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Effect of Sowing Methods and Irrigation Scheduling on Production and Productivity of Wheat Crop

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ABSTRACT: Due to the late harvesting of rice and sugarcane, wheat is frequently grown late in the western region of Uttar Pradesh. Poor crop establishment, inconsistent use of available irrigation water is a contributing factor to reduced wheat yield. For optimal wheat yield, ideal planting geometry is critical for better and efficient exploitation of plant resources. It is also a well-known premise that water management is one of the most important variables in getting a higher crop harvest. Bed planting, being a proven technology, can increase crop yields and save irrigation water to improve water productivity. A field experiment for wheat (*Triticum aestivum* L.) was handled at the Crop Research Centre of Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut (U.P.) during two consecutive rabi season of the years 2020-21 to 2021-22 to explore appropriate irrigation regimes and planting patterns in this area. The purpose of the research was to assess the influence of tillage techniques on growth and yield attributes of wheat crop under semi-arid climatic conditions in the years of the research. The following factors were tested: main plots; five tillage crop establishment methods were used: (T_1) Reduced tillage with rotavator line sowing, (T_2) Reduced tillage with conventional tool line sowing, (T_3) Furrow Irrigated Raised Bed, (T_4) Conventional tillage with broadcast, and (T_5) Conventional tillage with line sowing, and four irrigation scheduling methods were used: (I_1) Irrigation at critical stages (CRI), (I_2) CRI + IW/CPE 0.8, (I_3) CRI + IW/CPE 1.0, and (I_4) CRI + IW/CPE 1.2 were assigned to sub-plots and replicated thrice in split-plot design. The results showed that wheat sown on FIRB had significantly higher plant height (cm), dry matter accumulation (g m^{-2}), spike length (cm), spikelet per spike, grains per spike, and test weight (g) than all other tillage practices. Irrigation scheduling with CRI + IW/CPE= 1.0 evidenced to have significantly higher growth and yield parameter as compared to 0.8 and 1.2 IW/CPE ratio. The FIRBS planting and irrigation at CRI stage + IW/CPE 1.0 registered significantly highest growth attributes, yield attributes, grain yield, straw yield and harvest index.

Keywords: Wheat, FIRB, Roto-tillage, Reduce tillage, Conventional tillage, Productivity, Irrigation scheduling.

INTRODUCTION

Wheat (*Triticum aestivum* L.) is a major food crop in the world, which plays an important role in ensuring food security. In the year of 2021-22, globally wheat was grown in an area of about 222.62 million hectares, producing 779 million metric tons and productivity of 3.49 Metric tons per hectare (Anonymous 2021-22). Water is the scarcest input which has substantial impact on the efficiency of applied inputs and individual factor productivity particularly under semi-arid conditions. Rabi crops are irrigated by surface irrigation methods where the irrigation efficiency to be as low as 30–40% because of higher non-beneficial evapotranspiration (Rajanna *et al.*, 2016). The irrigated wheat systems contribute over 40% of wheat production in the developing world (Rajaram *et al.*, 2007).In general, yield and water-use efficiency (WUE) of wheat is found to be affected by deficit irrigation (Galavi and Moghaddam 2012). Moreover, the scheduling of irrigation is a key to water Management. Irrigation missing at some critical growth stage sometime drastically reduces grain yield (Kumar *et al*., 2014) due to lower test weight. Efficient water management, being one of the good agronomic management practices, it not only leads to improve crop productivity but also minimize susceptibility from disease and insect pest under favorable environment for flourishing these biotic stresses (Singh *et al.*, 2012).

