

EFFECT OF CROP ESTABLISHMENT METHOD AND IRRIGATION SCHEDULES ON PRODUCTIVITY AND WATER USE OF WHEAT

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Abstract: A field experiment was conducted during 2014-15 and 2015-16 at Meerut, Uttar Pradesh. The grain yield (46.52; 47.63 and 44.01 and 44.88 q ha⁻¹), straw (60.57; 61.55 and 59.94; 102.75 q ha⁻¹) biological yield (107.09; 109.40 and 102.75; 104.82 q ha⁻¹) was and harvest index (43.39; 43.49 and 42.53; 42.77) significantly higher in B₉₀₋₄ and 4 cm irrigation at IW/CPE 0.8 during both the year. Physiological traits, yield attributes and yields were significantly influenced by land configuration and wheat irrigation schedules. In land configuration systems, B₉₀₋₄ and 4 cm irrigation at IW/CPE 1.2 displayed significantly higher water use efficiency (2.53; 2.51 and 2.19; 2.18 kg m⁻³) compared with other treatments. However irrigation schedules × land configuration interaction was significant for yield attributes grain, straw and biological yield except 1000 grain weight.

Keywords: Land configuration, Irrigation schedules IW/CPE, Water use efficiency

INTRODUCTION

Wheat a major cereal crop is being cultivated in the country. The main reasons for its productivity are poor crop establishment and improper scheduling of irrigation. Amongst the other agronomic practices proper crop establishment method may considerably increase the production of wheat up to some extent. Ideal planting geometry is important for better and efficient utilization of plant growth resources get the optimum productivity of wheat. It is also well known fact that water management is one of the major factors responsible for achieving better harvest in crop production. Both crop establishment method and irrigation schedule are major causes of yield reduction in wheat, which also affect its water use efficiency. Farmers are always interested in getting higher yield which could not be possible without better crop management, good stand establishment and optimum utilization of resources. Crop production is influenced by its establishment and plant vigor representing the key factors towards crop development (Amanullah *et al.*, 2009).

To increase the water productivity of wheat, CYMMIT introduced a planting pattern termed as furrow irrigated raised bed planting system in Mexico. The adoption of the system rose from 6% of farmers in 1981 to 75% in 1994 in high-yielding irrigated wheat-growing areas of northwestern Mexico (Sayre and Hobbs 2004). In this system, the crop is planted on the top of beds and irrigation water is applied in furrows. The width of the bed and furrows commonly used are 40–45 and 25–30 cm, respectively, and the bed height is 15 cm– 20 cm. Inspired by the success of irrigated maize–wheat on permanent raised beds in Mexico, furrow irrigated raised bed planting system was introduced in Indo-

Gangetic Plains in the mid-1990s for wheat (Sayre and Hobbs 2004). Even after 2 decades of its introduction and promotion, a few farmers preferred bed planting over the conventional flat planting system. This was mainly due to lack of yield advantage in furrow irrigated raised bed planting system over flat planting system. Farmers can easily respond to this technology if efforts are diverted to demonstrate yield differences between flat and bed planting systems either by modifying bed configuration or crop rows planted on the top of the bed or selection of suitable cultivars. Keeping in view the above points, a study was conducted to compare crop establishment method especially in different bed size configurations and rows planted on the top of the bed with flat planting in wheat. Different crop establishment methods were assessed for wheat productivity and water saving.

MATERIAL AND METHOD

Experimental site

The field experiment was established in 2014 at SardarVallabhbhai Patel University of Agriculture & Technology, Meerut research farm (29° 04' N latitude and 77° 42' E longitude a height of 237m above mean sea level) U.P., India. The region has a semi-arid sub-tropical climate with an average annual temperature of 16.8°C. The highest mean monthly temperature (38.9°C) is recorded in May, and the lowest mean monthly temperature (4.5°C) is recorded in January. The average annual rainfall is about 665 to 726 mm (constituting 44% of pan evaporation) of which about 80% is received during the monsoon period. The predominant soil at the experimental site is classified as TypicUstochrept. Soil samples for 0–20 cm depth at the site were collected and tested prior to applying treatments and

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the basic properties were non-saline (EC 0.42 dS m⁻¹) but mild alkaline in reaction (pH 7.98). The soil initially had 4.1 g kg⁻¹ of SOC and 1.29 g kg⁻¹ of total N (TN), 1.23 g kg⁻¹ of total phosphorus, 17.63 g kg⁻¹ of total potassium, 224 mg kg⁻¹ of available N, 4.0 mg kg⁻¹ of available phosphorus, and 97 mg kg⁻¹ of available potassium.

