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Full Research Article

Productivity, Profitability and Nutrient Uptake as Influenced by Tillage Practices and Irrigation Scheduling in Wheat (*Triticum aestivum* L.) under Subtropical Climatic Conditions

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Abstract

To evaluate the effect of different tillage practices and irrigation scheduling in wheat on a sandy loam, a field experiment was conducted at Crop Research Centre of Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut (U.P.) during Rabi season of 2013–14 and 2014–15. Five tillage crop establishment methods, viz. T_1–wide raised beds, T_2–narrow raised beds, T_3–conventional tillage, T_4–reduced tillage, T_5–zero tillage were kept in main plots and three irrigation scheduling practices, viz. I_1–IW/CPE 0.45, I_2-IW/CPE 0.60, I_3-IW/CPE 0.75 were allotted to sub-plots in a split-plot design and replicated thrice. The result showed that number of grain spike^{-1}, test weight, spike length and number of spikelet's spike^{-1} were significantly higher with wheat sown on wide raised beds than all other tillage practices except narrow raised beds and zero tillage plots. Similarly furrow irrigated raised beds increased the mean grain yield of wheat significantly over rest of the plots and grain yield increased by and 18.3% over I_1 and 8.6% over I_2 in I_3 irrigation schedule. Higher nutrient uptake (NPK) by grain and straw as well as total uptake were recorded under wide raised beds followed by zero tillage and narrow raised beds. The maximum gross income, net income, benefit: cost ratio was significantly higher in wide raised beds plots. Similarly the highest mean net profit (₹ 63616.6 ha^{-1}) with mean B:C ratio of 2.14 was recorded with the application of three irrigations at 22, 65 and 105 DAS in wheat crop.

1. Introduction

Wheat (*Triticum aestivum* L.) is the second most important cereal crop of India next to rice and accounts for 31.5% of the total food grain basket of the country and 40% human population across globe. India produce 95.60 mt wheat with productivity 31.23 from 30.61 mha during 2013–14 (Ministry of Agriculture, 2013). The global population is growing continuously and it needs about 60% more food to feed the 9.5 billion people projected for 2050 (Singh, 2014a). The provision of irrigation is very important for achieving food security (Singh, 2012b) and it will remain vital as its share in world food production will rise to over 45% by 2030 (Faures et al., 2007) from the current level of 40%. However, without proper planning and management, the intensification of irrigated agriculture can result in biodiversity degradation and other ecological problems in agro-ecosystems (Singh, 2015a). For example, more than 33% of the World's irrigated land is affected by water logging and/or secondary salinization (Gupta and Kaushal, 1987) and these conditions pose threats to food security and environmental conservation (Singh, 2015b).

Soil tillage is among the important factors affecting soil properties and crop yield. Among the crop production factors, tillage contributes up to 20% [Khurshid et al., 2006] and affects the sustainable use of soil resources through its influence on soil properties (Lal and Stewart, 2013). Reducing tillage positively influences several aspects of the soil whereas excessive and unnecessary tillage operations give rise to opposite phenomena that are harmful to soil. Therefore, currently there is a significant interest and emphasis on the shift from extreme tillage to conservation and no-tillage methods for the purpose of controlling erosion process [Iqbal et al., 2005]. Alternative methods have been proven effective to sustain soil health and reduce water demand in the wheat crop in different agro ecological regions by many scientists. But the application of these new tillage and crop establishment methods needs to be tested on a wider scale for water, labor, and energy efficiency (Naresh et al., 2011). We believe that increased emphasis should be given to integrated approaches for agricultural development. There is a need to develop technologies and management practices that can simultaneously enhance production, preserve the natural resource base, and reduce poverty. In the open system of today, it is necessary to reduce the cost of production and to increase the productivity of wheat in order to compete in the international market. Moreover, in the recent years, it has been found that the conservation agriculture is feasible in India in which rows of wheat are planted on the top of the beds and irrigation is done through furrows, the system is better known as Furrow Irrigated Raised Bed (FIRB) planting system. This system permits reduction in cost of inputs i.e. seed, fertilizer and irrigation without reduction in wheat yields (Chauhan et al., 2001).

