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Effect of Tillage and Irrigation Methods on the Productivity, Profitability and Nutrient Uptake of Wheat

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Tillage and crop establishment method play an important role in the placement of seed at proper depth which ultimately affect germination and crop growth. The selection of suitable crop establishment method for wheat is dependent upon the time of sowing and availability of soil moisture. A field experiment was conducted during Rabi season 2017-18 and 2018-19 to evaluate the effect of tillage and crop establishment methods on productivity, nutrient uptake and profitability of wheat (*Triticum aestivum* L.). Results revealed that grains, straw and biological yields were significantly higher under treatment T_5 (wide bed furrow irrigated) and at par with T_2 (furrow irrigated with gated pipe Raised bed) and T_8 (zero till flat irrigated by gated pipe Controlled flood irrigation).Total nitrogen, phosphorus and potassium uptake were significantly more in treatment T_5

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than other treatments. Significantly maximum gross return (97818 ₹ ha^{-1}), was recorded under T_5 which was at par with T_8 and T_2. The maximum net return (61910 ₹ ha^{-1}) and B: C ratio (2.84) were fetched under T_8 than all other treatments followed by and T_5.

Keywords: Crop establishment methods; productivity; profitability.

1. INTRODUCTION

Wheat (*Triticum aestivum* L.) is the most widely grown as it is the staple food for 40 per cent human population across the globe and second most important cereal after rice. Wheat provides 21 per cent of the food calories and 20 per cent of the protein for more than 4.5 billion people in 94 countries. It is very important and remunerative *Rabi* crop of North India and second most important cereal crop after rice, grown under diverse agro-climatic conditions. Globally wheat was grown in an area about 215.48 million ha, production 764.5 million tons and productivity 3.39 t ha^{-1} USDA [1]. In India also wheat play a key role in food and nutritional security with an area 29.65 m ha and production 99.9 million tonnes with an average productivity 3371 kg ha^{-1} USDA [1] and contributes nearly one third of the total food grain production. In India, Uttar Pradesh is leading Wheat growing state with an area of about 9.65 million ha (36.6%), production of 26.87 million tonne (39.3%) and productivity 2785 kg ha^{-1} [2]. Wheat productivity in the state is far lower than that in Punjab (4.3 t ha^{-1}) and Haryana (4 t ha^{-1}) accounted to late sowing after long duration rice varieties and harvest of sugarcane, lack of quality seed, imbalanced fertilization, unscientific water management and poor mechanization etc. In western Uttar Pradesh wheat sowing is delayed up to end of December and sometimes even to first week of January leading to severe yield reduction. It contributes about 14.4 percent to the value added in agriculture and 3 percent to the GDP [3].To meet the demand of wheat, the global productions need a 1.6 to 2.6% annual growth rate, which can be mainly achieved through improvement in input use efficiency. However, under the current production practices, crop productivity and input use efficiency has declined. In the Indo-Gangetic Plains (IGP), ground water is being depleted 13 to 17 km^3 per year Rodell et al. [4].The improvement of input use efficiency in wheat crop can be achieved through two main strategies by adopting precise and more efficient crop management practices.

Potential resource conservation techniques (RCTs) like zero tillage, minimum tillage and Furrow Irrigated Raised Bed (FIRBS) planting system gaining importance in the IGP and are found to retrieve the scarce natural resources like water Hari et al. [5]. Raised bed planting systems has been used since time immemorial by farmers in many parts of the world. Their application has conventionally been accompanying with water management problems, to reduce the adverse impact of excess water on crop production. A widely adoption of raised beds in many semi-arid and arid areas is to plant crops on the edges of beds or ridges that are formed between furrows that carry irrigation water. Monsefia et al. [6] found that furrow-irrigated raised-bed planting system (FIRBS) is a form of tillage wherein sowing is done on raised-beds. The FIRBS planting can save irrigation water from 18 to 35% and enhance the input use efficiency and factor productivity in wheat Rajanna et al. [7]; Choudhary and Behera [8]. Ladha et al. [9] found zero tillage system was more profitable due to saving of labour, time, water and energy costs. There are several reports showing savings in irrigation water, labour and production costs, and higher net economic returns in zero tillage as compared with conventional tillage systems Choudhary and Behera [10] and [11].Yields with zero tillage are either equal or even better than those obtained with conventional tillage because of timely sowing of wheat, efficient use of fertilizers and weed control Choudhary and Behera [12]. Zero tillage systems conserve the land resource, cost effective and efficient. Zero-tillage is more profitable due to saving of labour, time, water and energy costs Ladha et al. [9]. Zero tillage (ZT) technique is an ecological approach for soil surface management and seed bed preparation resulting in less energy requirement, less weed problem, better crop residue management and higher or equal yield Karunakaran and Behera [13]; Choudhary and Behera [11].