Experimental design and management

A detailed description of crop establishment methods are necessary to compare the influence of land configuration practices on environmental performance (Derpsch et al., 2014). Six crop establishment methods B₁- 75 cm bed, 2 rows (B₇₅₋₂); B₂- 75 cm bed, 3 rows (B₇₅₋₃); B₃- 90 cm bed, 2 rows (B₉₀₋₂); B₄- 90 cm bed, 3 rows (B₉₀₋₃); B₅- 90 cm bed, 4 rows (B₉₀₋₄); B₆- Flat planting, rows 22.5 cm apart in main plots and three irrigation schedule practices were I₁-4 cm irrigation at IW/CPE 0.8; I₂- 5 cm irrigation at IW/CPE 1.0; I₃- 6 cm irrigation at IW/CPE 1.2. Allotted to sub-plots in a split-plot design and replicated thrice. The gross and net plot sizes were 7.0 m × 24.5 m and 6.0 m × 3.5 m, respectively and treatments were superimposed in the same plot every year to study the cumulative effect of treatments.

Preparation of furrow irrigated raised beds

At the beginning of the experiment soil was tilled by harrowing and plowings followed by one field leveling with a wooden plank, and raised beds were made using a tractor-drawn multi crop zero till cum raised bed planter with inclined plate seed metering devices. The dimension of the raised beds were 45 and 60 cm wide (top of the bed) × 18 cm height × 30 cm furrow width (at top) and the spacing from center of the furrow to another center of the furrow was kept at 75 and 90 cm. In furrow irrigated raised bed planting system, the crop was planted on the top of beds in bed configurations of 45 cm bed and 60 cm bed.

Preparation of Conventional tillage

After the rice harvest, following the conventional practice of two harrowing, two ploughing (using a cultivator) and one planking (using a wooden plank) that followed pre-sowing irrigation and wheat was seeded in flat planting, a uniform row-to-row distance of 22.5 cm was maintained. Using a seed drill with a dry-fertilizer attachment.

Nutrient application

Plant nutrients were applied as per the state recommendations for wheat (N₁₂₀+ P₆₀ + K₄₀). Urea, di-ammonium phosphate and muriate of potash, were placed in band in seed rows at the time of sowing using zero till cum raised beds planter with inclined plate metering device. The remaining N was broadcasted with dry urea in two equal splits of 30

kg N ha⁻¹, (N₃₀) at crown root initiation (CRI) and the flag leaf initiation (FLI) crop growth stages.

Sowing techniques

Wheat cultivar DBW-17 was shown on November 2015 and 2016 using 80 kg ha⁻¹ for raised beds and 100 kg seed ha⁻¹ for flat planting was done using zero till cum raised beds planter with inclined plate metering device.

Weed management

The crop was maintained with weed free using following practices. Weeds were controlled by spraying of herbicide Sulfosulfuron + Metsulfuron (Total) 35 g a.i. ha⁻¹ and applied uniformly in standing crop to control the weeds at 30-45 DAS. To check the weed growth, one inter culture operation was done during 2014-15 and 2015-16 eight weeks after sowing with the help of manual weeding.

Irrigation scheduling

Measured quantity of irrigation water was applied to the plots as per the irrigation schedule. For measuring irrigation water, volume method was used. Irrigations were scheduled on IW: CPE ratio in individual treatments. The source of irrigation water was Tube well with good quality water for irrigation.

Water application and measurements

Irrigation water was applied using polyvinyl chloride pipes of 15-cm diameter and the amount of water applied to each plot was measured using a water meter (Dasmesh Co., India). The quantity of water applied and the depth of irrigation was computed using the following equations:

$$\text{Quantity of water applied (L)} = F \times t \quad \dots(1)$$

$$\text{Depth of water applied (cm)} = L / A / 1000 \quad \dots(2)$$

Where F is flow rate (L/s), t is time (s) taken during each irrigation and A is area of the plot (m²). Rainfall data was recorded using a rain gauge installed within the meteorological station. The total amount of water (input water) applied was computed as the sum of water received through irrigation (I) and rainfall (R). Water productivity (WP_{I+R}) (kg/m³) was computed as follows (Humphreys et al, 2008)

$$WP_{I+R} = \text{Grain yield} / (\text{Irrigation water applied (I)} + \text{Rainfall received by the crop (R)}) \quad \dots(3)$$

