Agriways 4 (2) : 168-177 (July - December, 2016)

ISSN: 2321-8614 (Print)
ISSN: 2454-2318 (Online)

OPTIMUM TILLAGE PRACTICES FOR EFFICIENT INCORPORATION OF RICE RESIDUE

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ABSTRACT

The rice- wheat is the important crop rotation covering nearly 69.3 million hectare area out of which 62% is under rice cultivation (FAO, 2005) leading to huge production i.e. 88.47 million tonnes of rice residue. The combine harvesters are becoming more popular among other agricultural machines available for harvesting of these two cereal crops. The rice residue left on the field after combine harvesting creates problem in preparing the seedbed for wheat crop. The farmers usually burn this valuable by- product, which is a threat to environment. A field experiment was carried out to study the various combinations of tillage practices for efficient incorporation of rice residue. The performance of different tillage systems was evaluated with respect to percent rice residue incorporation, energy requirement and energy output-input ratio. Percent rice residue incorporation was found maximum 94.82 per cent with mould board plough followed by 82.84 per cent with disc plough, 82.36 per cent in disc harrow and 65.36 percent with rotavator treatments. Minimum input energy of 13906.42 MJ/ha was consumed in T4 (rotavator) treatment whereas maximum 15726.05 MJ/ha was in T2 treatment. The maximum output energy was obtained in mould board plough (154562 MJ/ha) followed by disc plough (148776 MJ/ha), rotavator (145064 MJ/ha) and harrow (139764 MJ/ha) treatment respectively. The saving of energy in tillage operation in lowest energy consuming treatment T4 (rotavator) was 11.6 per cent as compared to highest energy consuming treatment T2 (mould board plough). Energy output-input ratio was found maximum (10.4) with rotavator tillage treatment and minimum (9.2) with disc harrow tillage treatment. Based on above, it could be said that treatment T2 (mould board plough) was found effective tool for incorporation of rice residue after combine harvesting of paddy field. The rotavator was found most time and energy saving treatment compared to other treatments. The energy output-input ratio was also found maximum in case of rotavator tillage treatment.

Kewords : Tillage, rice residue

India is a predominantly agricultural country. About 70% of its population depends on agriculture. Wheat and rice are the two major cereal crops that occupy about 5055% of the total cropped area of India. Wheat alone covers about 25% of the total area covered by cereal crops, which is next only to paddy (4045%). In northern state of India, such as Uttar Pradesh, Uttaranchal, Punjab and Haryana the traditional harvesting using sickle is mainly replaced by mechanical harvesting i.e. by the use of combine. This method not only saves time and energy of the farmer but also saves the crop being damaged due to natural calamities. Besides several advantages of combine harvester the main well known disadvantage is the loss of straw which could otherwise be used as a fuel, feed and fibre. At present, at least 80% of paddy and 75% of wheat are harvested by combine harvesters in Punjab (Garg and Singh, 2002). This invariably shows that much of the crop residue is left in the field as the combine harvester leaves 35 to 40 cm of straw stubbles above the ground level. These states account for about 200 million tonnes of crop residues, which is about 37% of the total crop residues, produced in India **(Barauch and Jain, 1998).** Crop residues could be an important component of soil fertility management. They are currently burnt, especially rice residues in the high-yielding states like Punjab, Haryana and western Uttar Pradesh leading to degradation of natural resources. Rice residues can be converted to high-value manure of a better quality than farmyard manure, and their use, along with chemical fertilisers, can help sustain or even increase yield **(Sharma *et al*., 2006)**. InorganicOn an average for every four tones of paddy nearly six tones of straw is produced which shows a large amount of crop residue availability for disposal every year. The cereal crop residues remaining after a grain harvest comprises 50-75% of the total cereal biomass produced. Incorporation of crop residue in soil and optimization of tillage requirements for rice and wheat could be possible ways to prevent the rapid deterioration of soil properties and yields **(Bajpai et al., 1995; Singh et al., 2004; Tripathi et al., 2005)**. The challenge is to use this seemingly waste material in an economic manner. The left out of rice crop residue poses difficulty in preparing the bed seed for wheat crop and requires multiplicity of tillage operation before it is cut into pieces and mixed into soil. The agricultural waste incorporated in soil increased the soil fertility substantially and consequently the production increases. This involves more time and labour of the farmer resulting into delayed sowing and increased cost of production. In intensive agriculture production system, the time available for seed bed preparation of wheat crop after rice harvesting is very limited. The total turn around time for wheat after rice is about 15 to 20 days and delay in any operation results into late sowing of wheat which causes low yield of wheat. It has been established that the delay in sowing causes a loss in the yield to extent of 35 to 40 kg/ha per day **(Hobbs, 1985)**. Therefore, land preparation for wheat crop after paddy harvesting, which consumes considerable time and energy, should be completed within a short period under optimum soil moisture condition by using efficient tillage practices. The various tillage practices should be so planned that they may consume least time and energy resulting into less cost of production without adversely affecting the quality of seed bed and crop yield.

