RESEARCH PAPER International Journal of Agricultural Engineering | Volume 12 | Issue 1 | April, 2019 | 87-95
ISSN–0974–2662 ■ Visit us : *www.researchjournal.co.in* ■ **DOI: 10.15740/HAS/IJAE/12.1/87-95**

Energy analysis of different sowing equipment for cultivation of wheat crop (*Triticum aestivum* G.)

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Received : 12.11.2018; **Revised :** 15.02.2019; **Accepted :** 06.03.2019

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■ **ABSTRACT :** The energy analysis and performance of four sowing equipment treatment was determined for cultivation of wheat crop. Four different treatment such as zero till seed-cum-fertilizer drill, roto till seed-cum-fertilizer drill, 1x cultivator + 1 x disc harrow + seed-cum- fertilizer drill,1 x cultivator + 2 x disc harrow + raised bed planter at all prevailing environmental condition such climatic condition *i.e.* temperature and relative humidity, physical properties of soil *i.e.* soil moisture content, bulk density and shear strength, as well as machine and crop parameters were studied before sowing treatment (Aikins and Afuakwa, 2010). There are several drills like conventional, zero till, roto till, raised bed planting etc. can be used for sowing wheat. The improved machines not only deliver the desired amount of seed and fertilizer but also save time and energy. In each treatment the energy consumed in the form of direct energy, indirect energy, renewable energy, non-renewable energy, commercial energy and non-commercial energy was estimated taking into account all the inputs like seed, fertilizer, FYM, machines, human labour, diesel, etc. The source wise energy was minimum (13178.30MJ/ha) in treatment T_2 and 13300.19MJ/ha, 14236.79MJ/ha and 14686.61MJ/ha in treatments T_1, T_3 and T_4, respectively. The operation wise energy was minimum (5066.30MJ/ha) in treatment T_2 and 5188.19MJ/ha, 6124.79MJ/ha and 6574.61MJ/ha in treatments T_1, T_3 and T_4, respectively (Arvidsson, 2010). The performance of seed drill is improved by manipulating the depth of sowing and thickness of soil cover over the seed as well as pressing the soil cover. Better soil pulverization was observed in case of treatment T_2 where seed bed was prepared by rotary tiller. Cone index was found to be minimum at different depths in treatment T_4 which includes 1 x cultivator followed by 2 x disc harrow then sowing by using raised bed planter. The similar trend was observed even at 100 DAS. The field efficiency was found to be maximum (77.02%) in treatment T_1 and minimum (60.91%) in treatment T_4. Number of plants/m length, seed emergence, plant population were also less in treatment T_1 and similar in treatment T_2, T_3 and T_4. It was found more in treatment T_4 (Atkinson *et al.*, 2007).

■ **KEY WORDS :** Energy, Fertilizer, FYM, Machines, Human labour, Diesel,Seed drill, Planter, Economics

■ **HOW TO CITE THIS PAPER :** Waghmode, Arun and Patel, Rajneesh (2019). Energy analysis of different sowing equipment for cultivation of wheat crop (*Triticum aestivum* G.). *Internat. J. Agric. Engg.*, **12**(1):87-95, **DOI: 10.15740/HAS/IJAE/12.1/87-95.**

The energy requirement in various activities in crop production agriculture varies considerably due to variation on technology level adopted by the farmers and also because of diverse agro-climatic conditions (Mittal *et al.*,1985). Energy plays a vital role in increasing agricultural productivity and energy from various sources is derived in agriculture.

