Energy Assessment of Different Weed Management Practices for Rice-Wheat Cropping System in India

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ABSTRACT

The assessment of the energy requirements of the rice (*Oryza sativa* L.)-wheat (*Triticum aestivum* L.) cropping system was carried out at the research farm of Project Directorate for Cropping Systems Research, Modipuram, Meerut during the year of 2000-01 to 2003-04. The different weed management practices *viz*. hand weeding twice, herbicides + one hand weeding, criss-cross sowing + one hand weeding, criss-cross sowing + herbicides + one hand weeding, unweeded check were subjected in rice-wheat system to assess the input energy, output energy and net return of energy with two seedbed preparation practices as stale and traditional methods. Results revealed that the total input energy utilization was varied from 50820 MJ/ha to 52583 MJ/ha in stale seedbed and 50820 MJ/ha to 52724 MJ/ha in traditional seedbed for treatments unweeded and criss-cross sowing + herbicides + hand weeding once, respectively. The energy use by fertilizers represented the major part of total input energy accounting about 40 per cent followed by irrigation about 35.5 per cent in all treatments. The energy utilization for weed management was found slightly higher in traditional seedbed which varies from 925 to 1788 MJ/ha than stale seedbed which varies from 768 to 1364 MJ/ha in all treatments and it was accounting 1.47 to 3.40 per cent of total input energy.

Keywords: Input energy, output energy and net energy return.

1. INTRODUCTION

Rice *(Oryza sativa L.*)-wheat (*Triticum aestivum* L.*)* is the major cropping system in northern India covering about 10.5 M ha area which contributes about 32 per cent to the national food basket. In fact, both rice and wheat are the two most important crops and the staple food of millions of people in India and Asian countries. Therefore, their sustained high productivity is inevitable for national food security.

In recent years, the rice-wheat has started suffering a production fatigue, stagnation or decline in productivity. Rice is largely grown by transplanting of seedlings under puddled field conditions. It requires huge amount of the input energy for the growing the seedlings, transplanting, puddling, irrigations etc. With the advancement in the technology and general agricultural developments, the use of the energy resources has increased markedly. The rice is grown in different way of practices as transplanting, direct seeding in wet and dry bed. Under direct seeding in dry bed conditions, weeds are a major constraint to rice productivity because rice germinate almost simultaneously and weeds has no growth advantage. Grassy weeds are also more difficult to hand weed because of their similar morphology to that of rice, making them hard to distinguish from rice. Weeds have been reported to reduce the yield of dry-seeded rice by 15-60 per cent (Bhatnagar *et al.,* 1975). Direct seeded rice covers 26 and 28 per cent of the total rice area in South Asia and India, respectively (Panday and Velasco, 1999). Thus, energy aspect needs to analyze for an appropriate weed control measures for controlling the weeds will be of immense importance to the farming community. Traditional, low energy farming is being replaced by modern which require more energy use. The energy-agriculture relationship is, therefore, becoming more and more important with the intensification of the cropping systems and its management practices, which is considered to be only means of raising agricultural output in land scarce situations (Fluck, 1979 & Dhawan *et al*., 1985). Timely solving the problems, large scale implementing approaches of developing the agricultural energy system will contribute to independence of energy supply for overcoming the energy crisis and reviving national farming, which will be a considerable input in ensuring the national food security (Saini *et al*., 1998 & Singh *et al*., 1976). Lal *et al*. (2003), in their study on energy use and output assessment of food-forage production systems, reported sorgum (single cut)-berseen + mustard-maize+cowpea as most energy efficient and remunerative system among the five forage systems evaluated in terms of MJ, biomass production and gross income etc. The Benefit and cost ratio for the most energy efficient forage production was 1.37:1. The fertility of the soil could also be maintained by increasing organic carbon.

In the present attempt, it is proposed to analyze agricultural energy utilization pattern and net return energy of rice-wheat cropping system data from farm studies. The information on energy use in different weed management practices in system is not readily available. Therefore, in order to determine energy use in different inputs for rice-wheat system and for satisfactory energy output, the present study has been undertaken.

