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Effect of irrigation scheduling under different crop establishment methods on growth and water productivity of wheat

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Abstract
The present investigation was conducted at Agronomy Research Farm of Bihar Agricultural University, Sabour Bhagalpur (Bihar) to study the effect of irrigation scheduling under different crop establishment methods on yield of wheat during *Rabi* season 2022-23. The experiment was laid out in Split Plot Design, replicated three times with treatment consisted of three crop establishment method *viz.* conventional tillage wheat sowing (T_1), zero tillage wheat sowing (T_2) and wheat sown on furrow irrigated raised bed (T_3) in main plot and three irrigation scheduling level based on IW/CPE ratio *viz.* 4 cm irrigation at 0.8 IW/CPE (I_1). 5 cm irrigation at 1.0 IW/CPE (I_2) and 6 cm irrigation at 1.2 IW/CPE (I_3) in sub plots. Results showed that the different crop establishment methods the growth characters like no of tillers m^{-2} and dry matter accumulation m^{-2} recorded significantly superior at 60, 90 DAS and at harvest in FIRBs over all crop establishment methods applied, while in case of leaf area index it was found statistically at par with conventional tillage, however the plant height was not significantly influenced by crop establishment methods at all the crop growth stages. Significantly higher grain yield, achieved under conventional tillage method of crop establishment. In different irrigation scheduling treatments, in case of plant growth character like plant height, number of tillers, dry matter accumulation and LAI, there were no any significant difference were found between 5 cm irrigation at 1.0 IW/CPE and 6 cm irrigation at 1.2 IW/CPE and both treatments were found significantly superior over 4 cm irrigation at 0.8 IW/CPE ratio. Among different irrigation scheduling levels the irrigation depth of 5 cm irrigation at 1.0 IW/CPE ratio resulted in significantly higher grain yield. In crop establishment methods conventional tillage recorded the maximum water productivity, due to its higher yield over all treatments, while in case of irrigation scheduling the treatment 4 cm irrigation at 0.8 IW/CPE ratio was recorded significantly higher value of water productivity because the proportionate increase in grain yield was not recorded as the amount of water applied increases in other treatments. In different treatment combination highest water productivity was determined under conventional tillage method of crop establishment with 5 cm irrigation at 1.0 IW/CPE ratio.

Keywords: Conventional tillage, zero tillage, furrow irrigated raised bed, Irrigation scheduling

Introduction
Wheat (*Triticum aestivum* L.) is the most important crop among all cereals and used as a food grain in the world which ranks first (30% of all cereals) followed by rice (27%) and maize (25%). However, in India, it is the second most important food crop after rice. Wheat is the single most important cereal crop that has been considered as integral component of the food security system of several nations. It is one of the most important staple food crops of the world and North Indian population. It is the major constituent of the global food security along with good health. Therefore, it attracts the attention towards its production, productivity and quality. 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) [2]. Wheat serves as a crucial cereal crop within the country, but its overall yield suffers due to several key factors.

These include inadequate crop establishment and sub-optimal irrigation scheduling. Among various agronomic practices, adopting a suitable crop establishment method can significantly enhance wheat production to some degree. Both the choice of crop establishment method and irrigation schedule emerge as leading contributors to reduced wheat yields, ultimately impacting water productivity and economic outcomes in wheat production.

Conventional tillage is used to soften the soil and prepare a seedbed that allows seeds to be placed easily at a suitable depth into moist soil. This results in uniform seed germination. Generally, this method involves plowing or intensive (i.e., numerous) tillage operations. Residues from the previous crop are incorporated, along with any soil amendments (fertilizers, organic or inorganic) into the soil. Crop residues, especially loose residues, create problems for seeding equipment by raking and clogging. Tillage gives temporary relief from compaction using implements that can shatter below-ground compaction layers formed in the soil. Implements like rotavators create serious problems such as soil compaction, water stagnation and the yellowing of wheat leaves after the first irrigation. Overall, tillage consumes large quantities of fossil fuels, adds to the cost of cultivation, emits greenhouse gases (mostly CO_2), delays the planting of crops, leads to a decline in soil organic matter, leaves the soil bare and loose eventually leading to soil erosion disrupts the root channels of the previous crops and results in more wear and tear of agricultural machines.