Methodology

The field experiment was conducted at Crop Research Centre of Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, Udham Singh Nagar. The study includes various tillage practices for efficient incorporation of rice residue. The work was further extended to evaluate the economic feasibility of various tillage practices.

Tillage Treatments

In all four combinations of tillage treatments with tractor as power source was selected for conducting experiments. The different combination of tillage treatments was as follows:

T_1: Hand harvested + disc harrow 6 + Planker 1 (conventional tillage)

T_2: Combine harvested + m.b. plough 1 + disc harrow 4 + planker 1

T_3: Combine harvested + standard disc plough 1 + disc harrow 4+ planker 1

T_4: Combine harvested + rotavator 2 + planker 1

Results and discussion

Determination of rice residue availability

The amount of rice straw available prior to tillage operation was determined by placing a square frame of size 1 m 1 m randomly in each test field. The loose straw available within this frame was collected. Also the intact stubbles were cut from the ground level. The total weight of loose straw as well as stubbles present were determined and the data was expressed as amount of straw available per hectare basis. Similar readings were collected from various locations from the field and average of all such readings was worked out to determine the amount of straw available per hectare.

Determination of amount of straw incorporated

The amount of straw incorporated in various tillage treatments was determined by collecting the straw/residue available prior and after tillage treatments. The loose straw/residue was collected after tillage operation with the help of square frame of 1m 1m size in each plot. The frame was placed randomly in the each test plot after the final seedbed preparation was over. The loose straw/residue was collected within this frame and then weight of sample was taken. Finally the amount of straw incorporated was determined by using the following relationship.

$$W \quad \frac{Wb - Wa}{Wb} \quad 100$$

Where,

W = Amount of straw incorporated, percent

W_b = Amount of straw available before tillage operation, kg

W_a = Amount of straw available after tillage operation, kg

The above procedure was replicated at least three times in a particular test plot and then average was taken to determine the amount of straw incorporated in the plot.

Table 1 Amount of residue available before and after tillage operation and residue incorporation

Treatment	Residue before tillage operation, t/ha (db)	Residue left on the surface after tillage operation, t/ha (db)	Residue incorporated, %
T1	0.95	0.17	82.36
T2	5.22	0.26	94.82
T3	5.24	0.90	82.84
T4	5.29	1.83	65.36

Incorporation of residue

The observations recorded with respect to incorporation of residue in different treatments are presented in Table 1 and Fig.1. Table 1 indicates that the residue incorporation performed was found 94.8, 82.8, 82.4 and 65.4 percent of available rice residue into soil under treatment T3, T2, T1 and T4 respectively. The results indicate that incorporation of residue was found higher in mould board plough which accounted to 12.6, 12.1 and 30.7 percent more compared to the treatments T1, T3 and T4 respectively. Since, the mould board plough is an appropriate implement for inversion and higher depth of cut was obtained which, therefore, resulted in highest incorporation of residue.