The improvements in irrigation efficiencies are possible both at the project level (storage and conveyance efficiencies) and the field application level (by using improved irrigation methods and proper irrigation scheduling). Most of the area in the country is irrigated by surface application methods such as check basin, border strip and furrow irrigation. The selection of a particular method depends upon the topography, soil type, crop, stream size, economics and management aspects. Proper scheduling of irrigation (amount and timing) to crops is an important component of water saving technologies. There are numerous ways to schedule irrigations and estimate the required depth of water application [Prihar et al., 1997] suggested a simple approach based on meteorological

parameters to schedule irrigation to crops based on the ratio between fixed depth (75 mm) of irrigation water (IW) and net cumulative pan evaporation since previous irrigation (PAN-E minus rainfall). Irrigating wheat using this approach (IW/PAN-E =0.9) saves 2 irrigation compared to 5–6 irrigations at fixed growth stages without any yield loss (Prihar and Sandhu, 1987). All irrigation scheduling methods consist of monitoring indicators that determine the need for irrigation. Therefore, it is essential to improve irrigation water productivity and decrease irrigation demand while maintaining the crop productivity. [Li et al., 2010] reported that wheat receiving four irrigations at CRI, maximum tillering, boot stage and milk stage resulted in 13.7 and 29.0% higher grain yield over two (at CRI and boot stages) and three irrigations (at CRI, boot and milk stages), respectively. Irrigations are recommended at times corresponding to the specific growth stages (crown root initiation, early tillering, late jointing/boot, and heading/flowering) of the wheat [Maurya et al., 2008; Naresh et al., 2015]. Depending upon the soil type, four to five irrigations are generally required to get optimum grain yield of wheat under normal climatic conditions of North West India. [Naresh et al., 2015] reported that wheat grain yield increased in a step-wise manner as additional irrigation was applied but the highest protein content was achieved only with the fewest number of irrigations. Being the prime natural resource for assured crop production, water has to be used judiciously and in scientific manner. To increase availability of irrigation water there is need to quantify the irrigation water by using improved irrigation method and proper scheduling of irrigation to obtain more yield and economic returns. The objective of this research was to evaluate the effects of irrigation schedules on wheat productivity, economics and nutrient uptake under tillage alternatives.

2. Materials and Methods

The field experiments were carried out at the Crop Research Centre of Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut (U.P.) located at 29°04′ N latitude and 77°42′ E longitude at an altitude of 237 m amsl during *rabi* 2013–14 and 2014–15 at a same site in both the years. The region is characterized by a subtropical and semi-arid climate with a hot dry summer (March–June), wet monsoon season (late June–mid September) and a cool, dry winter (Oct.–Feb.). Average annual rainfall is 726 mm (constituting 44% of pan evaporation) of which about 80% is received during the monsoon. The soil of experimental field was sandy loam in texture consisting of 642 g kg^{-1} sand, 185 g kg^{-1} silt and 173 g kg^{-1} clay. According to FAO classification, soil was deep alluvial fine sandy mix developed under a hypothermic regime (Typic Ustochrept). The soil samples taken from 0 to 15 cm depth were analyzed and the pH of the soil was 8.0, organic carbon 4 g kg^{-1}, olsen P 14.1 mg^{-1} and available K 90.6 mg kg^{-1} of soil. The treatments consists of five tillage crop establishment methods (T_1–wide raised beds, T_2–narrow raised beds, T_3–conventional tillage, T_4–reduced tillage, T_5–zero tillage) in main plot and three irrigation scheduling treatments (I_1–IW/CPE 0.45, I_2–IW/CPE 0.60, I_3–IW/CPE 0.75) in sub plots. The study was made in split plot design with three replications. Half dose of N and full dose of P and K through urea, single super phosphate and muriatic of potash, respectively, were applied at sowing and remaining half N was applied at first irrigation. Wheat was sown on 15th November and 22nd November 2013 and 2014 and harvested on 15th April and 20th April, in 2014 and 2015, respectively. Other management practices were adopted as per recommendations of the crop under irrigated conditions. Growth parameters and yield attributes were recorded at harvest stage. The yield was estimated by the produce obtained from net plot area, treatment wise and finally expressed at 14% moisture. The nutrient uptake by the crops was obtained as product of nutrient concentration and yield. Two years data was statistically analyzed.