In Furrow-Irrigated Raised-Bed System (FIRBs) sowing is done on raised beds. This optimizes tillage operations, saves water and reduces lodging. The bed planting wheat is one of the novel techniques to save water and enhancing the productivity of other inputs applied. Typical irrigation savings under FIRBs ranged from 18 to 35% in wheat (Hobbs and Gupta 2003) [9]. The FIRBs planting system have number of advantages like better irrigation management, better crop establishment, better weed management, less soil compaction (Karunakaran and Behera 2013) [11] and higher N, P and K uptake (Idnani and Kumar 2013) [10]. The water-saving (50.73%) and water productivity (54.37%) of the wheat crop were higher under a raised-bed irrigation system.

Zero-tillage planting of wheat after rice has been the most successful resource-conserving technology to date in the Indo-Gangetic Plains, particularly in northwest India (Erenstein and Laxmi 2008) [7]. The productivity advantages of ZT wheat result from earlier planting (and thus avoiding terminal heat damage during the grain filling stage), control of *Phalaris minor*, a major weed of wheat, better nutrient management and water savings. Other advantages include improved soil and water conservation, increased use of land through intensification of cropping systems, reduced labour and energy requirements, reduced equipment inventories, reduced wear and tear on tractors and equipment, and greater environmental benefits. ZT reverses the loss of soil organic matter that happens in conventional tillage. Provides excellent seed-soil contact and hence facilitates uniform emergence of seeds. Improves soil quality and water retaining capacity by adding organic matter. As crop residues decompose, this creates an open soil structure that lets water in more easily, reducing runoff. Helps reduce CO_2 emissions and mitigate the adverse effect of global warming. ZT use leads to reduction in air pollution by minimizing crop residue burning. Improves the biological diversity of soil that increases the number of beneficial insects and keeps many insect pests in check. Establishing the wheat crop through zero tillage can be undertaken as a business.

Farmers in Bihar tossed away the past practice of frequent tillage and adopted the new concept in the form of zero tillage (Hobbs and Gupta, 2003) [9]. The productivity of wheat is low due to delayed sowing, following late harvesting of medium to long duration rice varieties resulting in sub-optimal crop establishment of wheat. Zero till sown wheat recorded 2 -3 days earlier germination compared to other methods of sowing. Zero tillage technique for wheat sowing advanced the sowing by 8-13 days in timely sown wheat while in late sown wheat it was 8-20 days advancement. Thus keeping the above points in view, trial has been conducted to accelerate the sowing of wheat after harvest of rice under zero tilled condition.

Water is a precious and scare input plays a vital role in assured crop production since it is essential for the maintenance to turgidity, absorption of nutrients and the metabolic process of the plants. Therefore, it becomes imperative to develop an optimum irrigation schedule to maintain the sufficient available soil moisture throughout the crop period for best exploitation of crop yield potential. Among the several recognized criteria of irrigation scheduling, climatological approach is very scientific and widely accepted among the scientists and research workers throughout the world. It is well known that evapotranspiration by a full crop cover is closely associated with the evaporation from an open pan. IW/CPE is a ratio between fixed amount of irrigation water (IW) and cumulative pan evaporation minus rains. This IW/CPE approach merits on account of its simplicity of operation and high water use efficiency. It is an established fact that in future, less and less of water will be available for agriculture on account of increasing water demand for domestic, industrial and other purposes. It is estimated that even after achieving the full irrigation potential, nearly 50% of the total cultivated area will remain rain fed.

