

Original Research Article

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Performance of Wheat (*Triticum aestivum* L.) under Tillage Practices and Water Regime on Water Productivity and Economics

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ABSTRACT

A field experiment was conducted during 2013-14 and 2014-15 at Crop Research Centre of Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut-250110 (U.P.). The objective of our study was to establish an understanding of how nutrient uptake and wheat yield can be improved and how land configuration and tillage practices can be modified to be more efficient in water use through layering of precision- conservation crop management techniques. The experiment consisting of five tillage practices T₁- Wide raised bed; T₂- Narrow raised bed; T₃- Conventional tillage; T₄- Reduced tillage; T₅- Zero tillage and three treatments viz., I₁ -IW/CPE 0.45; I₂ -IW/CPE 0.60; I₃ - IW/CPE 0.75; was laid out in split plot design with three replications. The maximum net profit among tillage practices Rs 64301.7 and Rs 60904.3 ha⁻¹ with B: C ratio 2.24 and 2.00 were recorded in wide raised beds plots. The wide raised beds plots increased the water use efficiency of 15.12 and 15.78 kg grain ha⁻¹ mm. The per cent increased in water use efficiency under wide raised beds over conventional tillage was 38.67 and 39.23 %. Among water regime highest net profit (Rs 65256.4 and Rs 61976.7 ha⁻¹) with B: C ratio of 2.24 and 2.04 was recorded with the application of three irrigations at 22, 65 and 105 DAS in wheat crop. The wide raised beds plots increased the water use efficiency of 15.12 and 15.78 kg ha⁻³ and water productivity (1.28 and 1.18 kg ha⁻³). The per cent increased in water use efficiency under wide raised beds over conventional tillage was 38.67 and 39.23 % during 2013-14 and 2014-15, respectively.

Keywords

Tillage, Raised bed, IW/CPE, WUE, Water productivity, B: C, Wheat

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Introduction

Wheat (*Triticum aestivum* L. emend. Fiori & Paol.) is very important and remunerative *rabi* crop of North India. It is the second most important cereal crop after rice, grown under diverse agro-climatic conditions on 28 m ha area in India with a production of 84 m tonnes

(Economic Survey, 2010-11). The North West India, which serves as India's food basket, may become food-insecure in the near future. Therefore, there is an urgent need to develop innovative alternative strategies for the future transformation of the irrigated wheat system toward improved practices, ones that (1) are more resource-use-efficient, (2) lead to food

security, and (3) are economically sustainable. Conservation agriculture (CA)-based resource-conserving technologies (RCTs) include many new technologies (more efficient implements; reduced or minimal tillage; soil, water, and crop management practices) that are more efficient, use less inputs, improve production and income, and attempt to overcome emerging problems (Gupta and Sayre, 2007). Alternative methods have been proven effective to sustain soil health and reduce water demand in the wheat crop in on-station trials in different agro-ecological regions by many scientists. But the applications of these new tillage and crop establishment methods need to be tested on a wider scale for water, labour, and energy efficiency on farm managed trials (Naresh *et al.*, 2011). There is a need to develop technologies and management practices that can simultaneously enhance production, preserve the natural resource base, and reduce poverty. In today's so stem, it is necessary to reduce the cost of production and to increase the productivity of wheat in order to compete in the international market. It has been well established that the zero tillage system reduces the cost of cultivation due to single tractor pass (Chauhan *et al.*, 2000). Water is an important input for realizing high wheat productivity; however, it is becoming the most limiting factor for crop production in most of the north western parts of India (Hira, 2009). As water for irrigation is a scarce resource, its optimum use optimization is fundamental to water resource use. It permits better utilization of all other production factors and thus leads to increased yields per unit area and time. Efficient water management requires a thorough study of plant water relationship, climate, agronomic practices and economic assessment. In cultivation of high yielding wheat varieties, irrigation assumes greater importance because during growing season of crop (October to April) weather remains relatively dry. The judicial application of