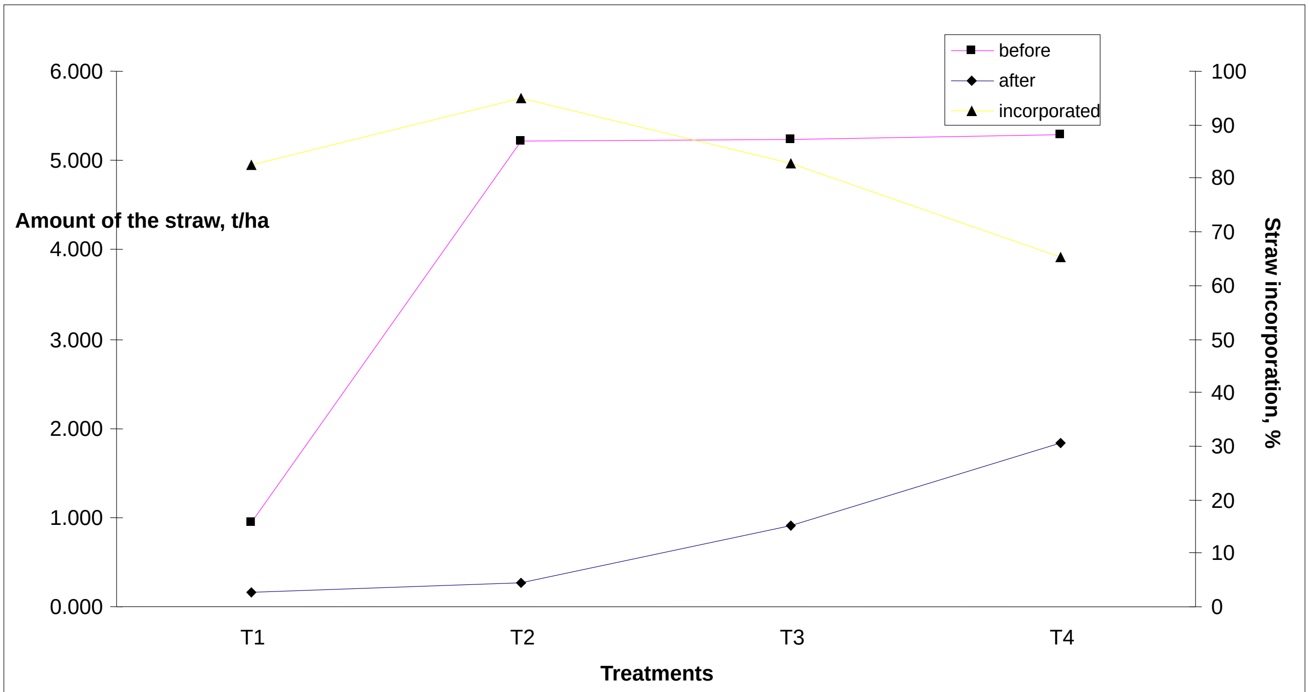

Fig. 1 Straw incorporation in different treatments and amount of residue available before and after the treatments

Determination of operation time

\ The operation time in respect of manual labour, tractor power and machines for all field operations were recorded by stop watch. The time taken by tractor along with implement and time lost while turning was recorded for different operations. The time spent in major break down was excluded as where the time required for minor repair and adjustment was included in the operational time.

Time required in performing various tillage operations for growing wheat is presented in Table 2. Table shows that the time required per hectare in tillage operation was 4.58 hours in T_4, 9.83 hours in T_1, 12.24 hours in T_3 and 13.04 hours in T_2 treatments respectively. Time required in sowing was 1.35 hours in all treatments. An equal amount of human hour has been used in respective treatments. Two man were required in sowing operation. Thus man-hour in sowing operation was just double. Total time required in tillage and sowing operation was 5.93 hours in T_4 followed by 11.18 hours in $T_{1,}$ 13.59 hours in T_3 and 14.39 hours in T_2 treatment.