2. MATERIALS AND METHODS

2.1 The Site and Experiment

The experiment was carried out at the research farm of the Project Directorate for Cropping Systems Research, Modipuram, Meerut during year from 2000-01 to 2003-04. The site is located at 29.40^0 N latitude, 77.4^0 E longitude and at 237 m above mean sea level, and categorized in hot-dry semi-arid subtropical climate with summers and severe cold winters. The mean annual rainfall of the site is about 700 mm and evapo-transpiration 1600 mm. The chemical and physical properties of soil are given as sandy loam consisting of 63.7, 19.1 and 17.2 per cent sand, silt and clay, respectively. The soil pH, electrical conductivity, organic carbon, available P and available K, were 8.20, 0.47 dS/m, 0.37 per cent 34 kg/ha and 350 kg/ha of soil.

The rice (*Oryza sativa* L. cv. Pant-12) and wheat (*Triticum aestivum* L. cv. PBW-343) were grown in two seedbed preparation practices (*i.e.* stale seedbed and traditional seedbed) in main plot. The each main plot were divided into five sub-plot according weed management practices treatments *viz.* hand weeding twice, herbicides + one hand weeding, criss-cross sowing + one hand weeding, criss-cross sowing + herbicides + one hand weeding, unweeded check. The crops were sown in line with spacing 20 cm at a seed rate of 60 kg/ha for rice and 100 kg/ha for wheat. The crops were replicated thrice in split-plot design. Each main plot was 12.5 m long by 6 m wide, and equally divided into 5 sub-plot using 6 m long by 2.5 m wide. The net area under experiment was 0.045 ha (consisting of 30 plots having 6 x 2.5 m size each). The data were analyzed in split-plot design as suggested by Panse and Sukhatme (1967).

Stale seedbed preparation for rice crop after harvesting wheat in April field was irrigated once and for wheat crop irrigation was applied in standing rice in third week of October, and then after harvesting rice at last week of October, two cross harrowing + one cultivator + one planking were performed, thereafter, field was left for germination of weed seeds for about 15 days. After germination of weed seeds, field was finally prepared by resorting to one shallow ploughing with cultivator followed by planking. Whereas in traditional seed bed, at sowing time two harrowing + two cultivator + one planking was done to prepare a well pulverized seedbed. A uniform dose of fertilizer for both rice and wheat were applied @ 37 kg N, 60 kg P and 60 kg K plus 20 kg Zn per ha as a basel dose and rest nitrogen in two spilt of 56.5 kg N doses at 25 days after sowing (DAS) and at 55-60 DAS was top dressed uniformly on both rice and wheat.

Weeds were controlled with appropriate herbicides as required in rice and wheat crop and hand weeding according the treatments. Herbicide for pre-emergence weeds control included (per ha) 4 L pendimethalin (Pendimethalin 35% EC) was sprayed after 1-2 days after sowing (DAS) for rice and 2,4 D (80 %WP) & isoproturon (Isoproturon 75% WP) were sprayed at a rate of 800 gm/ha and 1.25 kg/ha at 30-35 DAS for wheat crop. The first and second hand weeding was done at 25-30 DAS and 50-55 DAS for both crops according treatment.

2.2 Data Recorded for Energy Determination

The inputs used for different operations under rice-wheat crop sequences and outputs obtained in terms of yield were used for calculating energetics of systems. The energy use inputs were also calculated based on input-wise given source during crop period, namely, (i) seed (ii) chemical fertilizers (iii) herbicides (iv) plant protection (insecticides/pesticides) (v) diesel (pump) (vi) diesel (machinery) (vii) human labours etc. The different field operations performed for completion of each activity in the experiment were measured in terms of time taken for human/ machinery, fuel consumption and expressed as energy input in megajoules (MJ) using corresponding constants (Lal *et al*., 2003, Binning *et al*., 1983 and Alam, 1986) as detailed in Table 1. The human labour energy equivalent was calculated taking eight working hours per day (standard working hours) using figure of 1.96 MJ/man-hour for different operations. The farm production ((*i.e.* grain yield) was also converted in terms of energy output (MJ) using four years average yield under rice-wheat crops and units of energy as available (Gopalan *et al*. 1978).