2. MATERIALS AND METHODS

The present investigation was undertaken at Crop Research Centre, Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut (U.P.). Meerut lies in the heart of Western Uttar

Pradesh (latitude of 290 40′ North, longitude of 770 42′ East and at an altitude of 237 meter above mean sea level) with sub-tropical climate. The experimental field had an even topography with good irrigation and drainage facilities. The climate of this region is semi-arid and sub-tropical with extreme hot in summer and cold in winter season. There is gradual decrease in daily temperature as low as 4.8ºC & 2.9ºC in January & December, 2018. The relative humidity was found to be maximum 95.7 & 96.7%, and minimum in 30.3& 38.9 % in the month of April & December during 2018, respectively. The experimental soil was sandy loam in texture, low in available nitrogen and organic carbon while, medium in available phosphorus and potasium and slightly alkali in reaction.

2.1 Treatments detail

There were eight treatment combination of irrigation method and tillage practices *i.e.,*T_1 conventional flood irrigation (CFI), T_2 Furrow irrigated with gated pipe Raised beds(FIGPRB), T_3 All furrow irrigated (AFI), T_4 Alternate furrow irrigated (Alt.FI), T_5 Wide bed furrow irrigated (WBFI), T_6 Skip furrow irrigated (SFI), T_7 Sprinkler irrigation (SI), T_8 Zero till flat irrigated by gated pipe Controlled flood irrigation(ZTFIGP).The experiment was laid down in randomized block design (RBD) with three replication during 2017-18 and 2018-19.

2.2 Cultural Practices

Conventional practices in conventional flood irrigation (CT) of two harrowing, three ploughing (using a cultivator) thereafter planking (using a wooden plank) that followed pre-sowing irrigation and wheat was seeded in rows 20 cm apart using a seed drill with a dry fertilizer attachment. In case of furrow irrigated raised bed tillage (FIRB) soil was tilled by harrowing and ploughings followed by one field levelling with a wooden plank, and raised beds were made using a tractor-drawn multi crop raised bed planter with inclined plate seed metering devices. The dimension of the beds was 40 cm wide in narrow bed and 100 cm wide in wide bed furrow irrigated (top of the bed) x 12 cm height x 30 cm furrow width (at top) and the spacing from center of the furrow to another center of the furrow was kept at 70 cm. Three rows of wheat were sown on each raised bed keeping one row at center and remaining two at both edges. Zero-till (ZT) system of planting crops with minimum of soil disturbance was performed with Zero-till seed drill. By this equipment, seeds were placed directly into narrow slits 2-4 cm wide and 4-7 cm deep made with a drill fitted with chisel, inverted T” without land preparation.

2.3 Fertilizer Application and Crop Management

In order to raise ideal crop, all the plots received recommended dose of N:P:K @ 150:60:60 kg ha^{-1}, respectively. Full dose of phosphorus, potassium and half dose of nitrogen were applied uniformly as a basal (at the time of sowing) dose by using seed-cum-fertilizer drill at the time of seeding operation. N: P:K were applied through combination of Urea, DAP and MOP. Rest dose of N in form of urea was applied in two equal split doses at 25 and 55 DAS synchronizing with irrigation application. Weed infestation was checked through application of post emergence herbicide Sulfosulfuron @ 33.3 g a.i. ha^{-1} at 30 DAS in standing crop followed by one hand weeding was done at 45 DAS.