water calls for immediate attention and this is possible only by following some scientific basis for water application to the crop. Various agronomic practices have been developed to conserve rain or irrigation water. Proper utilization of conserved moisture is an effort towards increasing crop yield per unit amount of water used. Most of these practices increase the duration of moisture availability through an increase in the amount of available moisture in the soil. To increase the duration of moisture availability with the existing available moisture, the losses of it from plants (transpiration) and soil (evaporation) have to be reduced. Proper scheduling of irrigation (amount and timing) crops is an important component of water saving techniques. There are numerous ways to schedule irrigations and estimate the required depth of water application (Campbell and Cambell, 1982; Priharand Khepar, 1997). All irrigation scheduling methods consist of monitoring indicators that determine the need for irrigation (Prihar *et al.*, 1974). Suggested a simple approach based on meteorological parameters to schedule irrigation of 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). Being the prime natural resource for assured crop production, water has to be used judiciously and in a scientific manner.

Materials and Methods

The experiment was conducted at Crop Research Centre (CRC) of the University situated in Indo-Genetic plains of western Uttar Pradesh in Western Plains Zone. It's geographically located at 29° 05' 19" N latitude, 77° 41' 50" E longitudes and at an elevation of 237 metres above the sea level during *rabi*2013-14 and 2014-15 at a same site in both the years. The climate of this region is semi-arid and sub-tropical with extremes hot

weather in summer and cold weather in winter season. There is gradual decrease in mean daily temperature in January reaching as low as 5.6⁰C and further a gradual increase is registered reaching as high as 36.6 ⁰C in months of April. Occasionally, frost does occur during the months of December and January. The maximum temperature was highest in fourth week of April during both the years. Rainfall was occurred 177.0 mm and 203.3 mm during crop period in 2013-14 and 2014-15. The mean weekly weather data for the crop period of 2013-14 and 2014-15. The soil was sandy loam with pH 8.0 and 7.9 (1:2.5 soil to water). The top soil of the experimental site was sandy loam overlying silty clay, with an abrupt change to sandy loam at about 90 cm. Bulk density was 1.51 and 1.56 g/cm³ in the top-soil. Organic carbon 0.50 and 0.51%, available N-242.7 and 244.5 kg ha⁻¹ available P-12.0 and 12.3 kg ha⁻¹ available K 201.3 and 202.2 kg ha⁻¹ at the start of the experiment in 0 to 15 cm soil layer during 2013-14 and 2014-15, respectively. The treatments consists of five tillage practices (T₁, Wide raised beds, T₂, Narrow raised beds, T₃, Conventional tillage, T₄, Reduced tillage, T₅, Zero tillage) and three irrigation schedules (I₁ -IW/CPE 0.45, I₂ - IW/CPE 0.60, I₃ - IW/CPE 0.75). The study was made in split plot design with three replications. In FIRBS, 15 cm high and 45 cm broad bed with a furrow width of 25 cm between the beds was prepared with planting three rows of wheat in rows 15 cm apart (Jat *et al.*, 2005). Half dose of N and full dose of P and K through urea, single super phosphate and muriate of potash, respectively, were applied at sowing and remaining N was applied after first irrigation. Wheat DBW-17 was sown on 15 November and 22 November, in 2013 and 2014 and harvested on 15 April and 20 April, in 2014 and 2015, respectively. Other management practices were adopted as per recommendations of the crop under irrigated conditions. The nutrient uptake by

the crops was obtained as product of nutrient concentration and yield. Two years data was pooled and statistically analyzed. 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, between the 2 rows in flat planting by gravimetric method. 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 will be utilized to calculate the consumptive use.

Results and Discussion

Soil moisture studies

Moisture extraction pattern

The data on soil profile moisture extraction pattern of wheat crop under different irrigation levels and tillage practices treatments is shown in Table 1 (a, b and c). The soil profile was divided in four layers (0-15, 15-30, 30-60 and 60-90 cm) and the maximum amount of water was extracted (absorbed) from 30-60 cm layer followed by 0-15 cm, 15-30 cm, and minimum from 60-90 cm during both the years of study. The moisture extraction from the surface layer (0-15 cm) was increased slightly with increase in irrigation frequency during both the years of study.

Similarly, the moisture extraction was decreased slightly with increase in profile depth and irrigation frequency during both the years. The raised beds/zero till plots consumed more moisture from the deeper profile layer than conventional tillage practice and vice-versa during both the years of study (KINGRA and MAHEY, 2013; SINGH *et al.*, 2015).