Table1. Energy conversion factors used

Power source	Units	Equivalent energy (MJ)
Human labour (Adult)	Man-hour	1.96
Diesel	l	56.31
Chemical fertilizers		
Nitrogen (N)	kg	60.60
Phosphorus (P)	kg	11.10
Potash (K)	kg	6.70
Plant protection (superior)		
Granular chemical	kg	120
Liquid chemical	ml	0.102
Crop produce (grain)		
Rice	kg	14.70
Wheat	kg	15.70

3. RESULTS AND DISCUSSION

3.1 Energy Utilization Pattern in Weed Management Practices

Total amount of energy use in weed management was varied from 1.47 to 3.40 per cent of the total input energy. It was further noticed that the traditional seedbed used higher energy for weed management which varied from 15.3 to 23.7 per cent as compared to stale seedbed in all treatment. Among the five weed treatments, the hand weeding twice was found to be more energy consuming (*i.e.* 1364 MJ/ha in stale seed bed & 1788 MJ/ha in traditional seedbed) than other treatments because it consumed higher number of labours for weeding twice. This was followed by herbicides + hand weeding once as well as criss-cross sowing + herbicides + hand weeding once which was 1088 MJ/ha in stale seedbed and 1229 MJ/ha in traditional seedbed. In case of unweeded treatment, there was no weed management practices adopted with view of comparison of other treatments (Table 2).

Table 2. Input Energy in different weed management practices in rice-wheat cropping system (MJ/ha)

Treatments	Rice			Wheat			Rice-wheat system		
	Herbicides	Manual	Total	Herbicides	Manual	Total	Herbicides	Manual	Total
(a) Stale seed bed									
Hand weeding twice	0	690	690	0	674	674	0	1364	1364
Herbicides + Hand weeding once	480	125	605	232	204	435	712	329	1041
Criss-cross sowing +Hand weeding once	0	376	376	0	392	392	0	768	768
Criss-cross sowing + Herbicides + Hand weeding once	480	125	605	232	251	483	712	376	1088
Unweeded	0	0	0	0	0	0	0	0	0
(b) Traditional seed bed									
Hand Weeding twice	0	925	925	0	862	862	0	1788	1788
Herbicide + Hand weeding once	480	204	684	232	314	545	712	517	1229
Criss-cross sowing + Hand weeding once	0	439	439	0	486	486	0	925	925
Criss-cross sowing + Herbicides + Hand weeding once	480	204	684	232	314	545	712	517	1229
Unweeded	0	0	0	0	0	0.0	0	0	0

When comparison made with treatments and crop wise in rice-wheat system, the hand weeding twice used highest energy (*i.e.* 690 MJ/ha and 674 MJ/ha in stale and 925 & 862 MJ/ha in traditional seedbed for rice and wheat, respectively) followed by herbicides + hand weeding once as well as criss-cross sowing + herbicides + hand weeding once in both seedbed. The least energy was consumed by criss-cross sowing + hand weeding once which was 376 and 392 MJ/ha in stale seedbed whereas 439 and 486 MJ/ha in traditional seedbed for rice, wheat, respectively.

However, in comparison of different weed management practices adopted, the manual labour for one hand weeding consumed 329 MJ/ha in stale seedbed and 517 MJ/ha in traditional seedbed in treatment herbicides + hand weeding once, whereas, the hand weeding twice used 1364 MJ/ha in stale seedbed and 1788 MJ/ha in traditional seedbed for treatment hand weeding twice. This was due to higher weed density in the case of no use of herbicides and also more number of manual labours were used in traditional seedbed plot. In the stale seedbed, the seedbed preparation was done in such a way that the maximum number of weeds could germinate before sowing. The herbicides used for controlling weeds, consumed 712 MJ/ha energy for one spray in the rice-what cropping system. No weed management practices were adopted in the unweeded check treatment.

