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Reenu Kumar
Department of Agronomy, Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut, Uttar Pradesh, India

RK Naresh
Department of Agronomy, Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut, Uttar Pradesh, India

Vivek
Department of Agronomy, Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut, Uttar Pradesh, India

SP Singh
Department of Soil Science and Agricultural Chemistry, Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut, Uttar Pradesh, India

M Sharath Chandra
Department of Agronomy, Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut, Uttar Pradesh, India

Rajendra Kumar
Department of Agronomy, Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut, Uttar Pradesh, India

Akash Kumar
Department of Floriculture and Landscape Architecture, Dr. YSP University of Horticulture and Forestry, Solan, Himachal Pradesh, India

Mohd Shah Alam
Department of Agronomy, Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut, Uttar Pradesh, India

Pradeep Kumar Singh
Department of Agronomy, Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut, Uttar Pradesh, India

Corresponding Author:
Reenu Kumar
Department of Agronomy, Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut, Uttar Pradesh, India

Effect of crop establishment methods with residue retention on soil water dynamics, productivity and profitability of wheat under rice-wheat rotation in typic Ustochrept

Reenu Kumar, RK Naresh, Vivek, SP Singh, M Sharath Chandra, Rajendra Kumar, Akash Kumar, Mohd Shah Alam and Pradeep Kumar Singh

Abstract
A field experiment was conducted on sandy loam soil at Crop Research Centre of Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut, U.P. during *rabi*, 2018-19 in randomised block design with three replications. The treatments comprised of twelve tillage crop establishment methods were used for the experimentation and different observations were recorded during the crop growth period. The results indicated that the water productivity (WP) was remarkably low in conventional tillage (T_{12}) than FIRB, zero and reduced tillage treatments. Increase in water productivity under FIRB based on the fact that the proportionate increases in grain yield with lesser number of irrigation. Wheat grain yield under wide raised beds and zero tillage residue retention were 4.1% and 3.6% higher than conventional practices. Nutrient (N, P, and K) uptake in wheat was also higher in wide raised beds residue retention (T_9) than in the other treatments. Net profit and benefit cost ratio was highest under wide raised bed residue retention and the lowest under conventional tillage wheat.

Keywords: Crop establishment methods, residue management, economics, yield

Introduction
Wheat is one of the most important cereal crops of the world on account of its wide adaptability to different agro-climatic and soil conditions and it is the staple food of nearly 35 per cent of the world population. India occupies second position in the world wheat production. It was grown over an area of 215.48 million ha across the world and produced 731.4 million metric tons of grain with an average productivity of 3.39 tonnes per ha (USDA report, 2018-19) [16]. Wheat contribute nearly one third of the total food grain production and it covered area of 9.65 million ha with production of 102.21 million tonnes in 2018-19 (Kumar et al., 2019) [7-9, 12, 14]. Uttar Pradesh is India's leading wheat growing state of with an area of 9.65 million ha (36.6%), production of 29.67 million tonnes (39.9%) and productivity of 27.95kg per ha (Anonymous 2019) [2]. In Uttar Pradesh, wheat is grown in typical semi-arid climate which is characterized by high temperature during crop growth. The productivity of Uttar Pradesh is a little lower than that of the country but, far behind if compared to potential yield and advanced wheat cultivating states i.e. Haryana and Punjab (Singh *et al*., 2018) [6, 7, 9, 11, 12, 14]. Availability of water has become a pertinent problem and threatens the sustainability of crop production and global food security. This is especially relevant to the semi-arid regions of India, and more so under the future climate change predictions. When crop residues are retained on the surface in no-tillage, several positive effects are ensured including reduction in soil erosion, improvement in residual soil water content by reducing surface runoff and increasing infiltration (Wang *et al*. 2009) [17]. Considering this scenario, we can expect that water resources will be less available for irrigated agriculture and competition for water will increase in the near future in this region. Within this context, a large increase in water productivity is required to optimize agricultural productivity while reducing pressure on natural resources (Teixeira *et al*., 2014) [15]. In this sense, alternative best crop management options like conservation agricultural practices which include zero tillage and permanent beds have demonstrated potential benefits on crop yield and profits while saving water, energy and restoring soil degradation across diverse ecologies (Jat *et al*., 2014) [6, 14].
The purpose of the current study was conducted a field experiment to evaluate the effect of tillage cum crop establishment methods with residue retention on soil water dynamics, nutrient

uptake, productivity and profitability of wheat under rice-wheat rotation in Typic Ustochrept of western Uttar Pradesh, India.