Water use studies

Soil moisture content was measured at seeding, and before and after each irrigation on the top of the ridge and furrow in furrow irrigated raised bed planting system and between the 2 rows in flat planting by using neutron moisture meter. Water saving (WS) was calculated as:

$$WS = (Q_F - Q_B) / Q_F \times 100,$$

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

RESULT AND DISCUSSION

Yield attributes

Data on various yields attributing characters viz. spike length, number of spikelet's spike⁻¹, number of grains spike⁻¹, and test weight, as influenced by land configuration and different irrigation schedules are presented in (Table 1) revealed that B₇₅₋₂ land configuration significantly higher spike length over other treatments. The number of spikelet's spike⁻¹, number of grains spike⁻¹, and test weight higher with B₉₀₋₂ as compare to remaining treatments during the year of study. The number of grains pike⁻¹ was higher in 90 cm than 75 cm beds and flat planting. The irrigation scheduling 4 cm irrigation at IW/CPE 0.8 recorded significantly values for all the above yield attributes as compare to other irrigation schedules. Stimulated

vegetative growth of wheat on account of adequate and prolonged supply of water in treatment manifested itself in increased spike length, number of spikelet's spike⁻¹, number of grains spike⁻¹, and test weight(Jat and singh 2003; Maurya and singh 2008;).

Interaction effects between irrigation schedules and land configuration in relation to spike length, number of spikelet's spike⁻¹, number of grains spike⁻¹, and test weight were significant (Table 1). The magnitude of increase in spike length due to improvement in moisture supply by irrigation with furrow irrigated raised beds was observed under IW/CPE 0.8 (I₁) irrigation schedules with B₉₀₋₂ land configuration as compared to other treatments combination during 2014-15 and 2015-16, respectively.

Table 1. Effect of land configuration and irrigation schedules on yield attributes

Treatment	Spike length (cm)		No. of Spikelet's spike ⁻¹		No. of grains spike ⁻¹		Test weight (g)	
	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16
Land configuration								
75 cm bed, 2 rows	12.3	12.5	20.8	22.1	54.7	56.8	43.46	43.80
75 cm bed, 3 rows	11.3	11.5	19.3	20.3	51.0	53.0	41.40	41.67
90 cm bed, 2 rows	12.1	12.3	24.2	25.2	55.9	58.6	44.15	44.67
90 cm bed, 3 rows	11.0	11.3	23.9	25.2	55.4	57.8	44.01	44.41
90 cm bed, 4 rows	11.0	11.2	21.3	22.3	52.8	54.4	43.51	43.87
Flat planting	10.1	10.3	18.8	19.8	50.0	52.3	42.74	42.95
<i>SEm(±)</i>	0.06	0.07	0.32	0.20	0.35	0.45	0.14	0.15
<i>C.D. (P=0.05)</i>	0.18	0.22	1.00	0.63	1.11	1.41	0.45	0.46
Irrigation schedules								
4 cm irrigation at IW/CPE 0.8	12.1	12.2	22.7	24.1	55.0	57.7	44.17	44.58
5 cm irrigation at IW/CPE 1.0	11.4	11.9	21.6	22.6	53.0	55.4	43.72	43.23
6 cm irrigation at IW/CPE 1.2	10.5	10.4	19.4	20.4	46.8	47.9	40.75	40.87
<i>SEm(±)</i>	0.05	0.05	0.12	0.11	0.20	0.20	0.10	0.12
<i>C.D. (P=0.05)</i>	0.14	0.14	0.36	0.32	0.57	0.58	0.29	0.34
Interaction I × B	Sig	Sig	Sig	Sig	Sig	Sig	NS	NS

Yield

The grain (46.52, 47.63 q ha⁻¹), straw (60.57, 61.55 q ha⁻¹), biological (107, 109.40 q ha⁻¹) yields and harvest index (43.39 and 43.49) significantly higher (Table 2) were recorded with B₉₀₋₄ land configuration the as compared to all other treatments during experimentation. The grain yield increased 11.00 and 12.02 %, straw yield 7.0 and 7.3% with B₉₀₋₄land configuration over flat planting during first and second year, respectively. Treatments B₇₅₋₄ (B₂) and flat planting (B₆) were at par with each other during both the year of study. However, B₉₀₋₂ (B₃) was recorded the lowest grain yield during both the year of study.

Higher grain yield with bed planting of wheat has been also reported by (Bhahmaet *al.* 2007; Kumar 2010; Thindet *al.* 2010).