Materials and Methods

The field experiment was carried out at the Agronomy Research Farm of Bihar Agricultural University, Sabour, Bhagalpur, located between 25°50' N latitude and 87°19' E longitude at an altitude of 52.73 meters above the mean sea level during *Rabi* 20022-23. The experimental plot has uniform topography with homogenous fertility and soil characteristics typical to suit winter wheat cultivation. The fields were fairly leveled and had good drainage having an assured irrigation facility. The sub-tropical climate of Sabour is characterized by hot, dry summers, moderate rainfall and extremely chilly winters. The third week of October mark the beginning of the temperature decline, which becomes abrupt on December 15th. The coldest months are December and January, where the mean temperature typically drops as low as 8.2 ºC. Beginning around the middle of February, the temperature begins to climb once more, and by the beginning of March it is increasing quickly. The warmest months are May and June, which have a maximum average temperature of 29.6 ºC. Around 1100 mm of rain fall obtained on an average each year, with 80-85 percent of that falling during the four monsoon months (June to September). Rainfall during the monsoon season frequently begins late and ends early. The typical rainfall is 1207 mm (10 years average), largely falling between the middle of June and the middle of October, with less potential evapotranspiration than precipitation. Winter rains brought by westerly winds help nourish crop grown in rainfed zones. In July and August, mean relative humidity (R.H.) reaches a high of 93.5 and a low of 35% in April-May.The region is characterized by a sub-tropical and semi-arid climate with a hot dry summer (March–June), wet monsoon season (late June–mid September) and a cool dry winter (October–February). Average annual rainfall is 734 mm (constituting 44% of pan evaporation) of which about 80% is received during the monsoon. The soil was sandy loam with pH 7.33. The top soil of the experimental site was clay loam overlying silty clay, with an abrupt change to sandy loam at about 90 cm. Bulk density was 1.37 g cm^{-3} in the top-soil, and there was a hard pan (1.71 g cm^{-3}) at 15–30 cm. Organic carbon was 0.57, available N 172.84 kg ha^{-1}, available K_2O 147.86 kg ha^{-1} and available P_2O_5 23.11 kg ha^{-1} at the start of the experiment in 0 to 30 cm soil layer during 2022-23, respectively. The treatment consisted of three crop establishment method *viz*. conventional tillage wheat sowing (T_1), zero tillage wheat sowing (T_2) and wheat sown on furrow irrigated raised bed (T_3) in main plot and three irrigation scheduling levels based on IW/CPE ratio *viz*. 4 cm irrigation at 0.8 IW/CPE (I_1), 5 cm irrigation at 1.0 IW/CPE (I_2) and 6 cm irrigation at 1.2 IW/CPE (I_3) in sub plots. The study was made in split plot design with three replications. In FIRB, 15 cm height and 80 cm broad bed with a furrow width of 30 cm between the beds was prepared with planting four rows of wheat in rows 20 cm apart. Half dose of N and full dose of P and K through urea, DAP and muriate of potash, respectively, were applied at sowing and remaining N was applied after first irrigation. Wheat variety DBW 187 was sown on 15 December 2022 and harvested on 12 April 2023, respectively. Other management practices were adopted as per recommendations of the crop under irrigated conditions. One year data was statistically analysed.

Results and Discussion

Growth parameters

Plant height

Plant height increased with advancement of crop age and reached maximum at 90 DAS and slightly decreased thereafter (Table 1). Plant height exhibited rapid growth until reaching 90 days after sowing (DAS), after which it slowed down slightly. This slower initial growth was followed by a more rapid phase, attributed to better resource utilization, increased light absorption, heightened photosynthetic activity and an enhanced rate of nutrient uptake from the soil. Interestingly, no significant differences were observed among the various crop establishment methods at all stages of crop growth, which aligns with findings reported by Shekhar *et al*. (2014) [18].

At 30 DAS, plant height was not significantly affected by the various irrigation schedules (Table 1). This lack of influence can be attributed to the fact that there was no differential irrigation applied up to this point. However, plant height was significantly influenced by the different irrigation schedules during the experiment at 60 DAS, 90 DAS, and at the harvest stage. The tallest plants were observed under the 6 cm irrigation at a 1.2 IW/CPE ratio. Conversely, the driest moisture regime, with 4 cm of irrigation at a 0.8 IW/CPE ratio, produced significantly shorter plants compared to the wetter regimes. The increase in plant height is linked to cell expansion and relies on cell water potential. The rise in plant height at higher levels of moisture regimes may be attributed to the consistent and adequate moisture supply to the plant, which promotes robust root establishment and supports various metabolic processes. These findings closely align with the studies of Bandyopadhyay (1997) [3].