2.4 Yield (kg ha^{-1})

Grains were separated with the help of mini plot thresher from biological yield obtained from net area in each plot. The grain yield obtained from net plot area was recorded in kg $plot^{-1}$ was standardized to 14 per cent moisture and then weight was converted into kg ha^{-1}. After harvesting of the net plot area, the bundles of wheat crop was sun dried for four days and then weight recorded and converted into kg ha^{-1} for calculating the biological yield q ha^{-1}. Straw yield was worked out by subtracting the grain yield from total biological yield of net plot area and expressed in q ha^{-1}. Harvest index, which is the ratio of economic yield to biological yield expressed in per cent, was worked out by using the following formula given below.

$$\text{Harvest index (\%)} = \frac{\text{Grain yield}}{\text{Biological Yield}} \times 100$$

2.5 Plant Analysis

The nutrients content were analyzed in grains and straw at harvest and estimated separately from the selected plants of each plot. The plant samples for estimating the dry matter production (grains and straw) from each plot at harvest is thoroughly washed with distilled water and dried in hot air oven at60 ± 1ºC as dry matter accumulation. Dried samples were powdered in a willey mill to considerable fineness before storing them in polythene bags for further analysis.

2.6 Nutrient Uptake (kg ha^{-1})

Uptake of individual nutrients i.e. N, P and K were worked out by multiplying the grain yield and straw yield with their respective nutrient content (%) as follows:

Nutrient uptake (kg ha^{-1}) = Content (%) in grains/straw × grains/straw yield

Total uptake (kg ha^{-1}) = Uptake from grains + nutrient uptake from straw

2.7 Statistical Analysis

All the observations recorded during the course of investigation were analyzed by analysis of variance technique (ANOVA) using the statistical analysis (OPSTAT). The comparison of treatment means were made by the least significant difference at 5% probability (p=0.05).

3. RESULTS AND DISCUSSION

3.1 Yield

Tillage crop establishment methods significantly affect yield (grain, straw and biological q ha^{-1}) and harvest index % Table 1. Significantly higher grain yield (44.32 q ha^{-1}) of wheat was recorded in treatment T_5 than other treatments which was statistically *at par* with T_8 and T_2. However, the treatments T_1 and T_7 were recorded superior over rest of the treatments and *at par* with each other. Though, treatment T_6 was registered minimum grain yield (28.29 q ha^{-1}) than rest of the treatments followed by T_4, and T_3, with the value of 29.01 and 30.10 q ha^{-1}, respectively. Though, the per cent increment in grain yield of wheat was recorded with the tune of 20.99, 17.79 and 16.21% in relation to T_5, T_8 and T_3, respectively as compared to T_1 (Conventional flood irrigation). The yield per ha was improved due to improve in moisture supply and its beneficial effect on the per plant yield. The grain yield per plant improve with increase moisture supply mainly through improvement in number of effective tillers, number grains per spike, and test weight (Table 5). Similar trend have been observed by Choudhary and Behera [12]; Singh et al. [14], Sepat et al. [15], Idnani and Kumar [16], Naresh et al. [17], Mollah et al. [18] and Singh et al. [19].

Straw yield of wheat was varied from 46.22 to 61.87 q ha^{-1}. The maximum straw yield (61.87 q ha^{-1}) was recorded under the treatment T_5 than other treatments being statistically at par with T_2 and T_8. However, the treatments T_1 and T_7 were recorded superior over rest of the treatments. Though, the minimum straw yield was recorded into the treatment T_3 followed by T_4 and T_6. While, the treatments T_3, T_4 and T_6 were recorded at par with each other. The increase in straw yield of crop could be attributed to the significant effect of moisture supply on the vegetative growth of the crop plant. Thus the straw yield increase because of enhancement of vegetative growth under improved moisture supply. Atikullah et al. [20], Kumar et al. [21] and Kumar et al. [22] were observed similar trend.

Among the tillage crop establishment methods, treatment T_5 was found to be significantly superior to all other treatments except T_8 followed by T_2.The treatments T_3, T_4 and T_6 were recorded *at par* with each other. However, treatment $T_6$was recorded minimum biological yield 74.98 q ha^{-1}. Significant increase in grain, straw and biological yield with increased in tillage practices. FIRB and Zero till full fill the timely crop water requirement, which resulted into better growth in terms of dry matter accumulation. The higher growth finally resulted into significant increase in grain yield through yield attributed namely number of effective tillers, number of grains per spike and test weight.

The maximum harvest index (41.73%) of wheat was recorded in the treatment T_5 than other treatments being statistically at par with T_8 and T_2. Though, the treatment T_6 was recorded least harvest index (37.73%) followed by T_7, T_4, T_3 and T_1. While, the treatments T_1, T_3, T_4 and T_7 were recorded *at par* with each other.