Analysis of data shows that the total time required per hectare in tillage and sowing operation was 5.25, 8.46 and 7.66 hours more in treatment T_1, T_2 and T_3 respectively as compared to T_4 treatment. The total time required under treatment T_4 over $T_{1,}$ T_2 and T_3 treatments was 46.9, 58.7 and 56.3 percent respectively. The time saving in T_1 over T_2 and T_3 was 22.3 and 17.7 percent respectively. But the saving of time in T_3 over T_2 was 5.5 percent only. Thus it is clear that treatment T_4 was most time saving which was due to complete elimination of harrowing operation in this treatment. Amongst other treatments, T_1 was found a more time saving treatment.

Determination of fuel consumption

The quantity of fuel consumed in a particular operation for each machine was measured by top filling method. Before start of any operation the fuel tank was filled completely to its brim. After the operation was over the tractor was kept on samelevelled surface and the diesel was poured in the tank from a measuring cylinder. The amount required to fill the tank up to its brim gave the reading of diesel consumed.

Fuel required in performing tillage and sowing operations under various tillage practices are shown in Table 2 and Fig 1. The amount of diesel required per hectare in tillage operation was 40.63, 44.88, 42.75 and 17.00 litres in treatment T_1, T_2, T_3 and T_4 respectively whereas in sowing operation this requirement was 4.15 litre in all the treatments. Thus total amount of diesel required per hectare in tillage and sowing operation under various tillage practices were 44.78, 49.03, 46.90 and 21.15 litres in $T_{1,}$ T_2, T_3 and T_4 respectively.

Analysis of data shows that the total fuel consumptions per hectare in tillage and sowing operation compared to lower fuel consumption was 23.63, 27.88 and 25.75 litres more in treatment $T_{1,}$ T_2 and T_3 respectively as compared to T_4 . The saving of fuel in lowest fuel consuming operation T_4 over T_1, T_2 and T_3 were 58.16, 62.12 and 60.23 percent respectively. The saving of fuel in treatment T_1 over T_2 and T_3 were 9.46 and 4.95 percent respectively where as, saving of fuel in treatment T_3 over T_2 was approximately 4.75 percent only.

Tillage treatments	Time, h/ha	Fuel, l/ha
T_1	9.83	40.63
T_2	13.04	44.88
T_3	12.24	42.75
T_4	4.58	17.00