Table 1: Effect of crop establishment methods and irrigation scheduling on plant height (cm) at various crop growth stages.

Plant height (cm)				
Treatments	**30 DAS**	**60 DAS**	**90 DAS**	**Harvest**
Crop establishment methods				
T_1- Conventional tillage	24.31	58.27	81.24	80.43
T_2- Zero tillage	23.93	58.30	80.76	79.13
T_3- Furrow irrigated raised bed (FIRBs)	25.23	59.62	81.46	80.64
SEm±	0.82	0.91	1.25	1.23
CD (P=0.05)	NS	NS	NS	NS
Irrigation scheduling				
I_1- 0.8 IW/CPE	24.21	56.30	77.97	76.93
I_2- 1.0 IW/CPE	24.54	59.75	82.47	81.37
I_3- 1.2 IW/CPE	24.73	60.13	83.00	81.90
SEm±	0.65	0.99	1.37	1.35
CD (P=0.05)	NS	3.05	4.22	4.16
Interaction	NS	NS	NS	NS

Number of tillers

The choice of crop establishment method had a noteworthy impact on the number of tillers per square meter at all growth stages in the study, with the exception of the 30 days after sowing (DAS) stage (refer to table 2). Significantly more tillers per square meter were observed when using the FIRBs planting method for crop establishment compared to both the conventional and zero tillage methods. This difference can likely be attributed to the superior soil conditions associated with FIRBs, which provide ample growth resources, particularly increased fertilizer and water utilization efficiency, favourable aeration leading to greater tiller formation, and ultimately, a higher count of tillers per square meter. The zero tillage and conventional methods of crop establishment, on the other hand, exhibit significant differences at all stages of crop growth, although the conventional method did yield a higher number of tillers per square meter. Similar findings have been reported by Srivastava *et al*. (2002) [19]. It's worth noting that the lower number of tillers per square meter under the zero tillage method of crop establishment can be attributed to the comparatively less favourable soil conditions compared to other establishment methods.

A higher number of tillers were observed under the 5 cm irrigation at a 1.0 IW/CPE ratio, and this was significantly greater than the number of tillers under the 4 cm irrigation at a 0.8 IW/CPE ratio, while being comparable to the 6 cm irrigation at a 1.2 IW/CPE ratio. This increase in tiller number can be attributed to the adequate availability of moisture under the 5 cm irrigation at a 1.0 IW/CPE ratio, which improved nutrient availability, supported better root development, and ultimately resulted in a higher number of tillers per square meter. Conversely, the minimum number of tillers per square meter was recorded under the 4 cm irrigation at a 0.8 IW/CPE ratio, possibly due to insufficient moisture supply, which reduced nutrient availability and ultimately resulted in fewer tillers per square meter. These research findings closely align with the studies conducted by Bandyopadhyay (1997) [3].

Table 2: Effect of crop establishment methods and irrigation scheduling on number of tillers m⁻² at various crop growth stages.

Number of tillers m^{-2}				
Treatments	**30 DAS**	**60 DAS**	**90 DAS**	**Harvest stage**
Crop establishment methods				
T_1- Conventional tillage	211	370	359	340
T_2- Zero tillage	208	322	312	295
T_3- Furrow irrigated raised bed (FIRBs)	223	408	396	375
SEm±	5.8	9.3	9.1	8.7
CD (P=0.05)	NS	32.4	31.6	30.1
Irrigation scheduling				
I_1- 0.8 IW/CPE	213	350	340	322
I_2- 1.0 IW/CPE	215	383	372	352
I_3- 1.2 IW/CPE	213	367	356	337
SEm±	3	7	6	6
CD (P=0.05)	NS	21	21	20
Interaction	NS	S	NS	NS