India is basically agriculture based country covering agricultural land about 199.15 mha out of 329 mha in 2009 total geographical area (World Bank Report, 2010) and 75 per cent of farmers in the country are having land holding less than 2 ha and 70 per cent of the cropped in rain fed. The average yield of wheat in Madhya Pradesh and in India is 1835 kg/ha and 2830 kg/ha, respectively (Agricultural Statistics of Madhya Pradesh, 2009, Commissioner, Land Record, Gwalior). All major agri-input contribute to energy investment in production agriculture and it is a fact that the energy input is directly proportional to the productivity higher farm power availability has enhanced from 0.64 kw/ha in 1998 to 1.5 kw/ha in 2011. The commercial energy used in agriculture increased nearly six fold with growth rate of 11.8 per cent between 1980-81 to 2000 but share of agriculture in total energy consumption in the country increased 2.3-5.2 per cent during same period (Surendra Singh, 2002). Madhya Pradesh is the largest state having geographical area 31 mha along with cropping intensity of 135 per cent with net sowing area of 16 mha. Agriculture contribute 44 per cent to the state economy. Multiple cropping schemes in Madhya Pradesh were possible through the extension facility to 32 per cent (in 2002) and mechanization of agriculture through extensive use of tractors, seed drills, multi-crop threshers, combined harvesters etc.

■ METHODOLOGY

The experiment field was conducted in field number 44 of the form of Jawaharlal Nehru Krishi Vishwa Vidyalaya Jabalpur (M.P.) in 2012. The university is located at 23°13'15.32" N and 79°57' 50.82" E and 390 m above MSL. Soil type was clay loam which has sand-29.10 per cent, silt-20.15per cent, clay-50.75 per cent.

The following four treatments were selected for the experiment:

T_1 = Zero till seed-cum-fertilizer drill,

T_2 = Roto till seed-cum-fertilizer drill,

T_3 = 1 x cultivator + 1 x disc harrow + seed-cum-fertilizer drill,

T_4 = 1 x cultivator + 2 x disc harrow + raised bed planter.

Energy requirement :

In each treatment the energy consumed in the form of direct energy, indirect energy, renewable energy, non-renewable energy, commercial energy and non-commercial energy was estimated taking into account all the inputs like seed, fertilizer, FYM, machines, human labour, diesel, etc. (Canakei *et al.*, 2005)

The estimation of energy was done as explained below. The energy equivalent used in the study is shwon in appendix.

Energy from direct sources:

DE = HLH x 1.96 + BPH x 14.07+ FC x 56.31 + EC x 11.9 ..(1)

where,

DE = Direct energy (MJ),

HLH = Human labour hour used (h/ha),

BPH = Bullock paired hour used (h/ha),

FC = Fuel consumption (lit/ha),

EC = Electricity consumption (kWh/ha).

Energy from indirect sources:

IE = C x WM x OA + FYM x 0.3(MJ/kg) + S x 14.7 (MJ/kg) +CH x 120 (MJ/kg) x Fertilizer (N x 60.0 x P x 11.1 x K x 6.7)..(2)

where,

IE = Indirect energy input from machinery (MJ),

C = Energy co-efficient (MJ/kg),

WM = Weight of machinery used/h (kg),

OA = Operation area (ha),

FYM = Farm yard manure (kg/ha),

S = Seed (kg/ha),

CH = Chemicals (lit/ha),

N = Nitrogen (kg),

P = Phosphorus (kg),

K = Potash (kg).

Total energy:

TE = DE + IE ...(3)

where,

TE = Total energy (MJ) (Burhan *et al.*, 2004).

Soil parameters:

Soil moisture content:

The moisture per cent (dry basis) was calculated using the relationship given below.

$$Mc\ (db) = \frac{(Ww - Wd)}{Wd} \times 100 \qquad ...(4)$$

where,

Mc (db) = Moisture content dry basis (%),

Ww = Weight of undried soil (g),

Wd = Weight of oven dried soil (g).

Bulk density:

The bulk density of soil was determined by using following formula:

$$BD = \frac{M}{V} \quad ...(5)$$

$$V = \frac{\pi D^2}{4} x L \quad ...(6)$$

where,

BD = Soil bulk density (g/cc),

M = Dry soil mass in the core cutter (g),

V = Volume of cylindrical core cutter (cm³),

D = Diameter of cylindrical core cutter (cm),

L = Length of cylindrical core cutter (cm) (Benjamin and Cruse, 1987).