Material and Methods

The field experiment was conducted at Crop Research Centre of Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut during *Rabi* season 2018-19. The experiment was laid out in randomized block design (RBD) with three replication and twelve tillage crop establishment methods namely T_1-Zero tillage residue retention, T_2-Zero tillage without residue, T_3-Reduce tillage residue retention, T_4-Reduce tillage with residue, T_5-Roto till residue retention, T_6-Roto till without residue, T_7-Narrow raised bed residue retention,T_8-Narrow raised bed without residue,T_9-Wide raised bed residue retention, T_{10}-Wide raised beds without residue, T_{11}-Conventional tillage residue incorporation and T_{12}-Conventional tillage and wheat variety DBW-90 were tested. The soil of experimental field was sandy loam in texture with low in organic carbon (0.44%), available nitrogen (222.8 kg ha^{-1}) and medium in available phosphorus (16.7 kg ha^{-1}) and potassium (241.5 kg ha^{-1}). The data collected from the experiment were analyzed statistically by analysis of variance (ANOVA) method for randomized block design (RBD) with crop establishment methods treatments as one factor, respectively. The soil water dynamics, nutrient uptake, yield and economics data recorded, analysed and tabulated after statistical test.

Results

Water dynamics

Soil moisture studies

The soil profile moisture extraction pattern of wheat crop under different irrigation levels and tillage practices treatments (Table 1). 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 0-15 cm layer followed by 15-30 cm and 30-60 cm. However, minimum water was extracted from 60-90 cm and the moisture extraction from the surface layer (0-15 cm) was increased slightly with increase in land configuration, furrow irrigated raised beds plots stored more moisture from the deeper profile layer than flat planting practice and vice-versa during the year of study.

Table 1: Soil moisture depletion (cm) pattern at different stages as influenced by tillage techniques

Treatments		Soil moisture depletion				Total soil moisture depletion (cm)
		Depth of soil (cm)				
		0-15	15-30	30-60	60-90	
T_1	Zero tillage residue retention	4.5	3.5	4.1	3.6	15.7
T_2	Zero tillage without residue	4.0	3.2	3.6	3.1	13.9
T_3	Reduce tillage residue retention	4.3	3.4	3.8	3.4	14.9
T_4	Reduce tillage without residue	3.4	2.7	3.4	1.6	11.1
T_5	Roto till residue retention	3.6	3.0	3.5	2.1	12.2
T_6	Roto till without residue	3.0	2.1	3.0	1.2	9.3
T_7	Narrow raised bed residue retention	3.8	3.1	3.5	2.2	12.6
T_8	Narrow raised bed without residue	3.4	2.5	3.3	1.5	10.7
T_9	Wide raised bed residue retention	4.1	3.3	3.8	3.3	14.5
T_{10}	Wide raised beds without residue	3.5	2.8	3.4	1.8	11.5
T_{11}	Conventional tillage residue incorporation	3.9	3.1	3.6	2.5	13.1
T_{12}	Conventional tillage	3.1	2.4	3.2	1.3	10.0
Mean		3.7	*2.9*	*3.5*	*2.3*	*12.5*

Moisture depletion pattern

The effect of tillage practices on average profile soil moisture content in wheat during 2018-19 (Table 1). 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. The increases in profile moisture content are visible from the peaks under tillage practices different were because of moisture conserved due to land configuration as per treatments. The moisture content of conventional tilled plots (T_{12}) was always lower than zero and reduced till plots (T_1 & T_3) except in the peaks where the moisture content in the profile was always same due to recharging of profile by application of irrigation. The conventional till crop kept the average profile moisture content 1.5% lower than zero till plots throughout the crop season except after recharging the soil profile either by application of irrigation or by rainfall. The highest total moisture depletion (15.5 cm) from each layer was observed under FIRB method of sowing as compare to other seeding methods, ZTW (T_1), CT (T_{12}), RT (T_3), and RTW (T_5), due to more availability of moisture in rhizosphere. The amount of moisture depleted decreased with the soil depth due to lower density of roots in deeper layer compared with the upper layer due to increased surface evaporation the percentage contribution of upper 30 cm layer was more. The highest moisture depletion under the FIRB method might be due to less availability of moisture at upper layer and more evaporation from upper surface.

