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Energy budgeting of weed management in soybean

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ABSTRACT

An experiment was conducted at ICAR-Directorate of Weed Research, Jabalpur during *Kharif* season of 2015 and 2016 in order to assess the energy budgeting of weed management in soybean cultivation. Ten treatments comprising of pendimethalin (750 g/ha PE), pendimethalin (750 g/ha PE) *fb* imazethapyr (100 g/ha at 20 DAS), pendimethalin (750 g/ha PE) *fb* 1 HW (at 20 DAS), metribuzin (500 g/ha), metribuzin (500 g/ha) *fb* imazethapyr (100 g/ha at 20 DAS), metribuzin (500 g/ha PE) *fb* 1 HW (at 20 DAS), imazethapyr (100 g/ha at 20 DAS), imazethapyr (100 g/ha at 20 DAS) *fb* 1 HW (at 40 DAS), 2 HW (at 20 and 40 DAS) and unweeded check were laid-out in randomized block design with three replications. Sequential application of pendimethalin 750 g/ha PE *fb* imazethapyr 100 g/ha at 20 DAS was found to be the most energy efficient weed management strategy and had maximum value of total output energy (71.90 x 10^3 MJ/ha) and net energy returns (62.32 x 10^3 MJ/ha). Other parameters like energy ratio (7.50), energy profitability (6.50) and human energy profitability (164.27) were also higher under the same treatment whereas, it recorded less specific energy (11.53 10^3 MJ/ha) and energy intensity (0.48).

Key words: Energy budget, Herbicide, Indices, Soybean, Weed management

Soybean (*Glycine max*) is one of the most important oilseed crops in India. The crop is called "Golden bean" or "Miracle crop" of the 21st century because of its multiple uses (Jadhav 2014). Weed infestation is one of the major constraints in the cultivation of soybean. If weeds are not controlled during critical periods of crop-weed competition, reduction in the yield of soybean to the tune of 26 to 71 % has been recorded depending upon the type and intensity of weeds (Rathore *et al,* 2006). Hand weeding is a traditional and effective method of weed control, but unavailability of labour during peak period of demand and hinderance for manual weeding due to continuous rains in the growing period is the main limitations of hand weeding. Thus, the herbicidal weed control either alone or in integrated manner remains the only choice under such situations to minimize the weed menace effectively and economically. Sole application of herbicide as pre-emergence fails to control subsequent flushes of weeds. So, there is need to apply pre- and post-emergence herbicides in a sequential manner to reduce weed menace and keep the crop free from weed competition during entire critical period of crop growth (Tuti and Das 2011). Energy budgeting of weed management is also important because energy and economics are mutually dependent. There is a close relationship between agriculture, economics and energy. Very scanty information is available on this aspect. Therefore, the present study was undertaken to assess the energy budgeting of weed management in soybean.

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MATERIALS AND METHODS

An experiment was conducted at ICAR-Directorate of Weed Research, Jabalpur during *Kharif* season of 2015 and 2016. The total rainfall received during *Kharif* season (June to October) for the year 2015 and 2016 was 971.0 mm and 2114.8 mm, respectively. Minimum and maximum temperature ranged from 21.1 ^{0}C to 33.8 ^{0}C during 2015 and 22.1 ^{0}C to 35.8 ^{0}C during 2016. The relative humidity ranged from 78 to 91% in morning and 35 to 70% in evening during 2015 and 87 to 94% in morning and 55 to 91% in evening hours during 2016. Ten treatments consisted of pendimethalin (750 g/ha PE), pendimethalin (750 g/ha PE) *fb* imazethapyr (100 g/ha at 20 DAS), pendimethalin (750 g/ha PE) *fb* 1 HW (at 20 DAS), metribuzin (500 g/ha), metribuzin (500 g/ha) *fb* imazethapyr (100 g/ha at 20 DAS), metribuzin (500 g/ha PE) *fb* 1 HW (at 20 DAS), imazethapyr (100 g/ha at 20 DAS), imazethapyr (100 g/ha at 20 DAS) *fb* 1 HW (at 40 DAS), 2 HW (at 20 and 40 DAS) and unweeded check were laid-out in randomized block design (RBD) with three replications. Soybean '*JS 97-52*' was grown with row spacing of 45 cm and a plant to plant spacing of nearly 5 cm during both years. The recommended dose of fertilizers was 20 kg N, 60 kg P_2O_5 and 40 kg K_2O/ha, respectively. The whole quantity of N, P_2O_5 and K_2O were applied through di-ammonium phosphate and muriate of potash, respectively at the time of sowing as a basal application.