Soil moisture content studies

The effect of tillage practices under three water regimes on average profile soil moisture content Table 1 (a, b and c). In general, the profile moisture content was highest at the time of sowing (21%) and it was lowest at the time of crop maturity in all the treatments during both the years of study. The increases in profile moisture content are visible from the peaks under different water regimes were because of application of irrigation as per treatments. The moisture content of conventional tilled plots (T_3) was always lower than furrow irrigated raised beds plots (T_1 & T_2) during both the years of study except in the peaks where the moisture content in the profile was always same due to recharging of profile by application of irrigation. In between the season the lowest soil moisture content in conventional till crop and furrow irrigated raised beds plots was 74 DAS (16.1%) in I_1 , 104 DAS (16.2%) in I_2 and 90 DAS (15%) in I_3 during 2013-14, whereas, the lowest soil profile moisture content during 2014-15 in I_1 was recorded at 97 DAS (17%), in I_2 60 DAS (17.5%) and in I_3 97 DAS (16.9%). The conventional till crop under all the water regimes kept the average profile soil moisture content 1.5 % lower than furrow irrigated raised beds plots throughout the crop season except after recharging the soil profile either by application of irrigation as per treatment or by rainfall.

Seasonal water use

The data on crop seasonal water use under different irrigation and tillage practices crop during 2013-14 and 2014-15 is shown in Table 2. The seasonal water use increase with advancement of crop season in all the treatment during both the years of study. The highest water use was observed in I_3 followed by I_2 and it was lowest in I_1 during both years. Among the tillage practices raised beds/zero till plots treatment the crop consumed

markedly higher water than conventional tillage plots during the crop season. The crop consumed highest amount of water between 90-120 days (9.8 and 8.1 cm) during both the years of study. The lowest amount of water was consumed during first 30 days (3.2 and 3.1 cm) during both the years the water use on per day basis was maximum between 120 and the maturity of the crop. These finding was supported by Saren *et al.*, (2004).

Water use and water use efficiency

The crop water use during 2014-15 was slightly higher than 2013-14 (Table 2). The crop water use increased with increasing irrigation during both the years.

The crop water use increased markedly in conventional till plots (T_3) than raised beds crop plots (T_1) during both the years. The water use efficiency increased with the increased level of irrigation frequency during experimentation. The WUE was remarkably low in conventional till plots crop (T_3) than raised beds crop plots (T_1 and T_2) during both the years of study (Singh and katiyar 2014 and Singh *et al.*, 2015).

Water productivity

The average water productivity (Table 3) was higher in the bed planting T_1 (1.28 and 1.18 kg ha⁻³) followed by conventional (0.92 and 0.86 kg ha⁻³) and zero tillage (1.02 and 0.94 kg ha⁻³) might be due to the less consumptive use of water resulted in higher) reported higher in bed planting as compared to conventional planting with I_3 . The maximum water productivity was observed where irrigation was applied at (I_3) IW: CPE ratio of 0.75 (0.91 and 0.83 kg kg ha⁻³) than (I_2) IW: CPE ratio of 0.60 (1.01 and 0.92 kg kg ha⁻³) and (I_1) 0.45 IW: CPE ratio (0.91 and 0.83 kg kg ha⁻³) could be due to the prolonged availability of soil water content resulted in higher grain yield.

Table.1 (a) The moisture depletion pattern of I₁ different soil layers as influenced by tillage practices and water regime

Treatment	I ₁ 0.45 IW/CPE(water regime)									
	0-15 cm		15-30 cm		30-60 cm		60-90 cm		Total moisture depletion (cm)	
	2013-14	2014-15	2013-14	2014-5	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15
Tillage practices										
T ₁	2.52	2.56	4.20	4.22	3.58	3.55	6.54	6.55	16.84	16.88
T ₂	3.17	3.15	4.80	4.81	4.66	4.64	7.20	7.22	19.83	19.82
T ₃	3.78	3.80	7.35	7.33	5.26	5.25	7.73	7.73	24.12	24.11
T ₄	3.76	3.76	7.09	7.10	4.97	4.92	6.92	6.90	22.74	22.68
T ₅	3.53	3.55	6.72	6.73	4.77	4.76	7.45	7.48	22.47	22.52