Machine parameters:

Field efficiency:

The field efficiency is the ratio of actual field capacity (ha/h) to the theoretical field capacity (ha/h).

Theoretical field capacity:

The theoretical field capacity was calculated using the relationship given below:

$$\text{Theoretical field capacity}\left(\frac{ha}{h}\right) = \frac{\text{Rated width of equipment (m) x Speed of operation}\left(\frac{km}{h}\right)}{10} \quad ..(7)$$

Actual field capacity:

The actual field capacity was also calculated as per eq.

$$\text{Actual field capacity}\left(\frac{ha}{h}\right) = \frac{\text{Width of field coverage (m) x Length of field coverage (m)}}{\text{Time for cover ring total area (h) x 10000}} \quad ..(8)$$

The field efficiency was calculated using eq.

$$\text{Field efficiency (\%)} = \frac{\text{Actual field capacity}\left(\frac{ha}{h}\right)}{\text{Theoretical field capacity}\left(\frac{ha}{h}\right)} x\,100 \quad ..(9)$$

Fuel consumption:

For the measurement of fuel consumption (l/h) the intake and over flow fuel line is connected to a cylindrical plastic box from bottom and top. The cylindrical plastic box has the capacity of 2.8 lit and having the marking in 50ml apart. In each treatment the time of operation, area covered and the fuel consumed (ml) was observed and fuel consumption was estimated as given below:

$$\text{Fuel consumption}\left(\frac{1}{ha}\right) = \frac{\text{Fuel consumption}\left(\frac{ml}{s}\right)}{\text{Area covered}\left(\frac{m^2}{s}\right)} x\,1 \quad ...(10)$$

RESULTS AND DISCUSSION

The results obtained from the present investigation as well as relevant discussion have been summarized under following heads :

Energy requirement:

Source wise energy (MJ/ha) consumption under different treatments:

The energy consumed in electric motor, seed and fertilizer was same in all treatments which are because the time and number of irrigation (four times), seed rate and fertilizer rate was same in all treatments. The total energy consumed in treatment T_1 (13300.19MJ/ha) was lowest because the sowing was done directly by a zero till drill without field preparation. The highest source wise energy consumption was 14686.61 MJ/ha in case of treatment T_4 because field was prepared by 1 x cultivator followed by 2 x disc harrow then sowing by a raised bed planter. The total source wise energy required in case of treatment T_2 was 13178.30MJ/ha in which sowing was done directly by using a roto till drill which perform soil tillage and sowing simultaneously. The total source wise energy consumed in case of treatment T_3 was 14236.79MJ/ha which is higher than T_1 and T_2 as in this treatment seed bed was prepared by 1 x cultivator followed by 1 x disc harrow and then sowing was done using a conventional seed cum fertilizer drill. The energy