Furrow-irrigated raised-bed planting system (FIRBs) is a form of tillage wherein sowing is done on raised beds, this optimizes tillage operation, saves water, and reduces lodging, Monsefia *et al.* (2016). The bed planting wheat is one of novel techniques to save water and enhancing the productivity of other input applied. Typical irrigation savings under FIRBS ranged from 18 to 35% in wheat (Hobbs and Gupta 2003). Researchers revealed that better or equal yields under FIRBS as compared to conventional tillage. The FIRB planting systems have number of advantages like better irrigation management, better crop establishment, better weed management, less soil compaction (Karunakaran and Behera 2013) and higher N, P and K uptake (Idnani and Kumar 2013). The water-saving (50.73%) and water productivity (54.37%) of the wheat crop were higher under a raised-bed irrigation system. The raised-bed irrigation system obtained a 24.65% higher yield compared to the conventional irrigation system Soomro *et al.* (2017). Bakhsh *et al.* (2016) also reported better crop and water productivity of major crops under bed planting.

Tillage plays a key role in changing the hydro-physical properties. Conventional tillage involves intensive soil manipulation, wastage of energy resources, lacks sustainability and results from environmental hazards (Wang *et al.,* 2012). To overcome such problems adaptation of reduced tillage techniques can result in timely sowing of wheat and may help in saving energy units at the farm level. Bogunovic *et al.* (2020) reported that the soils treated with reduced tillage had the lowest values of bulk density and penetration resistance at 0–10 and 10–20 cm. Crittenden *et al.* (2015**)** also found greater soil penetration resistance under conservation tillage than conventional tillage although conservation tillage resulted in better soil fertility. We hypothesized that irrigation and tillage operation could interactively affect wheat growth and yield, particularly under water stress condition. Hence, the objective of our study was to assess the sole and combined effect of irrigation and tillage management on crop growth, yield attributes and yield of wheat in rice-wheat cropping system.

MATERIAL AND METHODS

A field experiment was conducted during the Rabi (winter) seasons of 2020-21 and 2021-22, to evaluate the outcome of irrigation schedules and crop establishment techniques on physiological parameters, and yield attribute of wheat (*Triticum aestivum* (L.) on sandy loam soils at the Crop Research Centre (CRC) of Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut, Uttar Pradesh, India. The rainfall pattern of the experimental site was relatively variable during the two years of study. There were 20 treatment combinations consisting of 5 main plots of crop establishment methods, *i.e.* (T_1) Reduced tillage with rotavator line sowing, (T_2) Reduced tillage with conventional tool line sowing, (T_3) Furrow Irrigated Raised Bed, (T_4) Conventional tillage with broadcast, and (T_5) Conventional tillage with line sowing, and sub plots consisting of four irrigation scheduling methods (I_1) Irrigation at critical stages (CRI), (I_2) CRI + IW/CPE 0.8, (I_3) CRI + IW/CPE 1.0, and (I_4) CRI + IW/CPE 1.2. The experiment was laid out in split plot design with 3 replications. The gross and net plot sizes were 4.00 m × 10 m and 2.50 m × 8 m respectively. Wheat (WB-02) was grown during the winter season (2^{nd} week of November to 4^{th} week of April in 2020-21 and 2021-22). Crop based fertilizers doses (N: P_2O_5: K_2O) were applied in different crops @ 150:60:60 kg ha^{-1} for wheat, respectively. In all the treatments, half dose N and full dose of P_2O_5 and K_2O doses were applied at sowing in wheat. Rest 50 % N was applied at first irrigation in wheat. The observations on growth (plant height, dry matter production m^{-2}) and yield components viz., number of effective tillers per metre row length, number of grains per ear, test weight was recorded from randomly selected plants from the net plot. Two years data was pooled and statistically analyzed.

A. Measurement of Crop Parameters

Data were recorded on spikes m^{-2}, grains $spike^{-1}$, 1000 grain weight, biological yield, grain yield and straw yield. Number of spikes in one meter long row at four different places were counted in each subplot and converted into number of spikes m^{-2}. Number of grains $spike^{-1}$ was recorded by counting the number of grains of 10 randomly selected spikes from each subplot and average number of grains $spike^{-1}$ was calculated. A random sample of 1000 grains from each treatment was collected and weighed with digital balance for 1000-grain weight. For biological yield, each sub- plot was harvested and weighed into $kg\cdot ha^{-1}$. For grain yield, the biomass of each subplot was sun dried, threshed, cleaned, and grains were weighed into $kg\cdot ha^{-1}$. Soil moisture content was measured at seeding, and before and after irrigation on the top of the ridge and furrow in furrow irrigated raised bed planting system, between the 2 rows in conventional flatbed planting by gravimetric method. Water saving (WS) was calculated as:

$$WS = (QF - QB)/QF \times 100,$$

Where, QF and QB are quantity of water applied in flat planting and furrow irrigated raised bed planting system, respectively. The soil moisture data will be utilized to calculate the consumptive use.