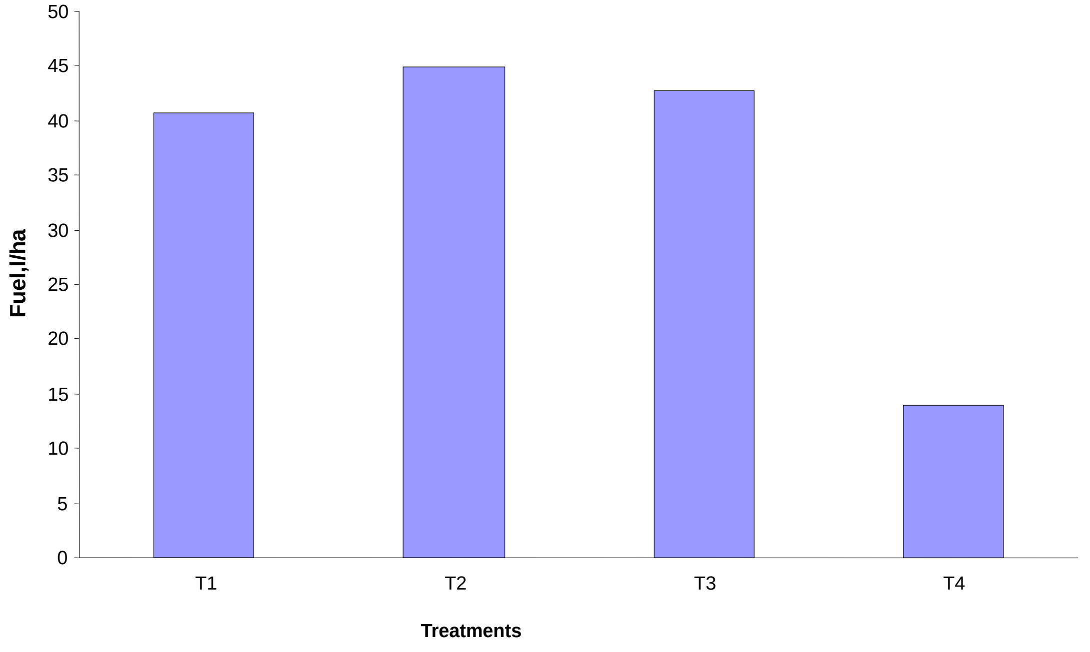

Fig.2 Fuel requirement in different tillage treatments

Determination of grain and straw yield

The crop within 1×1 m size M.S. bar frame was harvested at the ground level by sickle. The crop was weighed and threshed manually. The grains were separated form threshed crop using a blower. The weight of clean grain collected was measured by a balance and straw grain ratio was calculated. The process was repeated at least three times in each plot. The average grain and straw yield were calculated using the following relationship:

Average crop grain yield, kg/ha = (Average weight of grain collected from one square meter area, kg) × 10^4

Average straw yield, kg/ha = (Average weight of straw collected from one square meter area, kg) × 10^4

Table 3 Energy output- input ratio of different tillage treatment

Sl. No.	Treatment	Grain yield, kg/ha	Straw yield, kg/ha	Energy input, MJ/ha	Energy output (Grain), MJ/ha	Energy output (Straw), MJ/ha	Total energy output, MJ/ha	Output-input ratio
1	T_1	4105	5776	15187.73	60343.5	79420	139764	9.20
2	T_2	4470	6462	15726	65709	88852.5	154562	9.82
3	T_3	4242	6285	15473.7	62357.4	86418.8	148776	9.61
4	T_4	4127	6138	13906.4	60666.9	84397.5	145064	10.43

Grain yield

The data of grain yield is given in Table 3 shows that the yield is more in mould board plough treatment as compared to other tillage treatments. Analysis of variance shows that there was no significant effect of tillage treatments on grain yield. The yield in T_2 was 4470 kg/ha followed by 4242 kg/ha in T_3, 4127 kg/ha in T_4 and 4105 kg/ha in treatment T_1. Better yield in treatment T_2 was due to lower bulk density and cone index, better incorporation, more number of spikes per meter and better spike development compared to other treatments. Between treatment T_3 and T_4 the yield was slightly more in treatment T_3 (4242 kg/ha) as compared to T_4 (4127 kg/ha). This was also due to lower bulk density, cone index and better spike development

Straw yield

The straw yield is presented in Table3 shows that the straw yield had similar trend like grain yield. Analysis of variance shows that there was no significant effect of tillage on straw yield. The maximum straw yield was found in treatment T_2 (6462 kg/ha) followed by T_3 (6285 kg/ha), T_4 (6138 kg/ha) and T_1 (5776 kg/ha) treatments. Reason of above results may be better plant height and plant stand in respective treatments as compared to other treatments.

Determination of energy

The total energy requirement for growing a crop can be represented by the direct and indirect inputs of energy. The direct energy input is the energy required in carrying the field operations where as the indirect energy input includes energy required for manufacturing tractor and implements, seeds, fertilizers and chemicals. In this study we have exclude indirect energy input from manufacturing tractor and implements. The energy required for field operation was supplied through manual labour, tractor power and electric motor operated pump sets. The energy equivalent of various inputs required for growing a crop in the crop production system as suggested by **Panesar, B.S. (2002)** is presented in Appendix Table 3 .

Determination of harvesting, threshing and output energy

After taking the sample from crop yield, each plot was harvested manually. The man hours required for harvesting each plot were recorded. The harvesting energy then estimated by multiplying man- hours to the energy coefficient of 1.96 MJ/h. thus the average energy required for harvesting of each treatment was estimated accordingly. The harvested crop was piled equally at three places. The crop was threshed by a tractor operated thresher. Time, fuel consumption, man-hour and threshed were recorded for each pile. Later on it was averaged out and energy in threshing was estimated. The energy out put was calculated by taking energy coefficient of 14.7 MJ/kg for grain and 13.75 MJ/kg for residue as shown in above data.

Determination of energy output - input ratio

The output energy was calculated taking grain as main product and straw and residue as by product. The input energy was calculated taking direct and indirect field operation energy, energy from fertilizer, chemical and seed energy. The ratio of output energy to input energy is called as output - input ratio and presented in Table 3.