Water use and water productivity

The crop water use increased markedly in conventional till plots (T_{12}) than zero till and FIRB plots (T_1, T_7 & T_9) during the year of study. The water productivity increased with the increased yield and less water use during experimentation. The WP was remarkably low in conventional till plots crop (T_{12}) than FIRB, zero and reduced till crop plots (Table 2). The maximum water productivity was registered (1.68 kg m^{-3}) under zero till residue retention (T_1) land configuration, followed by narrow raised beds residue retention (T_7) > reduced till residue retention (T_3), wide raised beds residue retention (T_9) treatments during the year of study. Increase in water productivity under FIRB based on the fact that the proportionate increases in grain yield with lesser number of irrigation water.

Table 2: Effect of tillage-cum-crop establishment methods on grain yield (q ha^{-1}), consumptive use (cm), water use efficiency (q ha^{-1} cm), total water applied (cm) and water productivity (kg cm^{-3}) of wheat

Treatments		Grain yield (q ha^{-1})	Consumptive use (cm)	Water use efficiency (%)	Total water applied (cm)	Water productivity (kg cm^{-3})
T_1	Zero tillage residue retention	40.87	17.0	28.5	2.40	1.43
T_2	Zero tillage without residue	36.31	17.4	31.6	2.08	1.14
T_3	Reduce tillage residue retention	39.58	18.5	30.5	2.13	1.29
T_4	Reduce tillage without residue	35.62	19.1	34.6	1.86	1.02
T_5	Roto till residue retention	38.62	17.8	35.8	2.16	1.07
T_6	Roto till without residue	34.20	18.3	38.6	1.86	0.88
T_7	Narrow raised bed residue retention	45.63	19.7	25.4	2.31	1.79
T_8	Narrow raised bed without residue	36.12	20.3	28.8	1.77	1.25
T_9	Wide raised bed residue retention	47.51	22.4	22.4	2.12	2.12
T_{10}	Wide raised beds without residue	37.16	23.2	26.3	1.60	1.41
T_{11}	Conventional tillage residue incorporation	43.30	24.0	39.0	1.80	1.11
T_{12}	Conventional tillage	32.26	25.6	42.5	1.26	0.75
Mean		38.93	20.27	1.94	32.0	1.27

Nutrient content and their uptake by crop

Nitrogen

The nitrogen content (%), nitrogen uptake in grain of wheat was significant varied under different tillage practices during the year of study (Table 3). The nitrogen content in grain was 3.8 times higher than in straw of wheat crop. The maximum nitrogen content in grain (1.83%) was recorded in T_9 treatment and was at par with T_1, T_7 and T_{11}, respectively. The maximum nitrogen content in straw (0.55%) was observed in treatment T_9 (wide raised beds residue retention). T_7 tillage practice resulted in 0.53 per cent increase in nitrogen content (%) over T_{12} respectively. Wheat sown on wide raised beds residue retention (T_9) recorded significantly higher nitrogen uptake by wheat grain but was statistically at par with wheat sown on zero till, narrow raised beds and conventional tillage with residue retention/ incorporation, respectively. Treatments T_2 and T_4 were at par with each other, however, they recorded significantly higher nitrogen uptake over rest of the treatments. The lowest nitrogen uptake in wheat grain was observed under conventional tillage practice (T_{12}) and without residue retention tillage practices plots (T_6 & T_8) which were statistically at par with each other. The nitrogen uptake by wheat straw showed significant variation with tillage techniques. Wheat sown on wide raised beds/ zero till/ narrow raised beds/ conventional tillage with residue retention/incorporation recorded significantly higher nitrogen uptake by wheat straw and T_3 and T_5 were at par with each other, however, they recorded significantly higher nitrogen uptake over rest of the treatments. The lowest nitrogen uptake in wheat straw was observed under conventional tillage practice (T_{12}) and without residue retention tillage practices plots (T_4 & T_6) which were statistically at par with each other. The total uptake of nitrogen also followed same trend as observed in its uptake in grain and straw and increased with the increasing moisture availability due to residue retention/ incorporation (Table 3). The maximum total nitrogen uptake (119.32 kg N ha^{-1}) was recorded with the application of wheat sown on wide raised beds residue retention (T_9) but statistically at par with sowing wheat on narrow raised beds residue retention (T_7). However, the differences among T_1, T_3 and T_5 treatments were non-significant during the year of experimentation.