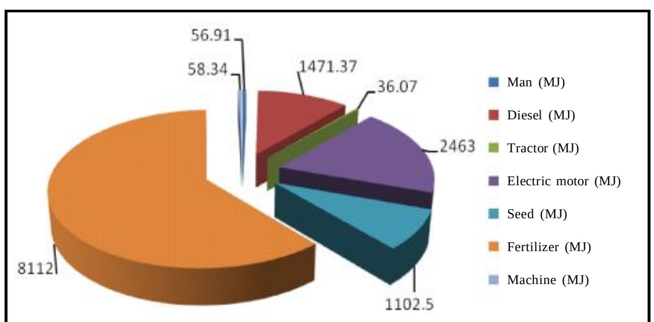

Fig. 1 : Source wise energy (MJ/ha) consumption under T_1 treatment

consumed in man, diesel, tractor and machine in case of treatment T_1 was 56.91, 1471.37, 36.07 and 58.34MJ/ha, respectively. In case of T_2 treatment, the energy consumed by man, diesel, tractor and machine was 4.62 per cent, 43.03 per cent, 51.42 per cent and 3.19 per cent, respectively. In case of treatment T_3 it was 69.69, 2321.76, 105.69MJ/ha. Whereas in treatment T_4 energy consumed by man, diesel, tractor and machine was 7.37 per cent, 16.21 per cent, 43.45 per cent and 32.33 per cent, respectively. It appears that energy consumed in man, diesel, tractor and machine in treatment T_1, T_2, T_3 and T_4 was less than T_4 because the treatment T_4 required more energy input in field preparation and sowing (Table 1) (Dipankar and Babu, 2004).

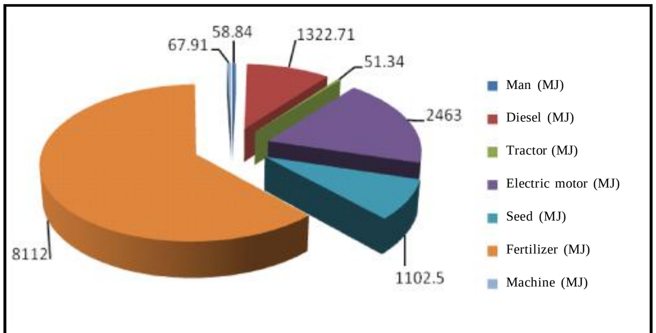

Fig. 2 : Source wise energy (MJ/ha) consumption under T_2 treatment

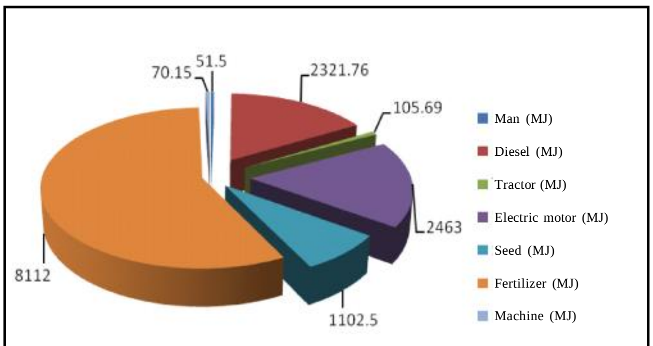

Fig. 3 : Source wise energy (MJ/ha) consumption under T_3 treatment

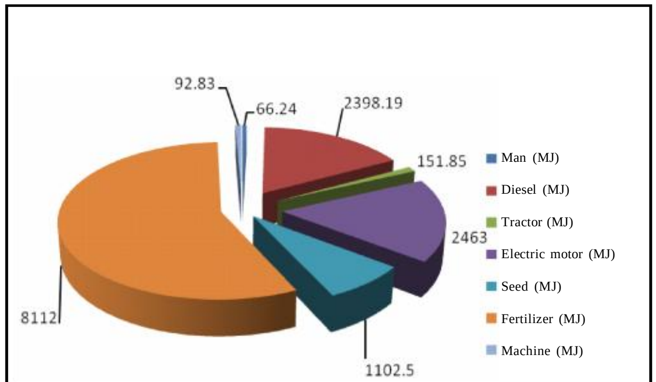

Fig. 4 : Source wise energy (MJ/ha) consumption under T_4 treatment

Operation wise energy (MJ/ha) consumption under different treatments:

The energy consumption in operations irrigation, top dressing, combine harvesting, threshing and transportation of grain was same in all treatments which are 2482.7, 10.19, 468.77 and 139.93 MJ/ha because the time consumed was near about same in all treatments.