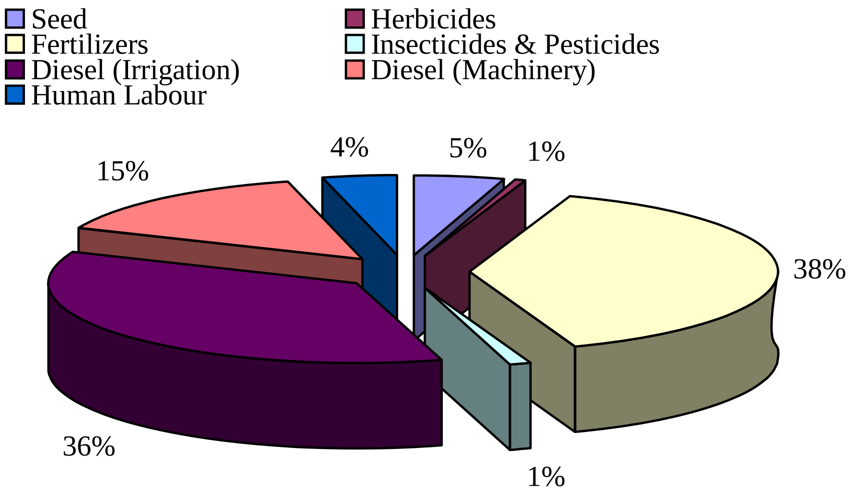
3.2 Input-wise Energy Utilization Pattern

The total input energy used in rice-wheat system varied from 50820 MJ/ha to 52583 MJ/ha in stale seedbed and 50820 MJ/ha to 52724 MJ/ha in traditional seedbed for treatments unweeded check and criss-cross + herbicides + hand weeding once in the both case, respectively (Table 3). The variation in total input energy was due to different weed management practices adopted according treatments.

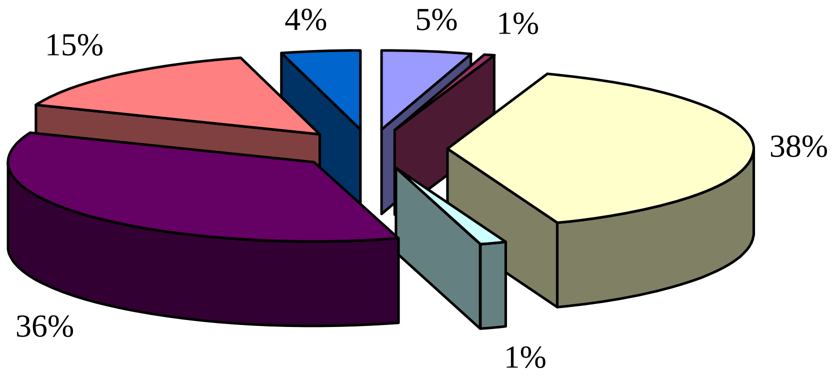
In case of input energy as human labour, the maximum input energy use was in hand weeding twice (*i.e.* 2855 MJ/ha in stale seedbed and 3269 MJ/ha in traditional seedbed) followed by criss-cross sowing + hand weeding once (*i.e.* 2250 MJ/ha stale seedbed and 2407 MJ/ha in traditional), criss-cross sowing + herbicides +hand weeding once (*i.e.* 1858 MJ/ha in stale seedbed and 1999 MJ/ha traditional seedbed) and herbicides +hand weeding once (*i.e.* 1811 MJ/ha in stale seedbed and 1999 MJ/ha traditional seedbed).The human labour energy was consumed not only in weeding but also other operations performed in the system. The unweeded check consumed 1481 MJ/ha as human labours energy in the both seedbed preparation which was used in different operations except weeding. The herbicides consumed about 712 MJ/ha energy in all treatments in both seedbeds. The energy used in machinery was found higher in criss-cross sowing (*i.e.* 7996 MJ/ha) than stale seedbed sowing (*i.e.* 7320 MJ/ha). It was because of higher machinery used during criss-cross sowing methods. The all other inputs used in the system are same in all treatments. Fertilizers consumed highest input energy as 20316 MJ/ha followed by 18582.3 MJ/ha for irrigation, from 7320 to 7996 MJ/ha for machinery and 667 MJ/ha for insecticides & pesticides. The input energy by fertilizers represented the major part of total energy use accounting about 40 per cent followed by irrigation about 35.5 per cent in all treatments, whereas, machinery consumed from 13.9 to 15.3 per cent energy use of total input energy of the system (Figure 1). This is in agreement with the result of Chaudhary e*t al.* (2004 a&b).