Table 3: Effect of tillage practices on nitrogen content grains (%), straw (%), uptake in grains (kg ha^{-1}), straw (kg ha^{-1}) and total nitrogen uptake (kg ha^{-1}) in wheat

Treatments		Nitrogen content (%)		Nitrogen uptake (kg ha^{-1})		Total nitrogen uptake (kg ha^{-1})
		Grains	Straw	Grains	Straw	
T_1	Zero tillage residue retention	1.75	0.49	71.52	27.79	99.32
T_2	Zero tillage without residue	1.61	0.38	58.46	20.04	78.50
T_3	Reduce tillage residue retention	1.54	0.47	60.95	26.23	87.18
T_4	Reduce tillage without residue	1.68	0.37	59.84	19.37	79.21
T_5	Roto till residue retention	1.55	0.44	59.86	24.13	83.99
T_6	Roto till without residue	1.73	0.34	59.17	17.21	76.38
T_7	Narrow raised bed residue retention	1.59	0.53	72.55	31.93	104.48
T_8	Narrow raised bed without residue	1.46	0.39	52.74	20.39	73.13
T_9	Wide raised bed residue retention	1.78	0.55	84.57	34.75	119.32
T_{10}	Wide raised beds without residue	1.72	0.41	63.92	21.79	85.70
T_{11}	Conventional tillage residue incorporation	1.70	0.51	73.61	29.18	102.79
T_{12}	Conventional tillage	1.60	0.27	51.62	11.38	62.99
S.Em (±)		0.05	0.02	2.34	0.72	3.02
C.D. (P=0.05)		0.14	0.04	6.94	2.10	9.01

Phosphorus

The phosphorus content in grains and straw of wheat was affected significantly by different tillage practices during the year of study (Table 4). It indicates that phosphorus content was 2.2 times more in grain as compared to straw. The maximum phosphorus content in grains (0.34%) and straw (0.17%) was recorded in wide raised bed residue retention (T_9) treatment, being significantly higher than rest of the treatments except narrow raised bed residue retention (T_7) and conventional tillage residue retention (T_{11}) and least content per cent in grains (0.25%) and straw (0.10%) was under conventional tillage (T_{12}) over rest of the treatments. Among different tillage practices on uptake of phosphorus was more in grain than straw during experimentation (Table 4). The phosphorus uptake (kg ha^{-1}) in wheat grains and straw was significantly higher with wheat sown on wide raised beds residue retention (T_9) followed by wheat sown on narrow raised bed residue retention (T_7) > conventional tillage residue retention (T_{11}) > zero tillage residue retention (T_1) > reduced tillage residue retention (T_3) > roto till residue retention (T_5) > zero tillage without residue (T_2) > reduced tillage without residue (T_4) and roto till without residue (T_6) treatment however, the least phosphorus uptake in grains (8.07 kg ha^{-1}) and straw (4.21 kg ha^{-1}) was recorded under conventional tillage (T_{12}) plots. The total phosphorus uptake (kg ha^{-1}) revealed that wheat sown on wide raised bed residue retention (T_9) gave significantly higher total phosphorus uptake (26.90 kg ha^{-1}) by wheat grains and straw followed by wheat sown on narrow raised beds residue retention (T_7) > conventional tillage residue incorporation (T_{11}) > zero tillage residue retention (T_1) plots and wheat sown by reduced and roto residue retention, and T_{12} "conventional tilled" plots resulted in significantly lower (12.28 kg ha^{-1}) total phosphorus uptake during experimentation.