Table 1: Source wise energy (MJ/ha) consumption under different treatments

Treatments	Man	Diesel	Tractor	Electricity	Seed	Fertilizer	Machine	Total	Energy (%less than T_4)
T_1	56.91	1471.37	36.07	2463	1102.5	8112	58.34	13300.19	9.44
T_2	58.84	1322.71	51.34	2463	1102.5	8112	67.91	13178.30	10.26
T_3	61.69	2321.76	105.69	2463	1102.5	8112	70.15	14236.79	7.21
T_4	66.24	2698.19	151.85	2463	1102.5	8112	92.83	14686.61	-

Table 2 : Operation wise energy (MJ/ha) consumption under different treatments

Treatments	Tillage	Sowing	Interculture	Irrigation	Fertilizer application	Combine harvesting and threshing	Transportation of grain	Total	Energy (% less than T_4)
T_1	0	2072.1	14.52	2482.7	10.19	468.77	139.93	5188.19	21.08
T_2	0	1953.4	11.27	2482.7	10.19	468.77	139.93	5066.3	22.94
T_3	1254.8	1761.9	6.45	2482.7	10.19	468.77	139.93	6124.79	16.09
T_4	1478.4	1994.6	0	2482.7	10.19	468.77	139.93	6574.61	-

The total energy consumed in treatments T_1, T_2, T_3 and T_4 was 5188.19, 5066.3, 6124.79 and 6574.61MJ/ha, respectively (Table 2). It is evident from the Fig. 5 to 8 that total operation wise energy consumed was highest in case of treatment T_4 because the tillage operation involved was 1 cultivator followed by 2 x disc harrow then sowing by raised bed planter. The lowest source wise energy consumption was in case of treatment T_2 because of the reason that field preparation and sowing was done directly by using roto till drill. The treatment T_3 had also more operation wise energy consumption then treatment T_1 and T_2 because of the reason that first field was prepared by using 1 x cultivator followed by 1 x disc harrow then sowing by seed cum fertilizer drill. The treatment T_1 has slightly more energy consumption than treatment T_2 because the sowing was done without field preparation by zero till seed cum fertilizer drill had inverted-T type furrow that caused more fuel consumption due to higher pull, it also required more time for interculture (weeding).

