%, 0.34%, and 0.22% in pH were documented under the 4-, 6-, 8-, and 10-day irrigation intervals, respectively, compared to the initial values at the start of the study. For ECe, a reduction of 15.77%, 11.31%, 9.34%, and 7.17% was observed when the field was irrigated at 4-, 6-, 8-, and 10-day intervals, respectively. Similarly, a reduction of 9.75%, 8.10%, 6.34%, and 3.04% was observed for SAR under the 4-, 6-, 8-, and 10-day irrigation intervals, respectively, compared to the initial value.

DISCUSSION

The major aim of system of rice intensification (SRI) is to cultivate irrigated rice on a more sustainable and profitable basis. The system of rice intensification improves farm-level productivity, profitability, and resource use efficiency. This goal is achieved through significant resource savings, with considerable reductions in capital investment, seed requirements, and water consumption (Uphoff 2003). Although, since a long time, rice has been traditionally considered an aquatic plant globally. However, this archetype has been repeatedly challenged, as the rice crop is capable of adapting to a wide range of hydric environments, and can thrive under both continuous flooded, and non-flooded environments. Keeping in mind the elevating shortage of fresh water, and addressing the water scarcity situation in Pakistan, this field study was conducted to evaluate the effect of continuous flooding and intermittent irrigation. The major aim of this study was to identify a water conservation strategy that can maintain the sustainable productivity of high water demand crops such as rice, and can improve their production on sustainable basis.

This study revealed that the frequency of irrigation considerably influenced the

morpho-physiological attributes of direct seeded rice during both growing seasons. Moreover, the results revealed that irrigation application at 8 days interval produced the higher plant height, number of tillers per plant, and panicle length than other experimental treatments. In contrast, irrigation at 10-day intervals produced the lowest values for all these traits in both seasons. Similarly, irrigation intervals had pronounced effects on yield and yield attributes of direct seeded rice. Irrigating direct seeded rice on an 8-day schedule promoted the highest values for grain per panicle, 1000-grain weight and straw yield. In contrast, the lowest values for the aforementioned yield parameters were observed with the 10-day irrigation interval. The observed improvement with an 8-day irrigation schedule may be explained by the development of a robust root system and adequate water availability, which in turn increased the availability and absorption of essential plant nutrients, enhanced photosynthetic activity and consequently, promoted plant growth and yield (Ibrahim, 2007). While irrigation schedules at 4 and 6 day intervals increased number of irrigations applied and delta of water (Table 6-7). This increased volume of water exceeded the water-holding capacity of the root zone, leading to leaching. Consequently, the leaching displaced essential nutrients from root zone establishing a zone of nutrient deficiency that restricted root development and imposed significant nutritional stress on the crops (Okasha et al., 2020).

In this study, the rice crop showed poor growth and yield performance under a 10 days interval of irrigation application. It might be attributed to the shortage of water, mainly during the critical developmental stages of rice crop including booting, flowering, and grain filling. Pantuwan et al. (2002) reported that water stress during these critical stages of rice crop is a primary factor in reducing rice crop yield. In the same way, Kamoshita et al. (2008) described that water stress during the vegetative and reproductive stages of rice crop suppresses floret initiation, resulting in sterile spikelets, and lower grain weight. Moreover, Yang et al. (2008) and Elsadek et al. (2023) described that three developmental stages of rice crop are more prone to water stress including panicle initiation, anthesis, and grain filling. Therefore, the exposure of rice crop to water stress at these developmental stages results in delayed flowering, reduced fertile panicles and poor grain filling (Pantuwan et al., 2002). Our study findings are consistent with the studies of Elsadek et al. (2023) and Bazkiaee et al. (2023), that the vegetative and reproductive growth phases of rice crop were improved with the application of medium level of irrigation than either excessive or inadequate water application.