B. Statistical Analysis

Data for each parameter over two year period was subjected to analysis of variance using a spilt plot block design with split plot arrangement according to OPSTAT. Treatment means were compared using least significant difference test at $P \leq 0.05$.

RESULTS AND DISCUSSION

The ANOVA revealed that crop establishment and irrigation scheduling had significant treatment impact on wheat development and production parameters across two years (2020-2021, 2021-2022). The results of two years of data revealed that wheat grain production was considerably ($P<0.05$) greater in conservation tillage than in conventional tillage.

A. Growth attributes

(i) Plant height. A perusal of the data revealed that conservation tillage based crop establishment methods resulted in significant increases in plant height at all growth stages. Plant height increased rapidly as the plants grew older and peaked at harvest under T_3 in both years. During the experiment period, treatment T_2 and T_5 were considerably comparable to T_3. T_1 (ROT) and T_4 (CTB) had the shortest plant heights during the trial. I_3 treatments were taller than rest of the treatments when it came to water regimens. During the experimental years, the pattern of plant height at different stages between irrigation water was IW/CPE 1.0 (I_3) >IW/CPE 0.8 (I_2) > IW/CPE 1.2 (I4)>CRI (I_1).Similar result was found by Jakhar *et al.* (2005); Idnani and Kumar (2012).

Table 1: Performance of wheat under crop establishment methods and irrigation scheduling on plant height (cm) of wheat.

Treatments	Plant height (cm)									
	30 DAS		60 DAS		90 DAS		120 DAS		At harvest	
	2020-21	2021-22	2020-21	2021-22	2020-21	2021-22	2020-21	2021-22	2020-21	2021-22
(A) Crop Establishment Methods										
T_1 ROT	18.3	19.5	48.1	49.9	66.2	67.8	68.2	69.7	69.6	70.7
T_2 RTC	19.9	21.7	52.5	54.2	71.0	72.8	73.1	74.8	74.6	75.6
T_3 FIRB	20.6	22.0	56.3	57.9	74.7	76.2	76.9	78.1	78.4	79.4
T_4 CTB	17.0	18.6	44.3	46.8	61.4	63.3	63.2	65.1	64.5	63.3
T_5 CT	19.6	20.3	50.1	51.8	68.6	69.5	70.6	71.6	72.1	73.2
SE(m)±	***0.56***	***0.64***	***1.79***	***1.93***	***1.89***	***2.00***	***1.95***	***2.03***	***2.00***	***2.03***
C.D (P=0.05)	***1.84***	***2.07***	***5.84***	***6.29***	***6.18***	***6.53***	***6.35***	***6.62***	***6.52***	***6.63***
(B) Irrigation Scheduling										
$\mathbf{I_1}$ (CRI)	16.4	17.8	44.8	45.6	62.3	64.1	64.2	65.5	65.5	66.7
$\mathbf{I_2}$ CRI + IW/CPE 0.8	20.1	21.5	51.9	53.1	70.6	71.6	72.7	73.4	74.2	75.9
$\mathbf{I_3}$ CRI + IW/CPE 1.0	21.1	22.8	54.4	56.2	73.1	74.9	75.2	76.7	76.8	77.8
$\mathbf{I_4}$ CRI + IW/CPE 1.2	18.9	19.7	49.9	50.3	67.4	68.8	69.4	70.6	70.8	71.6
SE(m)±	***0.38***	***0.43***	***0.99***	***1.05***	***1.32***	***1.38***	***1.36***	***1.41***	***1.39***	***1.42***
C.D (P=0.05)	***1.12***	***1.24***	***2.88***	***3.06***	***3.83***	***4.00***	***3.94***	***4.10***	***4.03***	***4.13***