Table.1 (b) The moisture depletion pattern of I₂ from different soil layers as influenced by tillage practices and water regime

Treatment	I ₂ 0.60IW/CPE (water regime)									
	0-15 cm		15-30 cm		30-60 cm		60-90 cm		Total moisture depletion (cm)	
	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15
Tillage practices										
T ₁	2.20	2.22	3.45	4.45	3.75	3.77	1.10	1.11	10.50	11.55
T ₂	3.03	3.08	5.13	5.15	4.63	4.63	2.59	2.61	15.38	15.47
T ₃	3.76	3.78	7.50	7.48	5.40	5.40	3.79	3.78	20.45	20.44
T ₄	3.83	3.83	7.29	7.26	4.82	7.80	3.49	3.48	19.43	22.37
T ₅	3.43	3.41	7.03	7.05	4.81	4.78	3.01	3.00	18.28	18.24

Table.1 (c) The moisture depletion pattern of I₃ from different soil layers as influenced by tillage practices and water regime

Treatment	I ₃ 0.75 IW/CPE(water regime)									
	0-15 cm		15-30 cm		30-60 cm		60-90 cm		Total moisture depletion (cm)	
	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15
Tillage practices										
T ₁	2.46	2.45	3.48	3.46	2.56	2.58	0.67	1.01	9.17	9.50
T ₂	3.74	3.75	4.74	4.75	3.16	3.15	1.49	1.50	13.13	13.15
T ₃	3.82	3.80	6.77	6.79	4.22	4.20	2.54	2.52	17.35	17.31
T ₄	3.79	3.80	6.13	6.12	3.71	3.73	2.13	2.13	15.76	15.78
T ₅	3.19	3.18	5.44	5.44	3.00	2.98	2.00	1.97	13.63	13.57

Table.2 Seasonal consumptive use and water use efficiency as influenced by tillage practices and water regime

Treatment	Water regime															
	Consumptive use (cm)								Water use efficiency (kg ha m ⁻³)							
	I ₁ (0.45)		I ₂ (0.60)		I ₃ (0.75)		Mean		I ₁ (0.45)		I ₂ (0.60)		I ₃ (0.75)		Mean	
	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014
	-14	-15	-14	-15	-14	-15	-14	-15	-14	-15	-14	-15	-14	-15	-14	-15
Tillage practices																
T ₁	36.05	38.90	29.51	32.32	28.18	31.33	31.25	34.18	1.17	1.06	1.67	1.50	1.97	1.74	1.57	1.41
T ₂	38.84	41.64	34.19	37.01	31.94	34.79	34.99	37.82	1.10	1.00	1.36	1.24	1.62	1.47	1.34	1.22
T ₃	42.92	45.51	39.06	41.89	35.96	38.75	39.31	42.05	0.85	0.78	1.11	1.02	1.31	1.19	1.08	0.99
T ₄	41.55	44.10	38.04	40.87	34.37	36.99	37.99	40.65	0.95	0.86	1.21	1.08	1.40	1.25	1.17	1.05
T ₅	41.09	43.98	36.93	39.77	32.04	34.82	36.69	39.52	1.07	0.97	1.18	1.07	1.49	1.34	1.23	1.11
Mean	40.09	42.82	35.55	38.37	32.50	35.34	36.05	38.84	1.02	0.93	1.29	1.16	1.54	1.38	1.26	1.15

Consumptive use water by the crop includes Soil moisture contribution, moisture depletion pattern and effective rainfall

Table.3 Water use pattern and water productivity of wheat as influenced by tillage practices and water regime