3. Results and Discussion

3.1. Yield attributes and yield

Yield attributes of wheat, viz. spike length (cm), number of spikelet's spike^{-1}, number of grains spike^{-1} and test weight were significantly influenced by tillage practices and irrigation scheduling (Table 1). Number of spikelet's spike^{-1} was significantly higher in T_1 followed by T_2 and T_5, whereas, number of grains spike^{-1} and test weigh grain were significantly higher in furrow irrigated raised beds plots. All the yield attributes in relation to individual spike length (cm) were recorded maximum under wide raised beds followed by zero tillage and minimum with conventional tillage (T_3). Significantly higher mean grain yield (48.58 q ha^{-1}) was recorded with wide raised beds (T_1) plots which was statistically similar to narrow raised beds (T_2) and zero tillage (T_5) in both years, respectively (Table 2). Whereas, higher mean straw yield (62.17 q ha^{-1}) was observed under T_1 which was significantly superior over T_4 (reduced tillage) and T_3 (conventional tillage) during both the years.

Table 1: Yield attributes of wheat as influenced by establishment methods and irrigation scheduling (pooled over 2 year)

Treat-ments	Spike length (cm)	No. of pikelet's spike^{-1}	No. of grains spike^{-1}	Test weight (g)
Tillage practices				
T_1	11.1	21.75	55.3	46.2
T_2	11.9	21.15	53.45	45.95
T_3	8.25	16.9	42.45	23.6
T_4	9.15	18.55	47.15	43.9
T_5	10.6	19.25	49.75	44.95
LSD (p<0.05)	0.52	0.78	2.605	1.19
Irrigation scheduling				
I_1	9.55	18.85	45.5	44.05
I_2	10.15	19.4	49.7	44.8
I_3	10.95	20.25	53.35	45.85
LSD (p<0.05)	0.305	0.48	1.47	1.185

The higher grain yield in FIRB was mainly due to higher number of spikelet's spike^{-1} as compared with zero tillage. Bilalis et al., 2011; Naresh et al. (2012) reported that the yield ha^{-1} was primarily improved due to more moisture supply, less penetration resistance impedance which responsible for better root development and its beneficial effect on the plant yield. The grain yield plant^{-1} improved with increased moisture supply mainly through improvement number of grains spike^{-1}, number of spikelet spike^{-1} and test weight. The significant increase in number of effective tillers, number of grains spike^{-1} and test weight in I_3 over I_1 was observed during both the years. The more number of grains spike^{-1} were because of significant increase in spike length and number of spikelet spike^{-1} with subsequent increase in irrigation from I_1 to I_3 (Table 1).

The grain and straw yield of wheat increased significantly with increase in irrigation level. Higher grain yield with bed planting of wheat has been also reported by Thind et al. (2010); Bhahma et al. (2007). The increase in grain yield of wheat under FIRBS could be attributed to higher yield attributes, the increase in frequency of irrigation increased the plant growth resulted in more grain and straw yield. The longer crop duration in I_3 than lower level of irrigation also help the crop to harvest the radiant energy through the process of photosynthesis for the longer period of time which resulted into higher biomass production. Similar results have been reported by Idnani et al., 2013

3.2. Nutrient uptake

Nutrient uptake (N, P and K) by grain and straw as well as total uptake by the wheat crop were recorded significantly higher with FIRB followed by ZT and CT (Table 3). Total uptake of N, P and K were recorded higher in FIRB as compared to ZT and CT. Among the irrigation management practices, application of IW/CPE 0.75 water regime significantly improved NPK uptake by grain, straw and total uptake by wheat crop as compared to other regimes of irrigation management. This might be due to the initial quick more availability of these nutrients, which encouraged the crop growth and finally higher grain and biomass yield, leading to an overall higher nutrient uptake (Rani et al., 2009; Saharawat et al., 2010).