Table 4: Effect of tillage crop establishment methods on phosphorus content in grains (%), straw (%), and uptake in grains (kg ha^{-1}), straw (kg ha^{-1}) and total phosphorus uptake (kg ha^{-1}) in wheat

Treatments		Phosphorus content (%)		Phosphorus uptake (kg ha^{-1})		Total phosphorus uptake (kg ha^{-1})
		Grains	Straw	Grains	Straw	
T_1	Zero tillage residue retention	0.30	0.15	12.26	8.51	20.77
T_2	Zero tillage without residue	0.28	0.12	10.17	6.33	16.50
T_3	Reduce tillage residue retention	0.29	0.14	11.48	7.81	19.29
T_4	Reduce tillage without residue	0.28	0.11	9.97	5.76	15.73
T_5	Roto till residue retention	0.29	0.13	11.20	7.13	18.33
T_6	Roto till without residue	0.27	0.11	9.23	5.57	14.80
T_7	Narrow raised bed residue retention	0.32	0.16	14.28	9.64	23.92
T_8	Narrow raised bed without residue	0.28	0.12	10.11	6.27	16.39
T_9	Wide raised bed residue retention	0.34	0.17	16.15	10.74	26.90
T_{10}	Wide raised beds without residue	0.28	0.13	10.40	6.91	17.31
T_{11}	Conventional tillage residue incorporation	0.31	0.15	12.74	8.58	21.32
T_{12}	Conventional tillage	0.25	0.10	8.07	4.21	12.28
SEm (±)		0.01	0.001	0.54	0.26	0.73
C.D. (P=0.05)		0.03	0.003	1.56	0.74	2.08

Potassium

The potassium content was 3.8 times more in straw as compared to grain in wheat and showed significant variation with planting techniques during the year of study (Table 5). Wheat sown on wide raised bed residue retention (T_9) recorded significantly higher potassium content by grains and straw which was statistically at par with narrow raised bed residue retention (T_7) in grains and straw was T_7 and T_{11}. Although, treatments T_1, T_2, T_3, T_5, T_8, T_{10} and T_{11} was recorded statistically superior potassium content per cent in grains and straw of wheat over rest of the treatments. However, the treatment T_{12} was recorded statistically inferior followed by T_6 and T_4, respectively. Among different tillage practices was significant for potassium uptake of wheat grains and straw during the year of study (Table 5). Wheat sown wide raised bed residue retention (T_9) resulted significantly more potassium uptake in grains and straw than other treatments which was at par with T_7 in straw. Although, except treatments T_{12} in straw and in grains T_{12} and T_6 were recorded significantly inferior over rest of the treatments. Total potassium uptake in grains and straw clearly showed that wheat sown with wide raised bed residue retention (T_9) resulted significantly more total potassium uptake (85.50 kg ha^{-1}) except narrow raised bed residue retention (T_7) which was recorded statistically at par (Table 3). Though, the treatments T_1, T_2, T_3, T_5, T_{10} and T_{11} were recorded statistically superior over rest of the treatments. However, the treatment T_{12} was recorded least total potassium uptake (41.95 kg ha^{-1}) followed by T_8, T_6 and T_4 with the value of 52.19, 51.73 and 53.89 kg ha^{-1}, respectively.