Table 2a: Interaction effect of crop establishment methods and irrigation scheduling on number of tillers m⁻² of wheat at 60 DAS

Crop establishment methods (T)	**No. of tillers m^{-2} at 60 DAS**			
	Irrigation scheduling			
	0.8	**1.0**	**1.2**	**Mean**
Conventional tillage	343	405	363	370
Zero tillage	341	309	316	322
FIRBs	367	435	422	408
Mean	350	383	367	
T at same level of I	SEm±	13	CD (P=0.05)	47
I at same level of T	SEm±	12	CD (P=0.05)	37

The interaction for the number of tillers was found significant only at 60 DAS. Irrigation applied at 1.0 IW/CPE ratio under FIRBs produced significantly more number of tillers (435 m-2) at 60 DAS but was at par with FIRBs with I3 and CT with I2.

Leaf area index

Leaf area index influenced significantly due to various crop establishment methods at all the stages of crop growth except at 30 DAS during the crop season (Table 3). It increased successively up to 60 DAS, thereafter, declined due to leaf senescence. Initially LAI increased slowly due to slow growth, after that, it brought the rapid increase due to well crop establishment, bright sunshine and rise in temperature. Higher leaf area index were obtained under FIRBs method of crop establishment which was significantly higher over zero tillage and statistically at par with conventional tillage. Higher LAI under FIRBs planting might be due to well established plant which gave more number of green leaves with enlarged size because of better plant stand and better nutrient mobilization due to relatively better soil environment for plant growth as compared to other method of crop establishment. The lower LAI was recorded under zero tillage due to relatively insufficient growth of leaves and comparatively lesser number of total green leaves. The results are in conformity to those Sharma and Acharya (1997) [17], Chhina (2000) [5] and Gangwar *et al.* (2004) [8].

The leaf area index (LAI) was also significantly affected by various irrigation schedules during the study year, as shown in table 4.3, specifically at 90 DAS. Increasing the irrigation depth under different irrigation schedules led to an increase in LAI. The highest LAI was observed under the irrigation schedule of 5 cm of irrigation at a 1.0 IW/CPE ratio. This increase can be attributed to the sufficient availability of moisture, which enhanced nutrient absorption and resulted in fully turgid leaves, a higher number of green leaves with larger sizes, ultimately leading to a higher leaf area index. Conversely, the lowest LAI was recorded under the irrigation schedule of 4 cm of irrigation at a 0.8 IW/CPE ratio, primarily due to the limited supply of moisture and nutrients. Soil moisture stress increases the number of epidermal cells and stomata but decreases their size. Unfavourable moisture conditions also reduce leaf area and accelerate leaf senescence. These results closely align with the findings of Pal *et al.* (2020) [13].

Table 3: Effect of crop establishment methods and irrigation scheduling on leaf area index at various crop growth stages

Leaf area index			
Treatments	**30 DAS**	**60 DAS**	**90 DAS**
Crop establishment methods			
T_1- Conventional tillage	0.75	3.62	2.36
T_2- Zero tillage	0.71	3.40	2.21
T_3- Furrow irrigated raised bed (FIRBs)	0.78	3.96	2.57
SEm±	0.02	0.10	0.06
CD (P=0.05)	NS	0.35	0.22
Irrigation scheduling			
I_1- 0.8 IW/CPE	0.73	3.47	2.26
I_2- 1.0 IW/CPE	0.76	3.77	2.45
I_3- 1.2 IW/CPE	0.75	3.73	2.42
SEm±	0.01	0.05	0.03
CD (P=0.05)	NS	0.14	0.09
Interaction	NS	NS	NS

Dry matter accumulation (g m^{-2})