3.2 Nutrients Uptake

The content per cent of nitrogen, phosphorus and potassium in grains and straw was significantly affected by tillage crop establishment methods (Table 2). Treatment T_5 was recorded significantly maximum nitrogen; phosphorus and potassium content per cent in grains and straw of wheat which was statistically *at par* with T_2 and T_8. Treatment$T_6$was recorded minimum nitrogen, phosphorus and potassium content per cent in grains and straw of wheat followed by T_4>T_3>T_1 and T_7 respectively.

It is evident that uptake of nitrogen, phosphorus and potassium in grains and straw differ significantly (Table 3). Significantly maximum uptake of nitrogen, phosphorus and potassium were recorded in grains and straw under treatment T_5 than all other treatments except T_2 and T_8. However, treatments T_1 and T_7 were superior and *at par* with each other than remaining of the treatments while, treatment T_6 was recorded minimum nitrogen, phosphorus and potassium uptake in grains and straw followed by T_4 and T_3. However, treatments T_3, T_4 and T_6 were at par with each other.

3.3 Total Uptake (kg ha^{-1})

Among the treatments significantly maximum total nitrogen uptake (114.60 kg ha^{-1}) was recorded in treatment T_5 which was statistically at *par* with T_8. However, treatment T_2 was superior to rest of the treatments followed by T_1 and T_7 were *at par* with each other. Though, the treatmentsT_3, T_4 and T_6 were *at par* with each other while treatment T_6 was recorded minimum total nitrogen uptake. Treatment T_5 was recorded significantly maximum phosphorus uptake followed by T_8 and T_2. However, treatments T_1 and T_7 were *at par* and superior than rest of the treatments. Treatments T_3, T_4 and T_6 were at par with each other while treatment T_6 was recorded minimum total phosphorus uptake. The maximum total potassium uptake (127.28 kg ha^{-1}) was recorded in treatment T_5 which was statistically *at par* with T_8 followed by T_2. However, treatments T_1 and T_7 were statistically superior to rest of the treatments. Treatments T_3, T_4 and T_6 were at par with each other while, treatment T_6 was recorded minimum total potassium uptake. The higher N and P uptake in grains is due to its chemical composition because of higher amino acid and protein content in grains require more N and P.

Table 1. Effect of tillage crop establishment methods on yield (grain, straw & biological q ha^{-1}) and harvest index of wheat

Treatments	Yield (q ha^{-1})			Harvest index (%)
	Grain	Straw	Biological	
CFI	36.63	55.74	92.38	39.67
FIGPRB	42.57	61.04	103.61	41.08
AFI	30.10	46.22	76.32	39.43
Alt.FI	29.01	46.25	75.26	38.54
WBFI	44.32	61.87	106.19	41.73
SFI	28.29	46.69	74.98	37.73
SI	35.97	58.50	94.48	38.06
ZTFIGP	43.15	61.25	104.40	41.33
SEm±	0.79	0.86	1.65	0.75
CD (*P= 0.05*)	2.33	2.50	4.83	2.20

Table 2. Effect of tillage crop establishment methods on nitrogen, phosphorus and potassium content per cent in grains and straw

Treatments	Content (%)					
	Nitrogen		Phosphorus		Potassium	
	Grains	Straw	Grains	Straw	Grains	Straw
CFI	1.65	0.54	0.318	0.154	0.456	1.65
FIGPRB	1.71	0.56	0.343	0.162	0.471	1.69
AFI	1.60	0.52	0.306	0.140	0.436	1.65
Alt.FI	1.59	0.51	0.303	0.136	0.431	1.65
WBFI	1.75	0.60	0.351	0.180	0.482	1.71
SFI	1.56	0.50	0.297	0.124	0.423	1.62
SI	1.68	0.56	0.326	0.156	0.459	1.68
ZTFIGP	1.73	0.57	0.344	0.168	0.478	1.70
SEm±	0.01	0.01	0.003	0.003	0.005	0.01
CD (*P= 0.05*)	0.04	0.03	0.011	0.010	0.016	0.03

Whereas, higher K content in straw is because of its higher content is required for providing strength to stem by forming cellulose, lignin and pectin. Wheat sown on wide bed furrow irrigated raised bed increased NPK content and uptake in grains and straw. The higher uptake of NPK in grains and straw under wide bed furrow irrigated raised bed because more availability of these nutrients, which encourage the crop growth and finally higher grain and biomass yield. Choudhary and Behera, 2020a [10]; Talukder et al. [23], Septa et al. [15], Jat et al. [24] and Idnani and Kumar [25] stated similar results.