The results have clearly shown that the grain yield in land configurations B₇₅₋₂, B₇₅₋₃, B₉₀₋₂ and B₉₀₋₃ was lower than that in flat planting due to low plant density, but the yield was higher in B₉₀₋₄ (B₅) than flat planting. The irrigation schedules having good tillering and higher rates of photosynthesis, had high biomass production and therefore was more suited for furrow irrigated raised bed planting system than flat planting.

Among the irrigation schedules IW/CPE 0.8 (I₁) and IW/CPE 1.0 (I₂) produced higher number of spikes

and biological yield than IW/CPE 1.2 (I₃). The significantly higher grain, straw, biological yields and harvest index was obtained in IW/CPE 0.8 (I₁) irrigation schedules and increased the grain yield 17.27 and 17.02 % over IW/CPE1.2 (I₃). Interaction effects between irrigation schedules and land configuration in relation to grain yield, straw yield and biological yield were significant (Table 2).

The magnitude of increase in spike length due to improvement in moisture supply by irrigation with furrow irrigated raised beds was observed under IW/CPE 0.8 (I₁) irrigation schedules with B₉₀₋₂ land configuration as compared to other treatments combination during 2014-15 and 2015-16, respectively.

Table 2. Effect of land configuration and irrigation schedules on grain, straw, biological yield and harvest index

Treatment	Grain yield (q ha ⁻¹)		Straw yield (q ha ⁻¹)		Biological yield (q ha ⁻¹)		Harvest index (%)	
	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16
75 cm bed, 2 rows	39.33	40.18	55.33	56.42	39.33	40.18	55.33	56.42
75 cm bed, 3 rows	40.28	41.39	56.47	57.20	40.28	41.39	56.47	57.20
90 cm bed, 2 rows	37.80	38.57	54.63	55.36	37.80	38.57	54.63	55.36
90 cm bed, 3 rows	43.06	44.12	57.79	58.33	43.06	44.12	57.79	58.33
90 cm bed, 4 rows	46.52	47.63	60.57	61.55	46.52	47.63	60.57	61.55
Flat planting	41.92	42.52	56.59	57.35	41.92	42.52	56.59	57.35
<i>SEm</i> (±)	0.57	0.54	0.74	0.80	0.57	0.54	0.74	0.80
<i>C.D. (P=0.05)</i>	1.79	1.70	2.34	2.50	1.79	1.70	2.34	2.50
Irrigation Schedules								
4 cm irrigation at IW/CPE 0.8	44.01	44.88	59.00	59.94	44.01	44.88	59.00	59.94
5 cm irrigation at IW/CPE 1.0	42.92	43.97	58.56	59.47	42.92	43.97	58.56	59.47
6 cm irrigation at IW/CPE 1.2	37.53	38.35	53.14	53.82	37.53	38.35	53.14	53.82
<i>SEm</i> (±)	0.18	0.18	0.28	0.29	0.18	0.18	0.28	0.29
<i>C.D. (P=0.05)</i>	0.51	0.53	0.83	0.86	0.51	0.53	0.83	0.86
Interaction I × B	Sig	Sig	Sig	Sig	Sig	Sig	NS	NS

Consumptive use

The consumptive use of water (23.0 and 23.8 cm) was more under flat method (Table 3) followed by the B₇₅₋₂, B₇₅₋₃, B₉₀₋₂, B₉₀₋₃ and lowest value of consumptive use was recorded under B₉₀₋₄ land configuration during both the year of study. The

consumptive use of water directly related with moisture depletion and it was higher under flat method and lowest under bed B₉₀₋₄ land configuration. During 2015-16 total consumptive use of water was more than 2014-15.

Treatment	Consumptive Use (cm)		Water use efficiency (kg m ⁻³)	
	2014-15	2015-16	2014-15	2015-16
Land configuration				
75 cm bed, 2 rows	22.2	22.8	1.77	1.76
75 cm bed, 3 rows	21.6	22.1	1.86	1.87
90 cm bed, 2 rows	19.3	20.0	1.96	1.93
90 cm bed, 3 rows	19.2	19.7	2.24	2.24
90 cm bed, 4 rows	18.4	19.0	2.53	2.51
Flat planting	23.0	23.6	1.82	1.80
Irrigation schedules				
4 cm irrigation at IW/CPE 0.8	23.2	23.8	1.90	1.88
5 cm irrigation at IW/CPE 1.0	21.5	22.1	1.99	1.99
6 cm irrigation at IW/CPE 1.2	17.2	17.6	2.19	2.18

The consumptive use of water directly related with moisture depletion and it was higher under flat method and lowest under B₉₀₋₄ (B₅) land

configuration. So, consumptive use of water was also in the order of moisture depletion. During first year total consumptive use of water was more than the

second year mainly due to the differences in weather conditions, such as hot and dry wind and lesser number of rainy day.