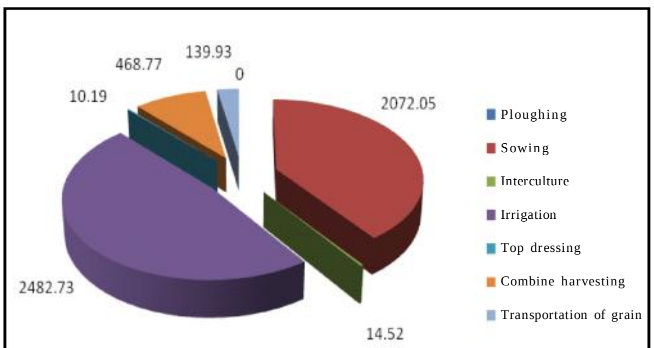

Fig. 5 : Operation wise energy (MJ/ha) consumption under T_1 treatment

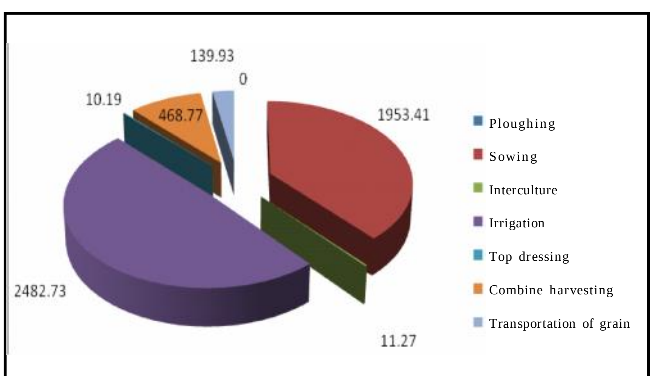

Fig. 6 : Operation wise energy (MJ/ha) consumption under T_2 treatment

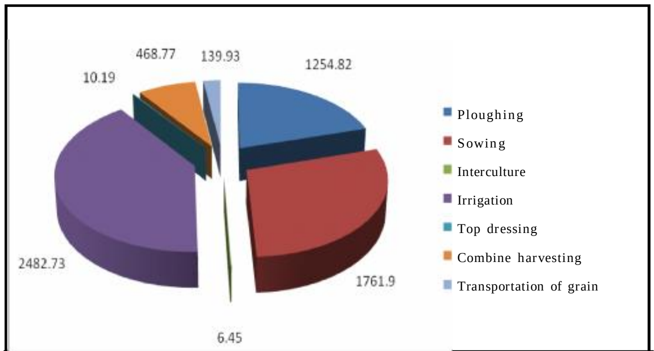

Fig. 7 : Operation wise energy (MJ/ha) consumption under T_3 treatment

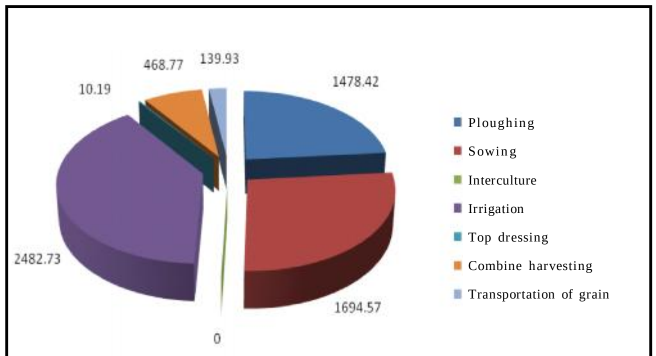

Fig. 8 : Operation wise energy (MJ/ha) consumption under T_3 treatment

The energy consumed in tillage operation in case of T_1 and T_2 treatment was zero (0) because field preparation was not done, the sowing is done directly by using zero till seed cum fertilizer drill and roto till seed cum fertilizer drill. In case of T_4 treatment the energy consumed was 17.82 per cent more than T_3 treatment due to additional a operation of disc harrow. The energy consumed in sowing operation in case of T_1, T_2 and T_4 treatment was 17.61 per cent 10.87 per cent and 13.21 per cent, respectively more than T_2. The energy consumed in interculture in case of T_1 and T_2 treatment was 125.12 per cent and 74.73 per cent more than T_3 treatment because of the reason that the sowing was done without field preparation that's why the weed grown intensity was more in treatment T_1 then T_2 treatment and T_3 treatment. In case of T_4 treatment the energy consumed in interculture operation was zero because pulverization and uprooting of weeds were grown minimum that's why there was no need of weeding (Mousavi-Avval *et al*., 2011).

Soil parameters:

Moisture content:

It is evident from the figure that before any tillage treatment was performed the soil moisture content was 18.8 per cent, 19.7 per cent and 24.2 per cent at 25, 50 and 75mm soil depth, respectively. Further the moisture content at shallower depth was found less due to the reason that on soil surface or at shallow depth the moisture loss occurs due to evaporation.

Bulk density:

In case of zero tillage treatment, there was virtually no change in bulk density after sowing as using this machine only a slit is formed for placing seeds in the field and there is no disturbance of soil. In the same treatment the bulk density after 100 DAS was observed to be 1.92g/cc which *i.e.* an increase from 1.56 to 1.92g/cc and with time this indicate more soil compaction. In case of roto till drill the bulk density reduced to 1.48g/cc from 1.56g/cc. The reduction is due to tilling of soil by rotary blades to a depth of 50mm. In this treatment the bulk density after 100 DAS was found 1.89g/cc. In treatment T_3 the bulk density reduced to 1.47g/cc after sowing from initially observed value of 1.56g/cc. This reduction in bulk density is because of the reason that the soil was tilled using 1 x cultivator followed by 1 x disc harrow, bulk density after