Dry matter accumulation was significantly affected by the choice of crop establishment method at all growth stages in the study, except at the 30 DAS stage, as shown in table 4. The FIRBs planting method for crop establishment led to a substantial increase in dry matter accumulation compared to both the zero tillage and conventional methods at all growth stages, with the exception of the 30 DAS stage. This increase can be attributed to the greater number of tillers per square meter and a higher leaf area index associated with FIRBs, both of which contributed to enhanced photosynthetic activity in the crop, resulting in the highest dry matter accumulation. These findings align with those reported by Tripathi *et al*. (2013) [20]. Conversely, the lowest dry matter accumulation, in comparison to the other methods, was observed under the zero tillage method of crop establishment during the experiment. This could be attributed to reduced plant height, a lower leaf area index, and fewer tillers per square meter, all of which contributed to diminished photosynthetic activity and ultimately resulted in lower dry matter accumulation. These results are consistent with those reported by Chhina (2000) [5] and Wiatrak *et al*. (2004) [21]. However, it's worth noting that Yonglu *et al*. (2000) [22] reported higher dry matter accumulation under zero tillage compared to the conventional method of crop establishment.

Dry matter accumulation was significantly influenced by different irrigation schedules at both 60 and 90 days after sowing (DAS) during the study years, as depicted in table 4.4. The highest level of dry matter accumulation was observed under the irrigation schedule of 5 cm of irrigation at a 1.0 IW/CPE ratio. This increase in dry matter accumulation is a result of the accumulation of photosynthates in various plant parts, which is contingent upon the availability of soil moisture. The greater plant height and leaf area index (as shown in table 1 and 3) were the primary factors contributing to the higher dry matter accumulation under the 5 cm irrigation at a 1.0 IW/CPE ratio. Conversely, the lowest dry matter accumulation occurred under the drier moisture regimes of 4 cm of irrigation at a 0.8 IW/CPE ratio. Water stress under such conditions can lead to a reduction in photosynthesis due to partial closure of stomata, resulting in decreased CO_2 supply. Water stress also diminishes the protoplasm's capacity to carry out photosynthesis and reduces translocation, possibly leading to the accumulation of end products that hinder the process. The reduction in photosynthesis, decreased translocation of carbohydrates and growth regulators, and disruptions in nitrogen metabolism, all contribute to the reduction in growth due to reduced turgor (Kramer, 1969) [12]. This increase in dry matter accumulation with increased moisture aligns with the findings of Ahmed (1992) [1], Dubey and Sharma (1996) [6], and Saren *et al.* (2004) [16].

Table 4: Effect of crop establishment methods and irrigation scheduling on dry matter accumulation (g m^{-2}) at various crop growth stages

Dry matter accumulation (g m^{-2})				
Treatments	**30 DAS**	**60 DAS**	**90 DAS**	**Harvest stage**
Crop establishment methods				
T_1- Conventional tillage	42.8	220.0	401.1	685.8
T_2- Zero tillage	40.3	193.5	353.0	603.8
T_3- Furrow irrigated raised bed (FIRBs)	48.8	246.4	449.4	768.6
SEm±	1.7	5.1	9.3	16.0
CD (P=0.05)	NS	17.6	32.3	55.4
Irrigation scheduling				
I_1- 0.8 IW/CPE	43.4	214.3	390.8	668.3
I_2- 1.0 IW/CPE	45.2	225.4	411.1	702.9
I_3- 1.2 IW/CPE	43.3	220.3	401.7	687.0
SEm±	0.7	2.4	4.5	7.6
CD (P=0.05)	2.2	7.6	13.8	23.6
Interaction	NS	NS	NS	NS

Water productivity

Water productivity (WP) was significantly affected by the choice of crop establishment methods in the year of the study. The conventional tillage method for crop establishment achieved a higher water productivity, primarily because it yielded more with less water consumption during the crop season. It was followed by the FIRBs method, while the lowest water productivity was observed under the zero tillage method of crop establishment.

Table 5: Effect of crop establishment methods and irrigation scheduling on water productivity at various crop growth stages.