Table 3. Level and pattern of input energy use in different weed management practices in rice-wheat cropping system (MJ/ha)

Energy Source	Hand weeding twice			Herbicides + Hand weeding once			Criss-cross sowing + Hand weeding once			Criss-cross sowing +Herbicides +Hand weeding once			Unweeded		
	Rice	Wheat	Total	Rice	Wheat	Total	Rice	Wheat	Total	Rice	Wheat	Total	Rice	Wheat	Total
(a) Stale seed bed															
Seed	882	1570	2452	882	1570	2452	882	1570	2452	882	1570	2452	882	1570	2452
Herbicides	0	0	0	480	232	711	0	0	0	480	232	712	0	0	0
Fertilizers	10158	10158	20316	10158	10158	20316	10158	10158	20316	10158	10158	20316	10158	10158	20316
Insecticides & Pesticides	511	156	667	511	156	667	511	156	667	511	156	667	511	156	667
Diesel (Irrigation)	15204	3379	18582	15204	3379	18582	15204	3379	18582	15204	3379	18582	15204	3379	18582
Diesel (Machinery)	3660	3660	7320	3660	3660	7320	3998	3998	7996	3998	3998	7996	3660	3660	7320
Human Labour	1505	1341	2846	941	870	1811	1192	1058	2250	941	917	1858	815	666	1482
Total Energy	31921	20263	52184	31836	20025	51861	31945	20319	52264	32174	20409	52583	31231	19589	50820
(b) Traditional seed bed															
Seed	882	1570	2452	882	1570	2452	882	1570	2452	882	1570	2452	882	1570	2452
Herbicides	0	0	0	480	232	712	0	0	0	480	232	712	0	0	0
Fertilizers	10158	10158	20316	10158	10158	20316	10158	10158	20316	10158	10158	20316	10158	10158	20316
Insecticides & Pesticides	511	156	667	511	156	667	511	156	667	511	156	667	511	156	667
Diesel (Irrigation)	15204	3379	18582	15204	3379	18582	15204	3379	18582	15204	3379	18582	15204	3379	18582
Diesel (Machinery)	3660	3660	7320	3660	3660	7320	3998	3998	7996	3998	3998	7996	3660	3660	7320
Human Labour	1741	1529	3269	1019	980	1999	1254	1153	2407	1019	980	1999	815	666	1482
Total Energy	32156	20451	52607	31914	20134	52049	32008	20413	52421	32252	20472	52724	31231	19589	50820



(a) Stale Seedbed Preparation



(b) Traditional seedbed preparation

Figure 1. Average input energy consumed in different inputs in rice –wheat cropping system in different seedbed