Table 3: Average energy for wheat crop of one ha for zero tillage sowing method

Sr.No.	Name of operation	Direct source of energy				Indirect source of energy			Total
		Man (MJ)	Diesel (MJ)	Tractor (MJ)	Electricity (MJ)	Seed (MJ)	Fertilizer (MJ)	Machine (MJ)	
1.	Sowing	10.27	908.28	30.29	0	1102.5	0	20.71	2072.05
2.	Interculture	14.52	0	0	0	0	0	0	14.52
3.	Irrigation x 4 times	19.73	0	0	2463	0	0	0	2482.73
4.	Top dressing	10.19	0	0	0	0	0	0	10.19
5.	Plant protection	Nil	0	0	0	0	0	0	Nil
6.	Fertilizers								
	N	0	0	0	0	0	7200	0	7200
	P	0	0	0	0	0	666	0	666
	K	0	0	0	0		246	0	246
7.	Harvesting + Threshing (combine harvester)	1.22	433.58	0	0	0	0	33.97	468.77
8.	Transportation of grain	0.98	129.51	5.78	0	0	0	3.66	139.93

Table 4: Average energy for wheat crop of one ha for roto tillage sowing method

Sr. No.	Name of operation	Direct source of energy				Indirect source of energy			Total
		Man (MJ)	Diesel (MJ)	Tractor (MJ)	Electricity (MJ)	Seed (MJ)	Fertilizer (MJ)	Machine (MJ)	
1.	Sowing	15.45	759.62	45.56	0	1102.5	0	30.28	1953.41
2.	Interculture	11.27	0	0	0	0	0	0	11.27
3.	Irrigation x 4 times	19.73	0	0	2463	0	0	0	2482.73
4.	Top dressing	10.19	0	0	0	0	0	0	10.19
5.	Plant protection	Nil	0	0	0	0	0	0	Nil
6.	Fertilizers								
	N	0	0	0	0	0	7200	0	7200
	P	0	0	0	0	0	666	0	666
	K	0	0	0	0		246	0	246
7.	Harvesting + Threshing (combine harvester)	1.22	433.58	0	0	0	0	33.97	468.77
8.	Transportation of grain	0.98	129.51	5.78	0	0	0	3.66	139.93

100 DAS was found 1.84g/cc.

Machine parameter:

Field efficiency:

The field efficiency was found to be 77 per cent, 66.4 per cent, 63.3 per cent and 60.9 per cent in treatments T_1, T_2, T_3 and T_4, respectively. The higher field efficiency was observed in case of zero till drill probably due to lesser wheel slippage as the machine operates in no tilled soil and better maneuverability with

Table 5: Average energy for wheat crop of one ha for conventional tillage sowing method

Sr. No.	Name of operation	Direct source of energy				Indirect source of energy			Total
		Man (MJ)	Diesel (MJ)	Tractor (MJ)	Electricity (MJ)	Seed (MJ)	Fertilizer (MJ)	Machine (MJ)	
1.	Tillage								
	Cultivator x 1	5.78	873.93	34.11	0	0	0	5.83	919.65
	Disc harrow x 1	5.73	290.67	31.57	0	0	0	7.2	335.17
2.	Sowing	11.61	594.07	34.23	0	1102.5	0	19.49	1761.9
3.	Interculture	6.45	0	0	0	0	0	0	6.45
4.	Irrigation x 4 times	19.73	0	0	2463	0	0	0	2482.73
5.	Top dressing	10.19	0	0	0	0	0	0	10.19
6.	Plant protection	Nil	0	0	0	0	0	0	Nil
7.	Fertilizers								
	N	0	0	0	0	0	7200	0	7200
	P	0	0	0	0	0	666	0	666
	K	0	0	0	0		246	0	246
8.	Harvesting + Threshing (combine harvester)	1.22	433.58	0	0	0	0	33.97	468.77
9.	Transportation of grain	0.98	129.51	5.78	0	0	0	3.66	139.93

Table 6 : Average energy for wheat crop of 1 ha for raised bed tillage sowing method