Methods of energy budgeting

The inputs and the energy requirements of each input for soybean production including weed management were collected, determined and presented. General inputs in soybean production were machinery, human labor, chemical fertilizers, irrigation water, fuel, pesticide and seed. Output was soybean seed and haulm as a product. The energy equivalent of different inputs and output were used to determine the energy values (Table 1). The human energy as an energy input was calculated by multiplying the number of man-hours (hr/ha) by estimated power rating of human labor (MJ/ha) from (Table 1). Energy used by woman labor was converted into human energy with suitable factors. Energy used by farm machinery was calculated by methodology given by Kitani (1999).

$$ME = M \times G \times T$$

Where, ME is the machinery energy (MJ), E the production energy of machine, G the mass of machine (kg), and T is the economic life of machine (year). Other inputs like fuel, seed, pesticide and chemical fertilizers used in soybean production were converted into energy value (MJ/ha) by multiplying the quantity of the material used in the production process by the energy equivalent of each material. For example, energy consumption of chemical fertilizer (nitrogen) was calculated by multiplying the amount of nitrogen used (kg/ha) by energy coefficient of nitrogen fertilizer (60.60 MJ/kg from Table 1); hence the result is the energy consumption of nitrogen fertilizer (MJ/ha) in soybean production. Also, energy used by other inputs can be determined by applying same methods as suggested for nitrogen. The amount of output energy (MJ/ha) was estimated by multiplying the soybean seed and haulm yield (kg/ha) by soybean energy equivalent (MJ/kg).

Energy indices

On the basis of energy input and output; energy ratio, net energy returns, specific energy, energy intensiveness, energy profitability and human energy profitability were calculated by using the following formulae as suggested by Mittal and Dhawan (1988) and Burnett (1982).

Table 1. Energy equivalents of inputs and outputs in soybean production

S. No	Particulars	Unit	Equivalent energy (MJ/unit)	Reference
A. Inputs				
1. Labour				
1a	Adult man	hr	1.96	Mittal and Dhawan (1988)
1b	Woman	hr	1.57	Mittal and Dhawan (1988)
2	Fuel (diesel)	l	56.31	Mittal and Dhawan (1988)
3	Seed	kg	18.14	Mittal and Dhawan (1988)
4	Electricity	kWh	11.93	Mittal and Dhawan (1988)
5	Pump	hr	2.40	Dagistan *et al.* (2009)
6. Chemical fertilizers				
6a	Nitrogen	kg	60.60	Kitani (1999)
6b	P_2O_5	kg	11.10	Kitani (1999)
6c	K_2O	kg	6.70	Kitani (1999)
7. Pesticide				
7a	Herbicide	kg *a.i*	288	West and Marland (2002)
7b	Insecticide	kg *a.i*	237	West and Marland (2002)
7c	Fungicide	kg *a.i*	196	West and Marland (2002)
8	Bio-fertilizer	kg	10.0	West and Marland (2002)
9	Irrigation	m^3	1.02	Singh *et al.* (2008)
10	Knapsack sprayer	hr	0.17	Dagistan *et al.* (2009)
11. Farm machinery				
11.a	Power thresher	hr	200	Kitani (1999)
11.b	Rotavator	hr	6.69	Kitani (1999)
11.c	Cultivator	hr	22.80	Dagistan *et al.* (2009)
11.d	Harrow	hr	37.62	Dagistan *et al.* (2009)
11.e	Tractor	hr	303.6	Dagistan *et al.* (2009)
11.f	Seed drill	hr	12.54	Dagistan *et al.* (2009)
B	Outputs			
12	Seed	kg	18.14	Kitani (1999)
13	Haulm	kg	12.50	Kitani (1999)