Table 5: Effect of tillage crop establishment methods on potassium content per cent in grains, straw, uptake in grains, straw and total potassium uptake (kg ha^{-1}) in wheat

Treatments		Potassium content (%)		Potassium uptake (kg ha^{-1})		Total potassium uptake (kg ha^{-1})
		Grains	Straw	Grains	Straw	
T_1	Zero tillage residue retention	0.26	1.02	10.63	57.85	68.48
T_2	Zero tillage without residue	0.21	0.94	7.63	49.58	57.20
T_3	Reduce tillage residue retention	0.26	1.00	10.29	55.81	66.10
T_4	Reduce tillage without residue	0.19	0.90	6.77	47.12	53.89
T_5	Roto till residue retention	0.24	0.98	9.27	53.74	63.01
T_6	Roto till without residue	0.21	0.88	7.18	44.55	51.73
T_7	Narrow raised bed residue retention	0.29	1.10	13.23	66.28	79.51
T_8	Narrow raised bed without residue	0.20	0.80	7.22	44.97	52.19
T_9	Wide raised bed residue retention	0.31	1.12	14.73	70.77	85.50
T_{10}	Wide raised beds without residue	0.22	0.96	8.18	51.01	59.19
T_{11}	Conventional tillage residue incorporation	0.27	1.08	11.69	61.80	73.49
T_{12}	Conventional tillage	0.19	0.85	6.13	35.82	41.95
	SEm (±)	0.01	0.03	0.38	1.97	2.32
	C.D. (P=0.05)	0.02	0.09	1.10	5.82	6.78

Yield

Grain yield

The variations in grain yield due to main effects of various treatments were statistically significant during the year of study (Table 3). The tillage crop establishment influenced the maximum grain yield significantly in treatment T_9 (furrow irrigated wide raised beds residue retention) and T_7 (narrow raised beds residue retention, and T_{11} conventional till residue incorporation) (45.63 and 43.30 qha^{-1}) remained statistically at par with it. The reduction in grain yield with establishment techniques application was 6.6 and 7.3 per cent compared to T_1 (zero tillage) and T_3 (reduced tillage) application, respectively. However, raised beds registered 13.1 and 12.7% a significant yield improvement over conventional practices.

Economics

The economics of wheat crop affected by different tillage crop establishment practices (Table 6 and Fig.1). The cost of cultivation of wheat crop increases with the increasing tillage intensity although the increase was very nominal during the year of study. Among the different tillage practices the cost of cultivation was highest in T_7 narrow raised beds residue retention followed by conventional tillage residue incorporation (T_{11}) and it was lowest in zero tillage practices plots. Among the different tillage practices the highest gross income and net profit were recorded in wide raised beds residue retention plots (T_9). 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 B: C ratio was highest (3.41) in the zero tillage (T_2) and lowest (2.37) in conventional tillage treatment (T_{12}). The B: C ratio under the treatments were in the descending order of $T_1 > T_9 > T_4 > T_{10} > T_7 > T_3 > T_{11} > T_6 > T_8 > T_5$ respectively.

Table 6: Effect of tillage crop establishment practices on profitability of wheat

Treatments		Cost of cultivation (Rs. ha^{-1})	Gross return (Rs. ha^{-1})	Net return (Rs. ha^{-1})	B:C ratio
T_1	Zero tillage residue retention	29295	92217	62922	3.14
T_2	Zero tillage without residue	24196	82632	58436	3.41
T_3	Reduce tillage residue retention	31973	89570	57597	2.80
T_4	Reduce tillage without residue	26905	81249	54344	3.01
T_5	Roto till residue retention	34136	87513	53377	2.56
T_6	Roto till without residue	28759	78114	49355	2.71
T_7	Narrow raised bed residue retention	35660	102034	66374	2.86
T_8	Narrow raised bed without residue	30490	82148	51658	2.69
T_9	Wide raised bed residue retention	34115	106375	72260	3.11
T_{10}	Wide raised beds without residue	29254	84316	55062	2.88
T_{11}	Conventional tillage residue incorporation	34908	96838	61930	2.77
T_{12}	Conventional tillage	30356	72000	41644	2.37
Mean		35667	87917	52250	2.47