Sr. No.	Name of operation	Direct source of energy				Indirect source of energy			Total
		Man (MJ)	Diesel (MJ)	Tractor (MJ)	Electricity (MJ)	Seed (MJ)	Fertilizer (MJ)	Machine (MJ)	
1.	Tillage								
	Cultivator x 1	5.78	813.93	34.14	0	0	0	5.83	859.68
	Disc harrow x 1st	5.73	290.67	31.57	0	0	0	7.19	335.16
	Disc harrow x 2nd	4.74	244.49	27.98	0	0	0	6.37	283.58
2.	Sowing	17.87	786.01	52.38	0	1102.5	0	35.81	1994.57
3.	Interculture	0	0	0	0	0	0	0	0
4.	Irrigation x 4 times	19.73	0	0	2463	0	0	0	2482.73
5.	Top dressing	10.19	0	0	0	0	0	0	10.19
6.	Plant protection	Nil	0	0	0	0	0	0	Nil
7.	Fertilizers								
	N	0	0	0	0	0	7200	0	7200
	P	0	0	0	0	0	666	0	666
	K	0	0	0	0		246	0	246
8.	Harvesting + Threshing (combine harvester)	1.22	433.58	0	0	0	0	33.97	468.77
9.	Transportation of grain	1.47	194.83	8.67	0	0	0	3.66	208.63

tractor causing less of time in turning. In case of roto till drill the field efficiency was found to be less than zero till drill and this may be due to reason that combination of roto till drill with seed drill causing more wheel slip and more time required in turning. The field efficiency was found low also the conventional seed cum fertilizer drill and raised bed planter was operated in tilled soil. This is obvious due to the reason that more wheel slip occurs in loose soil, further maneuverability of raised bed planter is difficult than conventional seed cum fertilizer drill.

Fuel consumption:

It is evident from that the fuel consumption 16.13 lit, 13.49 lit, 31.23 lit and 39.1 lit was in treatments T_1, T_2, T_3 and T_4, respectively. The above observed fuel consumption is cumulative which includes fuel consumed during all the operation performed in a treatment. In treatment T_2 the fuel consumption was the lowest because within treatment field and sowing was done simultaneously and in roto tilling the fuel consumption is expected to be lower compare to conventional tillage using cultivator and disc harrow. The fuel consumption in treatment T_1 was higher than T_2 because sowing was done directly in the field without any soil manipulation. The fuel consumption in case of treatment T_4 was highest because the operation includes field preparation using 1 x cultivator followed by 2 x disc harrow and then sowing was using raised bed planter in tilled soil. Both in treatment T_3 and T_4 high fuel consumption was observed due to combination of two operations is field preparation using conventional tillage implements followed by sowing equipment.

Conclusion:

The different parameters were measured which included soil moisture content, bulk density of soil field efficiency, fuel consumption, energy requirement and cost of operation. The source wise energy was minimum (13178.30MJ/ha) in treatment T_2 and 13300.19MJ/ha, 14236.79MJ/ha and 14686.61MJ/ha in treatments T_1, T_3 and T_4, respectively. The operation wise energy was minimum (5066.30MJ/ha) in treatment T_2 and 5188.19MJ/ha, 6124.79MJ/ha and 6574.61MJ/ha in treatments T_1, T_3 and T_4, respectively. The initial bulk density of soil reduced in treatment T_1, T_2, T_3 and T_4 as the soil manipulation occurred. The bulk density increased with days of sowing and on 100 DAS. It was minimum (1.73g/cc) as compare to other treatment as more soil opening and manipulation occurred in the treatments. The soil moisture content after sowing decreased in all the treatments at different depths. The highest reduction was observed in treatment T_4 due to more tillage operation and used of raised bed planter. The field efficiency was found to be maximum (77.02%) in treatment T_1 and minimum (60.91%) in treatment T_4. This is because maneuverability and initial in case of zero till dril. The field efficiency was found to be maximum (77.02%) in treatment T_1 and minimum (60.91%) in treatment T_4. This is because maneuverability and initial in case of zero till dril.

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