Water use efficiency (WUE) is the association between the crop yield, and volume of irrigation water application. The crop WUE is typically expressed as the crop yield obtained per unit of water applied (Aziz et al., 2024). The present study results showed that the maximum value for WUE (2.45 and 2.64 kg ha⁻¹ mm⁻¹) was achieved with the application of irrigation at 8-days interval. On the contrary, the lowest value of WUE (1.28 and 1.46 kg ha⁻¹ mm⁻¹) was noted with the irrigation application on 4 days cycle during the both crop growing seasons of 2019, and 2020, respectively. The results of our study expressed that irrigation application at 8 days interval was ideal for the higher rice production, which produced higher grains and straw yield in contrast with other irrigation intervals. This substantial rise in the rice grains, and straw yield could be attributed to the improvements in the fundamental yield attributes including number of

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tillers per plant, grains per panicle, and grains weight. In addition, this prominent increase in the paddy yield might be due to the optimal and sustainable availability of the irrigation water that results in promoting the transfer of maximum dry matter to the panicles, which ultimately increases economic yield (El-Refae, 2012).

Likewise, significant improvements were also observed in this irrigation application regime, which might have promoted the transformation, and plant uptake of essential nutrients including N, P, and K. Therefore, these significant improvements in the plant nutrients uptake might have contributed to the vital increase in the rice yield (El-Refae, 2012). Moreover, the studies conducted by Ghazy, (2025) and Ibrahim et al. (2017) also supports our study outcomes. On the other hand, this study findings revealed that significant reductions in straw and paddy yields were observed in 10 days irrigation intervals. This decrease in straw and paddy yield can be corroborated to a reduced leaf photosynthetic rate under water deficit conditions (Hirayama et al., 2006). Additionally, the plants close their stomata under water deficit conditions to preserve internal moisture, followed by reduced transpiration rate, leaf photosynthetic rate, and overall crop production (Hirayama et al., 2006). In this context, a study by Sarvestani et al. (2008), demonstrated that a significant decrease of 21% in the grain yield was observed due to the onset of drought stress during the vegetative stages of rice crop.

Currently, among our farmers, the prevailing method of irrigating rice crop is heavy flooding, which has far less water use efficiency. In this context, our study findings suggest that paddy fields can be irrigated effectively with far less water than the water currently being used in the heavy flooding. In addition, this study outcomes are supported by Zayed et al. (2007), El Refae et al. (2008), Ashouri, (2012) and Abou EL Hassan (2017) that intermittent application of irrigation to rice crop can produce higher paddy yields under water deficit conditions. Moreover, the emissions of greenhouse gases from paddy fields particularly methane (CH₄) can also be reduced about 70% through intermittent irrigation (Pandey et al., 2014).

Similarly, the results also demonstrated that the frequencies of irrigation had positive influence on the soil salinity indices including soil pH, EC_e, and SAR. However, the ameliorating impacts of the irrigation frequencies were more prominent in the second cropping season compared to the first crop growing season, particularly, the soil pH, EC_e, and SAR were significantly moderated with the irrigation intervals of 4 days. Furthermore, the current study outcomes revealed that maximum reductions in soil pH (0.45%), EC_e (15.77%) and SAR (9.75%) were noted under the irrigation intervals of 4 days to the rice crop. This reduction in the soil pH, EC_e, and SAR might be due to the maximum leaching of soluble salts out of the rhizosphere, due to more number of irrigations applied, and higher delta of water under this irrigation regime (Zaka et al., 2018). Chhabra (1996) provided that 75% reduction in soluble salts from the top 1 foot surface of the soil requires one-foot of flooded irrigation water. As a result, at the end of this study, a substantial decrease in the soil pH, EC_e and SAR was noted due to the leaching of highly soluble salts from the rhizosphere under all irrigation regimes. Additionally, similar results have been reported in several previous studies (Abdelhalim et al., 2017; Zaka et al., 2018; Tunio et al., 2020; Ahmed, 2021), that application of non-saline water for crop production significantly reduces the soil pH, EC_e and SAR in the salt affected soils.

CONCLUSION

The major aim of this study was determining the most effective, sustainable and appropriate irrigation interval for improving the crop growth, physiology, yield attributes, and water use efficiency of direct seeded rice in the salt affected soils of Pakistan. Under the conditions of this experiment, it can be concluded that an 8-day irrigation interval is optimal schedule to attain high rice yield and water productivity thus representing a viable water-saving strategy for Pakistan's cropping systems.

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