Water productivity				
Treatments	**Grain yield (q ha^{-1})**	**Total water applied (cm)**	**Water applied (m^3)**	**Water productivity (kg m^{-3})**
Crop establishment methods				
T_1- Conventional tillage	32.69	24.6	2460	1.34
T_2- Zero tillage	29.45	24.6	2460	1.21
T_3- Furrow irrigated raised bed (FIRBs)	29.87	24.6	2460	1.22
SEm±	0.61			0.03
CD (P=0.05)	2.12			0.09
Irrigation scheduling				
I_1- 0.8 IW/CPE	29.67	21.6	2160	1.37
I_2- 1.0 IW/CPE	31.57	24.6	2460	1.28
I_3- 1.2 IW/CPE	30.78	27.6	2760	1.12
SEm±	0.38			0.02
CD (P=0.05)	1.16			0.05
Interaction	S			S

This was primarily due to lower yields and higher water consumption associated with the zero tillage treatment during the crop season.

Water productivity (WP) was significantly influenced by the increase in irrigation depth during the study year, as shown in table 5. The highest water productivity, at 1.37 kg per cubic meter, was observed under the 4 cm irrigation at a 0.8 IW/CPE ratio.

Table 5a: Interaction effect of crop establishment methods and irrigation scheduling on water productivity of wheat.

Crop establishment methods (T)	Water productivity (kg m^{-3} of water applied)			
	Irrigation scheduling			
	0.8	1.0	1.2	Mean
Conventional tillage	1.40	1.41	1.21	1.34
Zero tillage	1.37	1.22	1.04	1.21
FIRBs	1,35	1.22	1.10	1.22
Mean	1.37	1.28	1.12	
T at same level of I	SEm±	0.03	CD (P=0.05)	0.02
I at same level of T	SEm±	0.03	CD (P=0.05)	0.08

This was followed by the irrigation schedule of 5 cm and 6 cm irrigation at 1.0 and 1.2 IW/CPE ratios during the experiment. This increase in water productivity can be attributed to achieving higher yields with a reduced amount of water usage. The decline in water productivity under the higher irrigation level of 6 cm at a 1.2 IW/CPE ratio might be explained by the fact that grain yield did not increase proportionately to the total amount of water applied under this treatment. Chavan and Pawar (1987) [4] found that water productivity increased as irrigation depth decreased and decreased as irrigation depth increased, which supports these findings. Similar results were reported by Rathore and Patel (1991) [14], Roy and Pradhan (1994) [15]. The highest water productivity, at 1.41 kg per cubic meter, was achieved with conventional tillage using 5 cm irrigation at a 1.0 W/CPE ratio. In contrast, the lowest water productivity, at 1.04 kg per cubic meter, was observed in zero tillage with 6 cm irrigation at a 1.2 IW/CPE ratio.

Water productivity was significantly influenced by different treatment combinations, as presented in table 5a. The highest water productivity was observed under the treatment combination that involved the conventional tillage method of crop establishment with 5 cm of irrigation at a 1.0 IW/CPE ratio. This higher water productivity can be attributed to the greater yield achieved when employing conventional tillage with 5 cm of irrigation at a 1.0 IW/CPE ratio.

On the other hand, a decline in water productivity was noted under the treatment combinations involving zero tillage and furrow irrigated raised bed methods of crop establishment, particularly when combined with 6 cm of irrigation at a 1.2 IW/CPE ratio. This decline can be explained by the fact that grain yield did not increase proportionately to the amount of water applied under this specific treatment combination.

Conclusion

It is inferred that conventional tillage of crop establishment method of wheat sowing and scheduling irrigation at 1.0 IW/CPE ratio produced maximum yield (34.57 q ha^{-1}) could be suggested for cultivation of wheat. The highest water productivity was observed under the same treatment combination.