(ii) Dry matter accumulation (g m^{-2}). The amount of dry matter accumulated by a crop is a significant aspect of the crop's photosynthetic efficiency, and when photosynthesis exceeds respiration, the plant's growth and development is sustained; conversely, the development process is slowed. As a result, it is the most accurate indicator of crop growth. A careful appraisal of the data in Table 3 revealed that dry matter accumulation m^{-2} continued to accumulate as the growth phase progressed until crop maturity throughout the research period in both years. Differences due to tillage treatments were found to be significant. In general, dry matter accumulation kept on increasing with age and reached maximum in both the years of study. Wheat sown on FIRB (T_1) produced maximum dry matter accumulation (g) and was significantly at par with T_2Reduced tillage with conventional tool line sowing. Treatment T_4 recorded least dry matter produced during 2020-21 and 2021-22, respectively. Similar result was found by Atikullah *et al.* (2014); Idnani and Kumar (2012).

Wheat produced statistically higher dry matter at all the growth stages during the years of study with application of water at IW/CPE 1.0, respectively. I_3 (1.0 IW/CPE) resulted in significantly higher dry matter accumulation (g m^{-2}) than the rest of the irrigation scheduling treatments during the years of study at all the crop growth stages of crop. Irrigation scheduling at 1.0 IW/CPE (I_3) treatment had resulted significantly higher dry matter accumulation (g m^{-2}) then 1.2 IW/CPE(I_4) at 90, 120 DAS and at harvest stage during the both years of experimentation. Irrigation scheduling at CRI (I_1) treatment resulted lowest amount of dry matter accumulation (g m^{-2}) during 2020-21 and 2021-22. Sarel *et al.* (2015) noticed higher dry matter accumulation of wheat with IW/CPE ratio of 1.0 over IW/CPE ratios of 0.25, 0.50 and 0.75. Narolia *et al.* (2016) observed that significantly increased dry-matter accumulation (894.2 g/m^2) with irrigation scheduling at IW/CPE ratio of 1.0 than other treatments.

Table 3: Performance of wheat under crop establishment methods and irrigation scheduling on dry matter accumulation (g m^{-2}) of wheat.

Treatments	Dry matter accumulation (g m^{-2})									
	30 DAS		60 DAS		90 DAS		120 DAS		At harvest	
	2020-21	2021-22	2020-21	2021-22	2020-21	2021-22	2020-21	2021-22	2020-21	2021-22
(A) Crop Establishment Methods										
T_1ROT	62.8	64.8	395.4	398.8	737.1	742.9	853.9	858.1	907.8	910.7
T_2 RTC	72.8	74.4	435.6	441.2	804.1	809.9	934.7	937.0	993.8	996.1
T_3 FIRB	79.5	82.6	443.1	450.3	811.7	815.5	946.3	950.2	1006.3	1010.6
T_4 CTB	59.6	60.4	362.3	365.4	673.8	677.9	783.5	787.3	832.9	836.2
T_5 CT	66.5	67.7	402.6	406.3	743.8	746.5	866.3	870.5	921.0	926.1
SE(m)±	***2.56***	***2.71***	***7.51***	***7.75***	***16.16***	***15.34***	***26.74***	***27.20***	***28.46***	***29.02***
C.D (P=0.05)	***8.36***	***8.84***	***24.46***	***25.26***	***49.39***	***49.99***	***87.11***	***88.6***	***92.71***	***94.53***
(B) Irrigation Scheduling										
I_1 (CRI)	49.8	50.9	304.7	307.8	571.1	575.5	665.2	668.9	707.9	712.9
I_2 CRI + IW/CPE 0.8	74.6	75.4	444.8	448.6	821.1	823.1	955.5	986.7	1015.8	1050.7
I_3 CRI + IW/CPE 1.0	78.2	80.2	461.1	466.3	847.8	852.6	983.9	959.2	1046.1	1019.7
I_4 CRI + IW/CPE 1.2	70.3	72.7	420.7	423.9	776.3	776.3	902.5	907.5	959.6	963.7
SE(m)±	***1.22***	***1.29***	***6.38***	***6.54***	***10.89***	***11.11***	***17.00***	***17.30***	***18.12***	***18.48***
C.D (P=0.05)	***3.52***	***3.74***	***18.45***	***18.91***	***31.48***	***32.06***	***49.13***	***50.10***	***52.35***	***53.39***