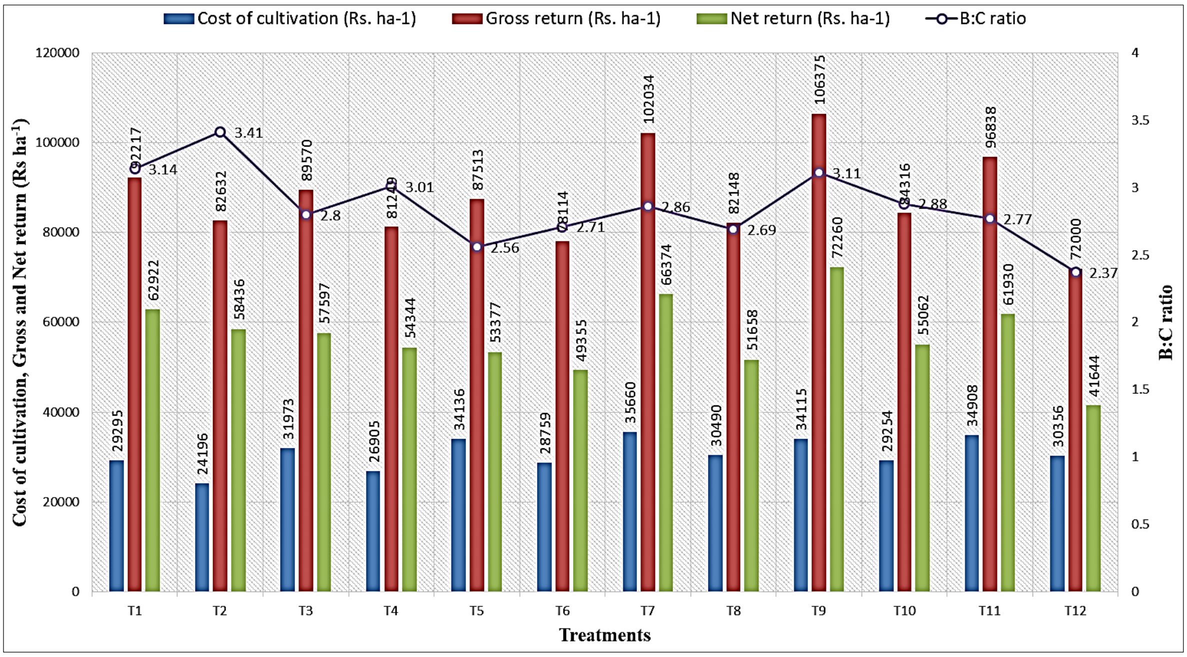

Fig 1: Effect of tillage crop establishment practices on profitability of wheat

Discussion

The seasonal variation in soil profile moisture content indicate that the average profile moisture varies between 14.4% and 12.5% among all the treatments, this zig-zag variation in average moisture content of profile was because of crop establishment management and the rainfall received during the crop season after the application of each irrigation the moisture content of the recharged profile reached at field capacity and in between the moisture content decreased in the profile due to high atmospheric evapo-transpiration demand, air temperature and longer day length. Similar results have been reported by Kumar and Yadav, 2005 [7-9, 12, 14]; Naresh *et al.*, 2012 [12, 14]. The quantum of moisture extraction from different soil profile layers decreased with the increase in profile depth. This low and highest moisture extraction from the deeper profile layer was may be due to low root density in deeper layers and from the top layer because of more root density and exposure of surface layer to the outer atmosphere which is more influenced by air temperature, sunshine hours and wind speed. In terms of percentage the moisture extracted from 30-60cm layer was around 29.8%, whereas, the water use from the surface was around 28.7% and moisture extracted from 15-30 cm was around 21.4%. The moisture extraction from combined 0-30 cm layer was around 50%. This fact can further be fortified by calculating the water use per cm of soil depth as in 0-15 cm layer. It was 0.44 cm cm^{-1} in T_1 and 0.55 cm cm^{-1} in T_9 in comparison to 30-60 cm layer, the respective values for T_7 and T_{11} are 0.31 and 0.38 cm cm^{-1}.The moisture extraction pattern in different treatments of tillage practices indicate that with the land configuration increase in the moisture extraction from surface layer has been increased and declined the moisture extraction from the deepest profile layer by 1-2% this may be because of more wetting of surface layer due to increased moisture availability resulted in more evaporation losses from the surface layer. Similar declining contribution of deeper profile layer to total crop water use trend was also seen by Dhaka *et al*., 2007 [3]. However, Maurya and Singh 2008 [6, 7, 9, 11, 12, 14], find that the crop establishment method affected the moisture depletion pattern, maximum total moisture depletion (24.07 and 22.83 cm) by wheat crop from each layer was recorded under conventional method of sowing as compared to the rest of the methods, such as zero tillage, rota till drill and bed planting method of crop establishment due to more availability of moisture in rhizosphere. The amount of moisture depleted decreased with the soil depth due to lower density of roots in deeper layer compared with the upper layer. Due to increased surface evaporation the percentage contribution of upper 30 cm layer was more. The highest moisture depletion under the conventional method might be due to less availability of moisture at upper layer and more evaporation from upper surface. Similar results have been reported by Zaman *et al*. 