Table 4 Operation wise diesel, time and energy input per hectare of Treatment T1 for incorporation of rice residue

Sl. No.	**Operation**	**Time, h**	**Fuel, l**	**Direct energy input, MJ**			
1	Seed bed preparation			Human	Mech.	Elect	Total
	Harrowing						
	I	1.583	6.875	3.10268	387.1313		390.2339
	II	1.916	7.25	3.75536	408.2475		412.0029
	III	1.875	7	3.675	394.17		397.845
	IV	1.458	6.5	2.85768	366.015		368.8727
	V	1.458	6.5	2.85768	366.015		368.8727
	VI	1.458	6.5	2.85768	366.015		368.8727
	Sub-total	**9.748**	**40.625**	**19.10608**	**2287.594**		**2306.7**
2	Fertilizer application	4.5		8.82	0		8.82
3	Sowing	1.35	1.66	2.646	93.4746		96.1206
4	Irrigation	7		13.72		44.5	58.22
5	Weeding	284.7		558.012			558.012
6	Harvesting	201.3		394.548			394.548
7	Threshing	8.21	32.84	16.0916	1849.22		1865.312
	Total Operational energy	**516.808**	**75.125**	**1012.944**	**4136.814**	**44.5**	**5287.732**
	Seed						1470
	Fertilizer						8310
	Chemical						120
	Total energy						**15187.73**

Table-5: Operation wise diesel, time and energy input per hectare of treatment T2 for incorporation of rice residue

Sl. No.	Operation	Time, h	Fuel, l	Direct energy input, MJ			
1	Seed bed preparation			Human	Mech.	Elect	Total
a	MB plough	3.75	10.375	7.35	584.2163		591.5663
b	Harrowing						
	I	2.666667	9.75	5.226667	549.0225		554.2492
	II	2.458333	9.5	4.818333	534.945		539.7633
	III	2.291667	7.75	4.491667	436.4025		440.8942
	IV	1.875	7.5	3.675	422.325		426
	Sub total	**13.04167**	**44.875**	**25.56167**	**2526.911**		**2552.473**
2	Fertilizer application	4.5		8.82	0		8.82
3	Sowing	1.35	4.15	2.646	233.6865		236.3325
4	Irrigation	7		13.72		44.5	58.22
5	Weeding	270.8		530.768			530.768
6	Harvesting	208.3		408.268			408.268
7	Threshing	8.94	35.76	17.5224	2013.646		2031.168
	Total operational energy	**513.9317**	**84.785**	**1007.306**	**4774.243**	**44.5**	**5826.049**
	Seed						1470
	Fertilizer						8310
	Chemical						120
	Total energy						**15726.05**

Table-6: Operation wise diesel, time and energy input per hectare of treatment T3 for incorporation of rice residue

Sl. No.	Operation	Time, h	Fuel, l	Direct energy input, MJ			
1	Seed bed preparation			Human	Mech.	Elect	Total
a	Disc plough	3.82	10	7.4872	563.1		570.5872
b	Harrowing						
	I	2.45	9.25	4.802	520.8675		525.6695
	II	2.291	9	4.49036	506.79		511.2804
	III	2	7.75	3.92	436.4025		440.3225
	IV	1.67	7	3.2732	394.17		397.4432
	Sub-total	**12.231**	**43**	**23.97276**	**2421.33**		**2445.303**
2	Fertilizer application	4.5		8.82	0		8.82
3	Sowing	1.35	4.15	2.646	233.6865		236.3325
4	Irrigation	7		13.72	0	44.5	58.33
5	Weeding	250		490	0		490
6	Harvesting	208.3		408.268	0		408.268
7	Threshing	8.48	33.92	16.6208	1910.035		1926.656
	Total operational energy	**491.861**	**81.07**	**964.0476**	**4565.052**	**44.5**	**5573.709**
	Seed						1470
	Fertilizer						8310
	Chemical						120
	Total energy						**15473.71**