B. Yield attribute

The wheat spike contains a variable number of around 24 to 28 spikelets, each with several florets. Grains can differ in terms of developmental stage, weight, number and fruiting efficiency when compared among different spikelets and even within individual spikelets. The middle spikelets have more and heavier grains than the basal and top spikelets. Spikelet numbers, grain weight and grain numbers per spikelet have also a significant effect on thousand grain weight (TGW) and grain number per spike. The degree and rate of filling of the grains in individual spikelets varies highly by their position at the spike.

(i) Spike length. Spike length is proportional to the number of spikelets and grains spike^{-1}, making it a crucial factor in grain production. Spike length might likewise be used as a criterion for determining grain production in cereal crops. The scrutiny of data as presented in (Table 4) revealed that T_3 (FIRB) treatment significantly increased spike length over (13.6 & 14.3) treatments but at par with T_2(RCT) treatment during the year of study. However, T_4 treatment produced lowest spike length (7.7 & 8.5), respectively. During the 2020-21 and 2021-22 growing seasons, the (I_3) IW/CPE 1.0 treatment considerably enhanced spike length over the other treatments, as shown in Table 4. During both years of the trial, treatment I_2 and I_4 were statistically equivalent in terms of spike length. When several irrigation management techniques were evaluated, all of them produced considerably longer spike lengths than irrigation provided solely at CRI (I_4). Similar report was found by Hariram *et al.* (2013).

(ii) Number of Spikelet's spike^{-1}. Table 4 gives data on how different treatments impacted the number of spikelets with spike^{-1}. The maximum number of spikelet's spike^{-1} was considerably higher in T_3 (FIRB) therapy than in all other treatments, with the exception of T_2 (ROT), which was comparable in both years of the research. However, compared to the other treatments, this had a much higher number of spikelets. T_3 and T_5 were likewise comparable, with T_4 recording the lowest number of spikelets spike^{-1} (12.1 and 13.3) in 2020-21 and 2021-22. Differences in irrigation management were also shown to be important in terms of the average number of spikelet's spike^{-1}.During 2020-21 and 2021-22, I_1 and I_4 generated considerably less average spikelet spike^{-1} (8.57 & 9.4, 14.8 & 15.3) than the other irrigation schedule treatments. In both years of the research, I_3 generated considerably more spikelet spike^{-1} (17.5 & 18.3) than all other treatments except I_2 (16.2 & 17.9).

(iii) Grains spike^{-1}. The more number of grains per spike were because of significant increase in spike length and number of spikelet per spike. The spike of a cereal plant is the grain-bearing organ whose morphological properties are proxy measures of grain yield. Table 4 shows the data with concerning the effects of different crop establishment technique and irrigation scheduling on number grains spike^{-1} of wheat. Result shows that sowing of wheat on FIRB (T_3) planting techniques produced significantly more grains spike^{-1} during the years of study over all other treatments but was statistically at par with sowing of wheat on reduced tillage with conventional tool line sowing (T_2), respectively. The differences in number of grains spike^{-1} among the treatments T_1 and T_5 were non-significant but significantly superior over T_4 in both the years. Treatment T_4 had the lowest grain per spikes (CTB). Decrease in the number of grains per spike was directly reflected in the grain yield and yield gap. It can be seen from the data that all irrigation levels significantly increased number of grains spike^{-1} over irrigation applied only at CRI stage (I_1). However; among all the treatments of irrigation scheduling I_2 (CRI+ IW/CPE 1.0) was found superior but I_2 (CRI + IW/CPE 0.8) was statistically at par during both the year of experimentation. Similar trends were found by Fahong *et al.* (2011); Tanwar *et al*. (2014).