3.3 Output Energy Pattern

The maximum output energy was noticed in treatment criss-cross sowing + herbicides + hand weeding once (*i.e.* 176410.2 MJ/ha in stale seedbed and 167472.5 MJ/ha in traditional seedbed) and almost equal output energy was obtained by herbicides + hand weeding once (*i.e.* 170221.9 MJ/ha in stale seedbed and 166579.9 MJ/ha in traditional seedbed) as detailed in Table 4 and Figure 2. The hand weeding twice gave third rank of obtaining output energy as 152680.8 MJ/ha in stale seedbed and 146845.4 MJ/ha in traditional seedbed. This was followed by criss-cross sowing + hand weeding once which varied from 114634.9 MJ/ha in stale seedbed to 106746.0 MJ/ha in traditional seedbed. The unweeded check treatment produced least amount of output energy which was 41597.2 MJ/ha in stale seedbed and 30329.0 MJ/ha in traditional seedbed (Table 4). The criss-cross sowing + herbicides + hand weeding once as well as herbicides + hand weeding once gave from 75.6 to 82.0 per cent higher output energy than unweeded check whereas, it was 13.5 per cent and from 32.7 to 36.2 per cent higher output energy than hand weeding twice and criss-cross sowing + hand weeding once, respectively.

The output-input ratio in case of both the treatments as criss-cross sowing + herbicides + hand weeding once and herbicides + hand weeding once shown almost equal as 3.4 and 3.3, respectively. Whereas, the least output-input ratio was obtained by unweeded plot (*i.e.* 0.8). The criss-cross sowing + herbicides + hand weeding once was to be most efficient weed management treatment in term of energy output. It means the more efficient treatment was due to consuming low input energy and giving higher output energy.

3.4 Net Return Energy Pattern

The net return energy was found significant with respect to weed management practices whereas seedbed preparation was non significant. The treatment criss-cross sowing + herbicides + hand weeding once (*i.e.* 119288 MJ/ha) was the statistically at par with herbicides + hand weeding once (*i.e.* 116446 MJ/ha) which were significantly higher than other treatments (Table 5 and Figure 2). This was followed by hand weeding twice (*i.e.* 97368 MJ/ha) which was significantly higher than criss-cross sowing + hand weeding once (*i.e.* 58348 MJ/ha).

When comparison made between weed management practices in each seedbed preparation of input and output energy, among five treatments, the net energy return of the system was found to be significantly high in criss-cross sowing + herbicides + hand weeding once (*i.e.* 123827 MJ/ha in stale seedbed and 114748 MJ/ha in traditional seedbed) than other treatments and which was statistically at par with treatment herbicides + hand weeding once (*i.e.* 118362 MJ/ha in stale seedbed and 114531 MJ/ha in traditional seedbed) as given in Table 5. This was followed by hand weeding twice (*i.e.* 100497.0 MJ/ha in stale seedbed and 94238 MJ/ha in traditional seedbed) and criss-cross sowing + hand weeding once (*i.e.* 62371 MJ/ha in stale seedbed and 54326 MJ/ha in traditional seedbed) which had significant difference in same seedbed preparation.

The criss-cross sowing + herbicides + hand weeding once as well as herbicides + hand weeding once treatment gained from 49.1 to 52.7, 18.8 and 4.4 per cent higher net return energy as compared with criss-cross sowing + hand weeding once, hand weeding twice and herbicides + hand weeding once, respectively. However, the unweeded treatment gave negative net return energy. So, without weed management practices adopted will not able to get output energy.

Table 4. Input and output energy of different weed management practices in rice-wheat cropping system