Table 7 Operation wise diesel, time and energy input per hectare of treatment T4 for incorporation of rice residue

Sl. No.	Operation	Time, h	Fuel, l	Direct energy input, MJ			
1	Seed bed preparation			Human	Mech.	Elect	Total
	Rotavator x2	4.58	17	8.9768	957.27		966.2468
2	Fertilizer application	4.5		8.82	0		8.82
3	Sowing	1.35	4.35	2.646	244.9485		247.5945
4	Irrigation	7		13.72	0	44.5	58.33
5	Weeding	229.2		449.232	0		449.232
6	Harvesting	205		401.8	0		401.8
7	Threshing	8.25	33	16.17	1858.23		1874.4
	Total operational energy	**459.88**	**54.35**	**901.3648**	**3060.449**	**44.5**	**4006.423**
	Seed						1470
	Fertilizer						8310
	Chemical						120
	Total energy						**13906.42**

Energy Requirement for Wheat Production under Various Tillage Practices

The total energy required from various sources under various tillage treatments for wheat production is presented in Table 4 to Table 7 and Fig. 3 It was observed that the total energy input (direct and indirect energy) was 15181.73, 15726.05, 15473.71 and 13906.42 MJ/ha in treatments $T_{1,}$ $T_{2,}$ T_3 and T_4 treatment respectively. The direct energy consumed in tillage operation was 5287.73, 5826.10, 5573.71 and 4006.43 MJ/ha which was 34.43,37.04, 35.44 and 28.81 percent of total energy in $T_{1,}$ $T_{2,}$ T_3 and T_4 treatments respectively. The highest energy of 15726.05 MJ/ha was consumed in treatment T_2 followed by 15473.71 MJ/ha in T_3, 15181.73 MJ/ha in T_1 and 13906.42 MJ/ha in T_4 respectably. The saving of energy in tillage operation in lowest energy consuming treatment T_4 was 11.6 percent as compared to highest energy consuming treatment T_2. The saving of energy in case of T_3 was 1.6 percent over highest energy consuming treatment T_2. The energy saving in T_4 over T_1 and T_3 was 8.4 and 10.1 percent respectively. Analysis shows that maximum energy was consumed in harrowing operation in all treatments. Mould board plough consumed higher energy than disc plough because more fuel consumption was recorded in mould board plough. In treatment T_1 the subsequent operation of harrow resulted in almost equal amount of energy except second operation which may be due to harrowing operation done as width wise and may be due to slippage of tractor resulting higher time and energy consumption in next operation. Harrowing operation in T_2 treatment consumed higher energy as compared to T_1 and T_3 treatments because bigger size of clod was observed after ploughing operation resulting into higher time and energy consumption in T_2 treatment. The energy consumption in fertilizer, seed and chemical used was same in all the treatments because recommended doses of input were applied in all the treatments under study. The harvesting operation was done manually and threshing was done using 50 hp tractor with thresher in all the treatments. The energy consumption in harvesting and threshing was highest in treatment T_2 as compared to other treatments. This was due to higher levels of wheat yield obtained in treatment T_2.

Energy Output Input Ratio in Different Tillage Practices

The energy consumed through field operations, seed, fertilizer and chemicals in growing wheat crop represents the energy inputs as where the energy available from grain and straw yield represents the energy out put. The energy output input ratios are presented in Table 3 for various tillage treatments under study. The Table 3 shows that the maximum output energy of 154562 MJ/ha was obtained in treatment T_2 followed by 148776 MJ/ha in T_3, 145064 MJ/ha in T_4 and 139764 MJ/ha in T_1 treatment respectively. The total energy consumption in T_3 and T_1 is almost same but the yield of wheat crop is more by 137 kg/ha in treatment T_3. The energy output- input ratios showing energy balance of the system indicate that treatment T_4 produced maximum output- input ratio of 10.43 followed by 9.82 in T_2, 9.61 in T_3 and 9.2 in T_1 treatment respectively. The energy output ratio of T_2 and T_3 is almost same. It is evident from output- input ratio that treatment T_4 was most efficient than other treatments.

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