3.4 Profitability

It was observed that sowing of wheat under wide bed furrow irrigated was more beneficial than conventionally sown for improving the profitability (Pooled data 2017-18 and 2018-19, Table 5). Treatments T_2 and T_8 were closely stand with T_5 in terms of gross return, net return and B: C ratio. Moreover wheat was grown successfully with T_8 as the productivity was nearly similar but profitability was highest compared with other treatments. Although wide bed furrow irrigated (T_5) closely stand with T_6, T_2, T_4 and T_3 resulted in higher cost of cultivation than remaining of the treatments. Among the tillage crop establishment methods, the maximum gross return (97818 ₹ ha^{-1}), net return (61910 ₹ ha^{-1}) and B: C ratio (2.84) were fetched under T_5 and T_8 while, minimum gross return (64630 ₹ ha^{-1}), net return (21846 ₹ ha^{-1}) and B: C ratio was under T_6 than rest of the other treatments. These results are in conformity with the findings of Brar et al. [26], Kumar et al. [20], Singh et al. [19] and Rajanna et al. [27].

Table 3. Effect of tillage crop establishment methods on nitrogen, phosphorus and potassium uptake in grains and straw

Treatments	Uptake					
	Nitrogen		Phosphorus		Potassium	
	Grains	Straw	Grains	Straw	Grains	Straw
CFI	60.16	30.03	11.63	8.58	16.71	92.16
FIGPRB	72.87	34.29	14.61	9.92	20.03	103.08
AFI	48.04	24.04	9.20	6.48	13.14	76.24
Alt.FI	46.03	23.29	8.78	6.28	12.50	76.16
WBFI	77.78	36.83	15.55	11.16	21.38	105.90
SFI	44.17	23.16	8.41	5.78	11.98	75.46
SI	60.53	32.26	11.72	9.11	16.53	98.16
ZTFIGP	74.73	35.02	14.86	10.31	20.61	104.14
SEm±	1.37	0.73	0.27	0.20	0.35	0.96
CD (*P= 0.05*)	4.00	2.14	0.80	0.57	1.02	2.82

Table 4. Effect of tillage crop establishment methods on total nitrogen, phosphorus and potassium uptake (kg ha^{-1})

Treatments	Total uptake (kg ha^{-1})		
	Nitrogen	Phosphorus	Potassium
CFI	90.20	20.21	108.87
FIGPRB	107.17	24.53	123.11
AFI	72.08	15.68	89.40
Alt.FI	69.32	15.05	88.66
WBFI	114.60	26.70	127.28
SFI	67.35	14.19	87.44
SI	92.78	20.83	114.69
ZTFIGP	109.75	25.17	124.75
SEm±	1.30	0.47	1.31
CD (*P= 0.05*)	3.79	1.37	3.84