Treatment	Water regime											
	I ₁ (0.45 IW/CPE)				I ₂ (0.60 IW/CPE)				I ₃ (0.75IW/CPE)			
	2013-14		2014-15		2013-14		2014-15		2013-14		2014-15	
	Total water use (cm)	Water productivity (kg m ⁻³)	Total water use (cm)	Water productivity (kg m ⁻³)	Total water use (cm)	Water productivity (kg m ⁻³)	Total water use (cm)	Water productivity (kg m ⁻³)	Total water use (cm)	Water productivity (kg m ⁻³)	Total water use (cm)	Water productivity (kg m ⁻³)
Tillage practices												
T ₁	41.05	1.03	43.90	0.94	39.51	1.25	42.32	1.15	43.18	1.28	46.33	1.18
T ₂	43.84	0.97	46.64	0.89	44.19	1.05	47.01	0.97	46.94	1.10	49.79	1.02
T ₃	47.92	0.76	50.51	0.71	49.06	0.89	51.89	0.82	50.96	0.92	53.75	0.86
T ₄	46.55	0.85	49.10	0.77	48.04	0.95	50.87	0.87	49.37	0.97	51.99	0.89
T ₅	46.09	0.95	48.98	0.87	46.93	0.93	49.77	0.85	47.04	1.02	49.82	0.94
Mean	45.09	0.91	47.82	0.83	45.55	1.01	48.37	0.92	47.50	1.05	50.34	0.97

Total water used by the crop includes Soil moisture contribution, moisture depletion pattern, effective rainfall and irrigation applied

Table.4 Effect of tillage practices and water regime on grain, straw, 1000 grain weight and harvest index

Treatment	Grain yield (q ha ⁻¹)		Straw yield (q ha ⁻¹)		1000 grain weight (g)		Harvest index (%)	
	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15
Tillage practices								
T ₁	48.96	48.19	62.78	61.55	46.7	45.7	43.81	43.83
T ₂	47.01	46.17	58.51	57.55	46.3	45.6	44.54	44.05
T ₃	42.34	41.45	51.47	50.57	44.0	43.2	45.14	44.59
T ₄	44.54	42.81	53.17	51.95	44.2	43.6	42.97	44.11
T ₅	45.07	43.90	59.12	56.81	45.2	44.7	45.88	45.77
<i>SEm</i> (±)	0.77	0.82	1.33	1.67	0.38	0.35	-	-
<i>C.D. (P=0.05)</i>	2.51	2.69	4.35	4.79	1.25	1.13	-	-
Water regime								
I ₁	40.95	39.87	51.19	49.84	44.3	43.8	44.46	44.29
I ₂	45.78	44.70	57.31	55.96	45.1	44.5	44.46	44.65
I ₃	50.02	48.94	62.54	61.26	46.4	45.3	44.48	44.47
<i>SEm</i> (±)	0.50	0.54	0.64	0.67	0.42	0.38	-	-
<i>C.D. (P=0.05)</i>	1.48	1.60	1.88	1.97	1.25	1.12	-	-
Interaction I × T	Sig	Sig	Sig	Sig	NS	NS	-	-

Table.5 Effect of tillage practices and water regime on profitability

Treatment	Gross income (Rs. ha ⁻¹)		Cost of cultivation (Rs. ha ⁻¹)		Net return (Rs. ha ⁻¹)		B:C ratio	
	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15
Tillage practices								
T ₁	92961.7	91414.3	28660.0	30510.0	64301.7	60904.3	2.24	2.00
T ₂	88642.9	87089.7	28865.0	30815.0	59777.9	56274.7	2.07	1.83
T ₃	79408.4	77802.9	29600.0	31350.0	49808.4	46452.9	1.68	1.48
T ₄	85273.0	81956.0	28550.0	30150.0	56723.0	51806.0	1.99	1.72
T ₅	83956.3	81832.8	26537.0	27367.0	57419.3	54465.8	2.16	1.99
Water regime								
I ₁	77290.5	75253.4	28372.5	29638.5	48918.0	45614.9	1.72	1.54
I ₂	86432.8	84395.7	28779.0	30045.0	57653.8	54350.7	2.00	1.81
I ₃	94421.9	92408.2	29165.5	30431.5	65256.4	61976.7	2.24	2.04

Bandyopadhyay (1997) reported that highest was obtained with IW: CPE ratio of 0.75 and decreased with the decrease in frequency of irrigation. Corroborative results in wheat have also been reported by Bandyopadhyay and Mallick (2003) and Kumar and Dhindwal (2009) under shallow water table conditions (Kumar 2010; Singh *et al.*, 2015).