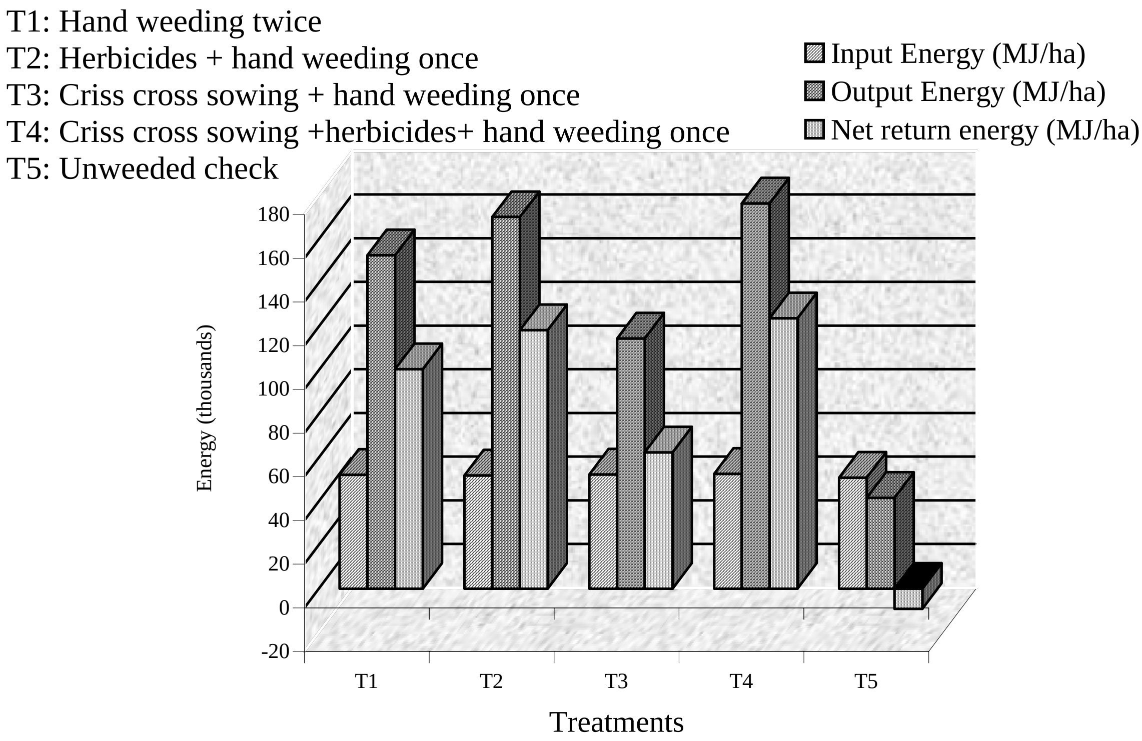
	Hand weeding twice			Herbicides + Hand weeding once			Criss-cross sowing + Hand weeding once			Criss-cross sowing + Herbicides + Hand weeding once			Unweeded		
	Rice	Wheat	Total	Rice	Wheat	Total	Rice	Wheat	Total	Rice	Wheat	Total	Rice	Wheat	Total
(a) Stale seed bed															
Input Energy (MJ/ha)	31921	20263	52184	31836	20025	51861	31945	20319	52264	32174	20409	52583	31231	19589	50820
	(61.2)	(38.8)	(100)	(61.4)	(38.6)	(100)	(61.1)	(38.9)	(100)	(61.2)	(38.8)	(100)	(61.5)	(38.5)	(100)
Output Energy (MJ/ha)	72727	79954	152681	79625	90597	170222	38160	76475	114635	83217	93193	176410	14340	27257	41597
	(47.6)	(52.4)	(100)	(46.8)	(53.2)	(100)	(33.3)	(66.7)	(100)	(47.2)	(52.8)	(100)	(34.5)	(65.5)	(100)
Output-input ratio	2.3	3.9	2.9	2.5	4.5	3.3	1.2	3.8	2.2	2.6	4.6	3.4	0.5	1.4	0.8
(b) Traditional seed bed															
Input Energy (MJ/ha)	32156	20451	52607	31914	20134	52049	32008	20413	52421	32252	20472	52724	31231	19589	50820
	(61.1)	(38.9)	(100)	(61.3)	(38.7)	(100)	(61.1)	(38.9)	(100)	(61.2)	(38.8)	(100)	(61.5)	(38.5)	(100)
Output Energy (MJ/ha)	69747	77098	146845	76762	89818	166580	33542	73204	106746	76616	90857	167472	8264	22065	30329
	(47.5)	(52.5)	(100)	(46.1)	(53.9)	(100)	(31.4)	(68.6)	(100)	(45.7)	(54.3)	(100)	(27.2)	(72.8)	(100)
Output-input ratio	2.2	3.8	2.8	2.4	4.5	3.2	1.0	3.6	2.0	2.4	4.4	3.2	0.3	1.1	0.6