(iv) Test weight. The amount of wheat that can be contained in a standard volume is measured in test weight. Table 4 show the results of 1000-grain test weight as a function of several crop establishment methods and irrigation scheduling in wheat in the rice-wheat system. T_3 (FIRB) treatment of sowing techniques considerably increased 1000 grain weight above all other treatments during the year of study, but was statistically at par with T_2 treatment during the year. The finding of experiment indicated that the test weight (Table 4) was 21.3 % higher in raised beds than conventional tillage. However, T_5 treatment produced significantly higher grain weight as compared to T_1 and T_4 respectively. The results support those of Sepat *et al*. (2010); Mollah *et al.* (2009).

During both years of research, irrigation scheduling in wheat failed to reach statistical significance on 1000 grain test weight. However, when compared to irrigation supplied at treatment T_3 CRI + 1.0 IW/CPE, optimal amounts of irrigation application to wheat considerably raised thousand grain weights. Although, test weight was increase in following order (I_3) IW/CPE=1.0 followed by I_2) IW/CPE=0.8> (1.2) IW/CPE=0.12> CRI.

Table 4: Performance of wheat under crop establishment methods and irrigation scheduling on yield attributes of wheat.

Treatments	Effective tillers (No. m^{-2})		Spike length (cm)		Spikelet per spike		Grains per spike		Test weight (g)	
	2020-21	2021-22	2020-21	2021-22	2020-21	2021-22	2020-21	2021-22	2020-21	2021-22
(A) Crop Establishment Methods										
T_1ROT	228	232	8.6	9.6	12.8	13.7	31.3	32.9	35.7	36.8
T_2 RTC	235	238	11.2	12.3	15.2	16.8	37.5	38.6	38.9	39.1
T_3 FIRB	238	241	13.6	14.3	17.2	18.9	39.8	40.8	40.7	41.9
T_4 CTB	166	168	7.7	8.5	12.1	13.1	27.6	28.7	33.6	34.2
T_5 CT	231	235	9.2	10.2	13.9	14.3	33.4	34.1	37.1	38.2
SE(m)±	***2.71***	***2.75***	***0.52***	***0.52***	***0.67***	***0.71***	***1.50***	***1.54***	***1.74***	***1.78***
C.D (P=0.05)	***8.84***	***8.96***	***1.71***	***1.70***	***2.18***	***2.33***	***4.88***	***5.03***	***NS***	***NS***
(B) Irrigation Scheduling										
I_1 (CRI)	170	173	7.5	8.3	8.57	9.4	20.4	21.4	32.9	33.9
I_2 CRI + IW/CPE 0.8	237	240	10.9	11.8	16.2	17.9	38.3	39.3	38.4	39.6
I_3 CRI + IW/CPE 1.0	241	243	12.0	13.2	17.5	18.3	41.3	43.4	40.5	41.3
I_4 CRI + IW/CPE 1.2	230	232	9.9	10.1	14.8	15.3	35.7	36.5	37.1	38.2
SE(m)±	***2.50***	***2.58***	***0.34***	***0.37***	***0.35***	***0.38***	***0.73***	***0.77***	***0.77***	***0.79***
C.D (P=0.05)	***7.25***	***7.46***	***0.98***	***1.08***	***1.02***	***1.11***	***2.13***	***2.24***	***2.23***	***2.30***

C. Yield

The most essential criterion for measuring the effect of administered treatments is grain yield. Crop yields refer to the amount of grain or other crops produced, as well as the efficiency with which land is used to generate food or agricultural goods. Grain yield is determined by a number of factors, including crop dry matter accumulation, number of tillers, number of grains spike^{-1}, and test weight.