References

1. Ahmed MDM. Growth, water and NPK utilization efficiency of wheat (*T. aestivum* L.) as affected by tillage, moisture regime and nitrogen fertilization after wet land rice in warm region. Munoz, Nueva Eciza (Philippines); c1992 .p. 250.
2. Anonymous. Economic Survey of Assam. 2021-22; Directorate of Economics and Statistics, Government of Assam, Guwahati.
3. Bandyopadhyay PK. Effect of irrigation schedule on evapo-transpiration and water use efficiency of winter wheat (*Triticum aestivum* L.). Indian J Agron. 1997;42:90-3.
4. Chavan DA, Pawar KR. Dry matter accumulation pattern of wheat as influenced by irrigation levels based on pan-evaporation. J Maharashtra Agr Univ. 1988;13:180-2.
5. Chhina GS. Studies on nitrogen management for no-tillage and strip-tillage system on wheat following rice. Ph.D. Thesis, Dept of Agronomy, PAU, Ludhiana; 2000.
6. Dubey YP, Sharma SK. Effect of irrigation & fertilizer on growth, yield and nutrient uptake by wheat (*Triticum aestivum* L.). Indian J Agron. 1996;41:48-51.
7. Erenstein O, Laxmi V. Zero tillage impacts in India's rice-wheat systems: A review. Soil Tillage Res. 2008;100(1-2):1-14.
8. Gangwar KS, Singh KK, Sharma SK. Effect of tillage on growth, yield and nutrient uptake in wheat after rice in the Indo-Gangetic Plains of India. J Agric Sci. 2004;142(7):453-9.
9. Hobbs PR, Gupta RK. Resource-conservation technologies for wheat in the rice-wheat system. In: Ladha JK, et al., editors; c2003. p. 149-72.
10. Idnani LK, Kumar A. Performance of wheat (*Triticum aestivum*) under different irrigation schedules and sowing methods. Indian J Agric Sci. 2013;83(1):37-40.
11. Karunakaran V, Behera UK. Effect of tillage, residue management and crop establishment techniques on energetics, water use efficiency and economics in soybean (Glycine max)–wheat (*Triticum aestivum*) cropping system. Indian J Agron. 2013;58(1):42-7.
12. Kramer PJ. Plant and soil water relationship: A modern synthesis. 8th ed. New Delhi: Tata McGraw-Hill Publishing Company Ltd; 1969. 482 p.
13. Pal S, Kumar S, Kumar P, Singh A, Gangwar HK. Effect of moisture regime on IW/CPE ratio on soil properties, yield and water use efficiency of wheat crop (*Triticum aestivum* L.). Int J Current Microbiol Appl Sci. 2020;9(3):2499-506.
14. Rathore AL, Patel SL. Studies on nitrogen and irrigation requirement of late sown wheat. Indian J Agron. 1991;36:184-7.
15. Roy K, Subrato, Pradhan AC. Response of late sown wheat to irrigation and nitrogen. Crop Res. 1994;7(2):221-5.
16. Saren BK, Day S, Mandel D. Effect of irrigation and sulphur on yield attributes, productivity and consumptive use efficiency of wheat (*Triticum aestivum* L.). Indian J Agric Sci. 2004;74:257-61.
17. Sharma JC, Acharya CL. Response of wheat (*Triticum aestivum* L.) grown on an acidic alfisol to nitrogen and tillage. Indian J Agron. 1997;42(4):622-5.
18. Shekhar C, Singh D, Singh AK, Nepalia V, Choudhary J. Weed dynamics, productivity and soil health under different tillage and weed control practices in wheat (*Triticum aestivum*) maize (*Zea mays*) cropping sequence. Indian J Agron. 2014;59(4):561-7.
19. Srivastava RK, Dinesh S, Rajesh S, Sah D, Singh R. Studies

on various modes of tillage operations, seeding rates and fertility levels on yield of wheat var. HUW-234 under puddled rice-wheat sequence. Res Crops. 2002;3:332-4.
20. Tripathi RS, Raju R, Thimmappa K. Impact of zero tillage on economics of wheat production in Haryana. Agric Econ Res Rev. 2013;26(1):101-8.
21. Wiatrak PJ, Wright DL, Marois JJ. Tillage and residual nitrogen impact on wheat forage. Agron J. 2004;96(6):1761-4.
22. Yonglu T, Gang H, Tao Y, Lixum Y. High yielding techniques for wheat under the rice-wheat cropping system in the Sichuan province of China. In: Soil and crop management practices for enhanced productivity of the rice-wheat cropping system in the Sichuan province of China. RWC paper series 9. New Delhi; c2000. p. 11-23.