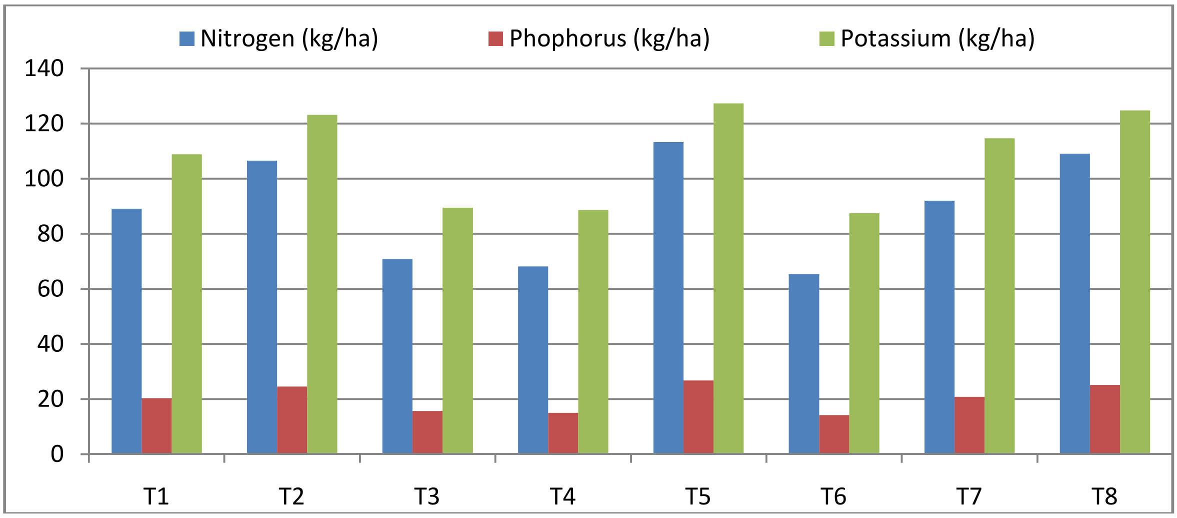

Fig. 1. Effect of tillage crop establishment methods on total nitrogen, phosphorus and potassium uptake (kg ha^{-1})

Table 5. Effect of tillage crop establishment methods on gross return, cost of cultivation, net return and B: C ratio of wheat

Treatment	Gross return (₹ ha^{-1})	Cost of cultivation (₹ ha^{-1})	Net return (₹ ha^{-1})	B:C ratio
CFI	82239	39399	42841	2.09
FIGPRB	94438	43196	51242	2.19
AFI	67709	43917	23792	1.55
Alt.FI	65776	43556	22220	1.51
WBFI	97818	41908	55910	2.34
SFI	64630	42784	21846	1.51
SI	81916	36227	45689	2.26
ZTFIGP	95541	33631	61910	2.84
SEm±	1380	-	1380	0.04
CD (*P= 0.05*)	4036	-	4036	0.11

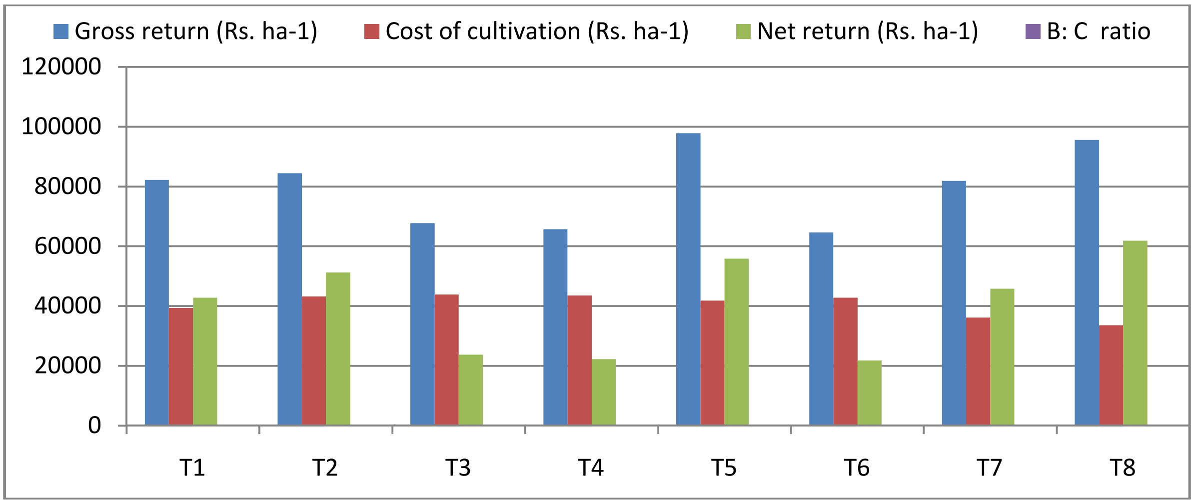

Fig. 2. Effect of tillage crop establishment methods on gross return, cost of cultivation, net return and B: C ratio of wheat

4. CONCLUSION

Adoption of wide bed furrow irrigated, zero till flat irrigated by gated pipe, and controlled flood irrigation methods are concluded as the best tillage crop establishment methods for higher yield, nutrient uptake and profitability of wheat under rice-wheat cropping system in irrigated condition. Grain yield and NPK uptake were significantly maximum in wide bed furrow irrigated over conventional flood irrigation method. Moreover, Zero till flat irrigated by gated pipe method obtained maximum returns and minimizes 16.32 per cent cost of cultivation followed closely by wide bed furrow irrigated respectively.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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