(i) Grain yield (q ha^{-1}). Tillage-management practices caused significant variation in grain yield. The pertaining data to grain yield as influenced by crop establishment methods and irrigation scheduling are shown in Table 5. Yield of grain was slightly higher during second year as compared to first year of experimentation. During both study years, the variance in grain yield due to diverse treatment effects was statistically significant. Amongst the crop establishment methods, T_3 (FIRB) produced maximum grain yield which was remained at par to T_2 (RTC). The reduction in grain yield due to more tillage *i.e*. traditional practices with was 5.15%, 11.13% and 20.25 %compared to T_1 (ROT), T_2 (RTC) and T_5 (CT) practices, respectively. There was yield improvement due to lesser tillage operation in FIRB and reduced tillage, respectively over conventional tillage. Similar trends were observed during 2020-21. These findings for yield increase under bed planting are in close agreement with the works of Chauhdary *et al.* (2016), who reported 13% more yield under bed planting in comparison to that under conventional flat sowing. Similar result was found by Bakhsh *et al.* (2018); Rajanna *et al.* (2019); Iqbal *et al.* (2021).

Irrigation exerted a significant positive influence on wheat yield and it increased with increasing frequency of irrigation **(**Table 5). The maximum grain yield was obtained with irrigation with IW: CPE 1.0 which remained statistically at par with IW: CPE 0.8. The superiority of this treatment might be owing to better availability of water and nutrient, improved vegetative growth (Rajanna *et al.,* 2019). However, under limited irrigation, the extent of yield reduction due to restricted water availability depends on the degree, duration and timing of the imposed soil-moisture deficit (Dar *et al.*, 2019). Irrigation only at CRI stage recorded minimum grain yield during the years of study, respectively. The results support those of Bandyopadhyay *et al.* (2021); Goswami *et al.* (2020).

(ii) Straw yield (q ha^{-1}). Table 5 clearly showed that average straw yield was higher during the second year as compared to that in first year. It is evident from the data that the major effect of different modes of tillage and interaction effect of irrigation water was significant for straw. During 2020-21, the significantly highest straw yield (63.6 & 65.8 q ha^{-1}) was recorded due to moisture retention along with wheat sown on FIRB (T_3) over remaining treatments except wheat sown on (T_2). The differences in the straw yield due to conservation tillage treatments proved significant. The straw yield increased significantly with the every successive increase in moisture supply by moisture retention and bed configuration. T_5 and T_1 were at par with each other, however, they recorded significantly higher straw yield over conventional tillage with broadcasting. Treatment T_4 (conventional tillage) recorded minimum straw yield 54.5 & 55.2 qha^{-1} during 2020-21 and 2021-22, respectively.

In both growing seasons, irrigation treatments had a considerable impact on straw yield. In both seasons, the highest straw yield was obtained with the IW: CPE 1.0, whereas the lowest yield was obtained with the IW: CPE 0.8, as shown in Table 5. The increase in straw production could be related to increased irrigation water availability, which boosts yield components. Similar trend were found by Gupta *et al.* (2016); Narolia *et al.* (2016).

(iii) Biological yield (q ha^{-1}). The biological yield refers to the total dry matter accumulation of a plant system. Improved harvest index represents increased physiological capacity to mobilize photosynthates and translocate them into organs having economic yield (Table 5). Wheat sown on FIRB (T_3) being at par with wheat sown on reduced tillage with rotavator line sowing (T_2) in biomass production during both the year. Whereas, wheat sown by conventional method (T_5) and wheat sown by rotavator tillage (T_1) in second year produced significant increase in biological yield over conventional tillage with broadcast technique (T_4), respectively. Table 5 clearly showed that the differences among the irrigation levels were obtained to be significant. Highest biological yield of wheat was produced with CRI+IW/CPE 1.0(I_3) irrigations with 5 irrigations (113.6 &116.4q ha^{-1}) which were higher as compared to I_1, I_2 and I_4 during first and second year, respectively.