Yield

Yield is a function of various parameters like crop dry matter accumulation, number of tillers, number of grains spike⁻¹ and 1000 grain weight etc. Yield is the most important criteria for evaluating the effects of applied treatments. Crop productivity is the rate at

which a crop accumulate biomass which depends primarily on the photosynthesis and conversion of light energy into chemical energy by green plants.

The data on crop yield is presented in (Table 4) revealed that crop yield increased with each increment in moisture retention level. The grains yield was higher during 2013-14 and 2014-15. Tillage influenced the grain yield significantly during both the years of study. Wheat sown on wide raised beds (T_1) were recorded the maximum grains yield, straw yield and biological yield and narrow raised beds (T_2) remained statistically at par with it.

The reduction in grain yield due to more tillage i.e. traditional practices with was 3.06, 2.43 and 3.25 % compared to T_1 (wide raised beds), T_2 (narrow raised beds) and T_3 (zero tillage) practices, respectively. However, wheat sown on wide raised beds registered 11.79 and 11.32 % a significant yield improvement over conventional practices. Significantly higher grain yield straw yield and biological yield was obtained in IW/CPE 0.75 (I_3) was treatment which remained statistically at par with I_2 treatment. I_1 “conventional tillage” treatment recorded minimum grain yield (40.95 and 39.87 q ha⁻¹) during the years of study, respectively. Similar reported was Singh and Katiyar (2014) and Sepat *et al.*, (2015). Significantly yield increased with the every successive increase in moisture supply by moisture retention and bed configuration. Similar results of increased yield were also reported by Idnani and Kumar, (2012) and Mishra, *et al.*, (2016). The interaction, tillage \times irrigation water was significant for the grain, straw and biological yield. The magnitude of increase in straw yield due to improvement in moisture supply by tillage modes with wheat sown on raised beds was higher in I_3 as compared to other irrigation water.

Profitability

The economics of wheat crop affected by different tillage practices and water regimes is depicted in (Table 5). The cost of cultivation of wheat crop increase with the increasing of water regimes although the increase was very nominal during both the years. Among the different tillage practices the cost of cultivation was highest in T_3 conventional tillage followed by reduced tillage/narrow raised beds and it was lowest in zero tillage/wide raised beds practices plots. Among the different tillage practices the highest net profit, gross income, B: C ratio was recorded in (T_1) wheat sown on wide raised beds. This may be because of higher water use efficiency than other tillage practices as well as comparatively higher increase in grain yield than in other treatment. The minimum net profit, gross income, B: C was observed in (T_3) conventional tillage treatment during both the years, respectively. From the above results it is clear that increase in irrigation level increased the available moisture in soil, which may be attributed to increase the cost of cultivation, gross income, net profit and B: C ratio because of more increase in grain yield and gross income in comparison to increase in cost of cultivation. These results are in conformity with the findings of Kumar *et al.*, (2013); Naresh *et al.*, (2013).

Wide raised beds performed best with highest grain yield followed by narrow raised beds and zero tillage. The increased water regimes increased the growth and yield significantly and it was highest in I_3 where 3 irrigation were applied at 22, 65 and 105 DAS. The economics of wide raised beds gave maximum return in terms of net profit Rs 62603 ha⁻¹ with a B:C ratio of 2.12 followed by narrow raised beds recommended and zero tillage with B:C ratio of 1.95 and 2.07, respectively. The highest net profit of Rs

65256.40 and Rs 61976.70 ha⁻¹ was available with three irrigations applied at 22, 65 and 105 DAS during 2013-14 and 2014-15, respectively. The B: C ratio was also highest with three irrigations i.e. 2.24 and 2.04 during 2013-14 and 2014-15. The improved yield, profit and B: C ratio under conservation tillage over years indicates that consistent build-up of organic matter. Thus for introducing a suitable management practice, it is necessary to now the yield reductions level of plant water deficit in different tillage/water regimes practices. Such information is necessary for crop planning in various agro-climatic conditions both under un-irrigated and irrigated situations. Results of this investigation can be extended to similar soil and climatic condition for wide area.

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