Table 3. Effect of land configuration and irrigation schedules on consumptive use and water-use efficiency

Consumptive use by the crop includes total soil moisture depletion (cm) and soil moisture contributes Irrigation schedule of 4 cm irrigation IW: CPE 0.8. In contrast, the lowest consumptive use of water (17.2 and 17.6 cm) was under the irrigation schedule of IW: CPE 1.2 due to combination of higher surface evaporation and more transpiration so that moisture stresses condition occurs (Ahamad 2002; Maurya and singh 2008).

The consumptive use of water showed an increasing trend with increase in irrigation water during both the years. The highest consumptive use was recorded with irrigation schedule of IW: CPE 0.8 (I₁). This was mainly due to fact that the greater loss of applied water through evapotranspiration because of more availability of water resulted into better foliage and ultimately better plant growth. As a result of this was greater absorption of moisture by crop favored by highest water use at wettest regime. In contrast, the lowest consumptive use of water (17.6 and 17.2 cm) was under the irrigation schedule of IW: CPE 1.2 (I₃) due to combination of lower surface evaporation and reduced transpiration under less moisture availability.

Water-use efficiency

It is evident from the data (Table 3) that highest water use efficiency was recorded (2.53 and 2.51 kg m⁻³) under B₉₀₋₄ (B₅) land configuration over flat planting method (B₆) during both the year of study. Treatment B₉₀₋₄ (B₅) increased 39.01 and 39.44% over flat method during 2014-15 and 2015-16, respectively. This might be due to higher grain yield obtained under B₉₀₋₄(B₅) land configuration with lesser amount

of water used. Declined water-use efficiency (WUE) under flat method with IW: CPE 0.8 (I₁) might be due to fact that grain yield did not increase proportionately to that of consumptive use under this treatment.

An examination of data (Table 3) clearly indicates that water-use efficiency decreased with increase in levels of irrigation during both the years. Maximum value of WUE, 2.19 and 2.18 kg m⁻³, were noted in IW: CPE 1.2 (I₃) during first and second years respectively. It increased 15.2 and 16.0% over IW: CPE 0.8 (I₁) during first and second year, respectively. However minimum water-use efficiency was under IW: CPE 0.8 (I₁) during both the years. Decrease in WUE with IW: CPE 0.8 (I₁) based on the fact that the proportionate increase in grain yield was less than increase in the consumptive use of water.

Water productivity

The maximum water productivity was registered (2.45 and 2.98 kg m⁻³) under B₉₀₋₄ land configuration, followed by B₉₀₋₃ flat, B₇₅₋₃>B₇₅₋₂>B₉₀₋₂, treatments during both the years.

Higher water productivity (2.21 kg m⁻³) was affected by irrigation schedule of IW: CPE 1.2 (I₃) during 2014-15, but during 2015-16 higher water productivity (2.93 kg m⁻³) was observed under IW/CPE 1.0 (I₂). Increase in water productivity (Table 4) with IW: CPE 1.2 (I₃) based on the fact that the proportionate increase in grain yield with lesser number of irrigations during experimentation (Kumar 2010; Singh et al., 2015).

In general, water productivity affected by irrigation schedules the higher water productivity observed with IW: CPE 0.8 (I₁) during both the year of study. However minimum water productivity was observed in IW: CPE 1.2 (I₃). Decrease in water productivity with IW: CPE 1.2 (I₃),

Table 4. Effect of land configuration and irrigation schedules on water productivity Total water used by the crop includes applied irrigation and effective rainfall

Treatment	Total water applied (cm)		Water Productivity (kg/m ³)	
	2014-15	2015-16	2014-15	2015-16
Land configuration				
75 cm bed, 2 rows	19	16	2.07	2.51
75 cm bed, 3 rows	19	16	2.12	2.59
90 cm bed, 2 rows	19	16	1.99	2.41
90 cm bed, 3 rows	19	16	2.27	2.76
90 cm bed, 4 rows	19	16	2.45	2.98
Flat planting	19	16	2.21	2.66
Irrigation scheduling				
4 cm irrigation at IW/CPE 0.8	21	16	2.10	2.81
5 cm irrigation at IW/CPE 1.0	20	15	2.15	2.93
6 cm irrigation at IW/CPE 1.2	17	18	2.21	2.13

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