Table 2: Yield and economics of wheat as influenced by tillage practices and irrigation scheduling (pooled over 2 year)

Treat-ments	Grain yield q ha^{-1}	Straw yield q ha^{-1}	Gross income (₹ ha^{-1})	Net income (₹ ha^{-1})	Ben-efit: Cost ratio
Tillage practices					
T_1	48.575	62.17	92188.0	62603.0	2.12
T_2	46.59	58.03	87866.3	58026.3	1.95
T_3	41.895	51.02	78605.7	48130.7	1.58
T_4	43.675	52.56	83614.5	54264.5	1.86
T_5	44.485	57.97	82894.6	55942.6	2.08
LSD (p<0.05)	2.6	4.57			
Irrigation scheduling					
I_1	40.41	50.52	76272.0	47266.5	1.63
I_2	45.24	56.64	85414.3	56002.3	1.91
I_3	49.48	61.90	93415.1	63616.6	2.14
LSD (p<0.05)	1.54	1.93			

Table 3: Nutrient uptake of grain and straw as influenced by tillage practices and irrigation scheduling (pool over 2 year)

Treatments	N		P		K		Total N uptake	Total P uptake	Total K uptake
	Grain	straw	Grain	straw	Grain	straw			
Tillage practices									
T_1	85.08	31.38	16.82	9.77	22.03	104.53	117.45	26.58	126.56
T_2	81.47	31.31	15.61	9.39	20.68	100.17	112.79	25.00	120.85
T_3	70.51	26.71	12.24	7.22	17.05	92.00	97.22	19.46	109.05
T_4	75.77	29.04	13.49	7.97	18.83	94.17	104.80	21.46	113.00
T_5	75.50	31.06	13.70	8.81	18.95	101.73	106.55	22.51	120.68
LSD (p<0.05)	4.69	1.35	1.02	0.75	1.31	7.58	6.56	1.38	8.21
Irrigation scheduling									
I_1	75.03	27.87	12.95	7.82	18.03	93.96	101.39	19.83	111.99
I_2	77.35	30.00	14.26	8.80	19.46	97.74	107.36	21.38	117.19
I_3	82.32	32.43	15.91	9.27	21.04	103.98	114.54	24.47	125.01
LSD (p<0.05)	3.31	1.29	0.80	0.48	0.90	4.00	4.27	1.07	4.79

3.3. *Economics*

Gross income, net income, benefit: cost ratio was influenced by tillage practices and irrigation scheduling during both the year (Table 2). The maximum gross income (₹ 92180/-), net income (₹ 62603/-) and benefit cost ratio (2.12) were recorded with FIRB (T_1), which was at par with ZT but higher than CT. whereas the minimum net return and benefit: cost ratio were recorded in CT. Higher net return in FIRB and ZT than CTR has been reported by Jat et al. (2009). Among the irrigation practices, the maximum mean gross income (₹ 93415.1 ha^{-1}), net income (₹ 63616.6 ha^{-1}) and benefit: cost ratio (2.14) was recorded with water regime IW/CPE 0.75 followed IW/CPE 0.60 in both the years. This might be due to higher productivity of the wheat crop. These results are in conformity with the findings of Gathala et al., 2011; Jat et al., 2013; Naresh et al., 2015.

4. Conclusion

An improvement in growth attributes, yield attributes and yield of wheat was observed under FIRBS as compared to other method of planting. In case of irrigation schedules, irrigation at IW/CPE 0.75 (three irrigations) gave higher yield as compared to other irrigation schedules in subtropical climatic conditions of northern India i.e. western Uttar Pradesh condition. The same reason could be ascribed to this as well.

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