2006 [18]; Ram *et al*., 2013 [13]. The lowest consumptive use of water 11.8 cm was recorded in the deficit irrigation water supply crop which was the outcome of severe water stress to which the crop was exposed throughout the growth period. Inadequate moisture availability to the crop resulted in lower evapo-transpiration. Similarly under T_4, Aggarwal and Goswami (2003) [1] found that the water use by wheat crop was lower, whereas grain yield and water use efficiency were higher under treatment where 3 rows of wheat was sown on 37.5 cm wide beds separated by 30 cm furrow as compared to the conventional flat sowing and 2 rows sown on bed. Sowing of 3 rows of wheat on 37.5 cm wide bed alternating with 30 cm wide furrows in alluvial sandy-loam soils resulted in better soil physical environment, resulting in better root growth, reduced irrigation requirement because of furrow irrigation, significantly higher grain yield and increased water use efficiency compared with conventional flat sowing system with flood irrigation. The similar results were also reported by Limon *et al*. (2000) [10], Hobbs (2001) [4, 6]. The increasing availability of soil water was the only variable which could cause variations in the consumptive use of water of the crop. Higher soil moisture status in the soil profile due to frequent irrigation which cause better plant growth and led to higher soil moisture extraction. In general, the soil moisture extraction was higher from the top 30 cm depth in the treatments where crop was irrigated more frequently. This could be explained on the basis of fact that the top layers were moist almost throughout the crop season under the treatments involving frequent irrigations which led to favourable soil moisture conditions for higher consumptive use of water, particularly the component of evapo-transpiration from the top soil. The higher value of consumptive use with increased moisture supply was also observed by Naresh *et al*., (2012) and Kumar *et al*., (2015) [7-9, 12, 14].

The tillage crop establishment practices increased the NPK uptake by the crop with increase in moisture availability during the year of study. The nitrogen and phosphorous uptake was more through the grain (67% of total N and 63% of total P) and potassium was more through the straw (82% of total) than grain. The higher N and P uptake in grain because of its chemical composition due to higher amino acid and protein content in grain require more N and P, 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. The higher NPK uptake was mainly because of higher grain and straw yield in T9 followed by T7 compared to T11 during experimentation. Similar trend have been observed by Ingle *et al*. (2007) [5].

Tillage practices increased 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. Among the different tillage practices the highest net profit and B: C ratio was recorded in wheat sown on zero till (T1) plots. This may be because of higher efficiency of zero till systems than other tillage methods as well as comparatively higher increase in grain yield with zero till systems than in other treatment except FIRB system.

Conclusion

Among crop establishment methods and residue management, wide raised bed residue retention (T_9) significantly improved wheat yield over conventional tillage and higher nutrient uptake NPK over rest of the treatment. The Water productivity (WP) was remarkably low in conventional tillage (T_{12}) than FIRB, zero and reduced tillage crop establishment method by minimising evaporation and increase transpiration, hence improved yield and water use efficiency of wheat with zero tillage residue retention (T_1) and water productivity with wide raised bed residue retention (T_9) over rest of the treatments. The increase in water productivity under FIRB due to proportionate increases in grain yield with lesser number of irrigation. The maximum net profit was recorded with wide raised bed residue retention (T_9) and B:C ratio with zero tillage without residue (T_2) and lowest with conventional tillage (T_{12}). Thus, wide raised bed residue retention (T_9) found excellent to increase nutrient uptake, productivity and profitability of wheat crop.

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