The averages for 4 years data are used. The figures in Parenthesis shows the percentage of input and output energy to the total system energy

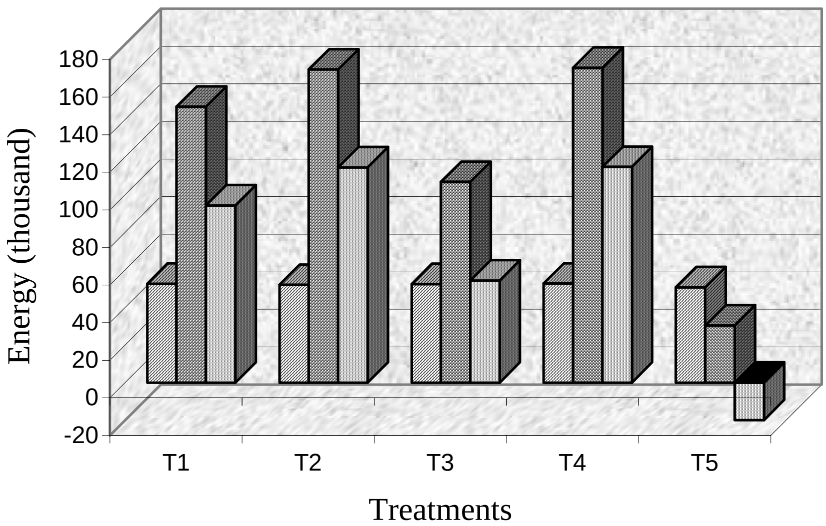
Table 5. Net return energy of different weed management practices in rice-wheat cropping system (MJ/ha)

	Hand weeding twice			Herbicides + Hand weeding once			Criss-cross sowing + Hand weeding once			Criss-cross sowing + Herbicides + Hand weeding once			Unweeded			Mean		
	Rice	Wheat	Total	Rice	Wheat	Total	Rice	Wheat	Total	Rice	Wheat	Total	Rice	Whe at	Total	Rice	Wheat	Mean of system
Stale seedbed	40807	59690	10050	47789	70572	118361	6215	56156	62371	51044	72783	123827	-16890	7668	-9222	25793	53374	79167
Traditional seedbed	37592	56647	94238	44847	69684	114531	1534	52791	54326	44364	70384	114748	-22967	2476	-20491	21074	50397	71471
Mean	39199	58169	97368	46318	70128	116446	3875	54474	58348	47704	71584	119288	-19929	5072	-14857	23433	51885	39199
CD $_{(0.05)}$																		
Main plot (Seedbed)	7872	1501	8675	(NS)														
Sub-plot (Weed management)	2942	2076	3654															
Interaction (1)	4161	2936	5167															
Interaction (2)	8257	2935	9283															

Interaction (1): For comparing two weed management practices for same main plot
(2): For comparing two main plots at same or different weed management practices



(a) Stale seed bed Preparation



(b) Traditional seedbed preparation

Figure 2. Input, output and net return energy pattern of different weed management practices in different seedbed

4. CONCLUSIONS

It may be concluded that the net energy return of different weed management practices can be quantified and stratified for sound planning of increasing productivity. In present investigation, among five weed management treatments, the criss-cross sowing + herbicides + hand weeding once was the highest energy gained treatment (*i.e.* 123827 MJ/ha in stale seedbed and 114748 MJ/ha in traditional seedbed) but statistically at par with treatment herbicides + hand weeding once (*i.e.* 118361 MJ/ha in stale seedbed and 114531 MJ/ha in traditional seedbed). The criss-cross sowing + herbicides + hand weeding once as well as herbicides + hand weeding once gained from 49.1 to 52.7, 18.8 and 4.4 per cent higher net return energy as compared with criss-cross sowing + hand weeding once, hand weeding twice and herbicides + hand weeding once, respectively. However, proper weed management is essential for good energy harvest.

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