(iv) Harvest index (%). Harvest index is an important parameter indicating the efficiency in partitioning of dry matter to the economic part of crop. Higher harvest index, means higher is the economic return of the crop. The data regarding harvest index have been presented in (Table 5). Wheat sown on FIRB produced significant higher harvest index which was at par with reduced tillage with rotavator line sowing. However, the lowest harvest index found in conventional tillage with broadcast sowing. Among all the irrigation scheduling treatments, all the treatments proved higher than solo irrigation at CRI stage (I_1) during the years of study but all treatments were at par with each other, respectively. However, the highest harvest index was obtained under I_3 (IW/CPE=1.0) which was at par with I_2 (IW/CPE=0.8) and lowest under I_1 (CRI stage) treatment during the years of study. Harvest index remained highest with irrigations at IW: CPE 1.0; however, it was statistically at par with the harvest index obtained with irrigations at IW: CPE 0.8. Our results confirm the report of Galavi and Moghaddam (2012); Nayak *et al*. (2015).

Table 5: Performance of wheat under crop establishment methods and irrigation scheduling on grain, straw, biological yield (q ha^{-1}) and harvest index (%) of wheat.

Treatments	Yield (q ha^{-1})						Harvest Index (%)	
	Grains		Straw		Biological			
	2020-21	2021-22	2020-21	2021-22	2020-21	2021-22	2020-21	2021-22
(A) Crop Establishment Methods								
T_1ROT	39.0	40.5	58.0	59.8	97.1	100.3	40.2	40.4
T_2 RTC	44.6	46.2	61.2	62.8	105.8	109.0	42.2	42.4
T_3 FIRB	46.9	47.7	63.6	65.8	110.5	113.5	42.4	42.0
T_4 CTB	26.1	27.5	54.5	55.2	80.6	82.7	32.4	33.3
T_5 CT	42.2	43.6	59.1	61.3	101.3	104.9	41.7	41.6
SE(m)±	***1.16***	***1.82***	***1.56***	***1.60***	***1.99***	***2.05***	***1.20***	***1.21***
C.D (P=0.05)	***3.80***	***3.87***	***4.68***	***5.24***	***6.41***	***6.72***	***3.94***	***3.97***
(B) Irrigation Scheduling								
I_1Irrigation at critical stages (CRI)	27.8	28.4	43.5	44.7	71.3	73.1	39.0	38.9
I_2CRI + IW/CPE 0.8	43.9	44.7	64.5	65.7	108.4	110.4	40.5	40.5
I_3CRI + IW/CPE 1.0	46.7	48.1	66.9	68.3	113.6	116.4	41.1	41.3
I_4CRI + IW/CPE 1.2	40.1	41.6	62.2	63.9	102.3	105.5	39.2	39.4
SE(m)±	***1.07***	***1.10***	***1.44***	***1.47***	***1.96***	***2.07***	***0.86***	***0.87***
C.D (P=0.05)	***3.10***	***3.28***	***4.51***	***4.26***	***5.77***	***6.00***	***NS***	***NS***

Production technologies such as scheduling irrigation and planting techniques leading to higher productivity per unit of water use need to be developed. The present investigation was carried out to find out performance of wheat in terms of growth, yield, physiology, and water use under different crop establishment techniques and irrigation schedules because the behaviour of water distribution in the root zone soil and its use by the crops, and thereby the irrigation schedule under different crop establishment techniques, is likely to be different than the normal tillage practices and individual crops.

CONCLUSION

The study highlights the importance of irrigation scheduling supplemented with sowing method for improving yield and water savings of wheat crop. The study concluded that adoption of bed planting (FIRBS) performed best with highest yield attributes and yield of 46.9 & 49.5q ha^{-1} followed by reduced tillage. FIRBS (Bed) planting of wheat was found to be of the most effective and promising resource conservation practices in semi-arid climatic situations. Among the moisture regimes, applying irrigation at CRI + IW: CPE = 1.0 considerably increased growth and yield.

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