Energy ratio (ER)

$$\text{Energy ratio} = \frac{\text{Output energy (MJ/ha)}}{\text{Input energy (MJ/ha)}}$$

Net energy returns

$$\text{Net energy returns (MJ/ha)} = \text{Output energy (MJ/ha)} - \text{Input energy (MJ/ha)}$$

Specific energy

$$\text{Specific energy} = \frac{\text{Input energy (MJ/ha)}}{\text{Yield (t/ha)}}$$

Energy intensiveness

$$\text{Energy intensiveness} = \frac{\text{Input energy (MJ/ha)}}{\text{Cost of cultivation (Rs/ha)}}$$

Energy profitability

$$\text{Human energy profitability} = \frac{\text{Output energy (MJ/ha)}}{\text{Labor energy (MJ/ha)}}$$

Human energy profitability

$$\text{Energy profitability} = \frac{\text{Net energy returns (MJ/ha)}}{\text{Input energy (MJ/ha)}}$$

RESULTS AND DISCUSSION

Major weed flora

The experimental field was infested with monocot weeds like *Echinochloa colona* (29.67%), *Dinebra retroflexa* (35.15%) and *Cyperus iria* (1.67%), and dicot weeds like *Euphorbia geniculata* (24.20%), *Phyllanthus niruri* (5.80), *Commelina benghalensis* (2.67%) and *Alternanthera sessilis* (1.93%).

Productivity

The seed yield (223.33 kg/ha) and haulm yield (2008.17 kg/ha) were minimum in unweeded control. It may be due to severe competitional stress during entire critical period of crop growth, leading to poor growth parameters and yield attributing traits and finally the minimum seed yield. But, the yields increased marginally when weeds were controlled with pre-emergence application of either pendimethalin (750 g/ha) (386.67 kg/ha) or metribuzin (500 g/ha) (460 kg/ha) being higher under plots treated with pendimethalin (750 g/ha) *fb* imazethapyr (100 g/ha) and metribuzin (500 g/ha) *fb* imazethapyr (100 g/ha) (831.67 and 806.67 kg/ha, respectively). However, none of the herbicidal treatments surpassed hand-weeding twice (20 and 40 DAS), which proved significantly superior over other treatments (Table 4). The crop under two hand weeded plots resulted highest yield (1061.67 kg/ha). Since the weather conditions during crop growing season were not favorable for its growth and development. The crop yield was less than the potential yields. However, it was nearer to average productivity of the country.

Energetics

Energy input requirement of crops: Common input energy required for the production of soybean is presented in Table 2. Total common input energy required for the cultivation of soybean was 9267.3 MJ/ha (100%). Of the inputs for different operations, field preparation consumed the bulk of energy for crops which was 21.10% of the total common input energy required for the crop production (Table 2). Energy for sowing of crop contributes 6.82%. Energy consumed by diesel for field preparation was 14.58% of the total common input energy consumption. Seed is an important input for the cultivation of any crop. For the cultivation of soybean, only seed contributes 11.74% of the total common input energy required. In the production systems, fertilizer accounted for the largest share of total energy input (23.15%). Among the fertilizers, energy embedded in N fertilizer was particularly high (13.07%), although it was applied at lower rate (20 kg N/ha). Seed treatment through bio-fertilizer and fungicide is also a very important practice which shared very negligible input energy (0.17%). Energy required for spraying of insecticide which includes insecticide, water, labor and sprayer constituted only 0.96%. Energy required by labor for seed treatment and application of fertilizer was 0.25%. Energy requirement for harvesting and post harvest process was 18.18%.

Energy used in different treatments of soybean cultivation is presented in Table 3. Unweeded check required almost zero energy because neither hand weeding nor herbicide application was done in this treatment. Among the herbicidal treatment, maximum energy (313.98 MJ/ha) was required in plots treated with pendimethalin (750 g/ha) PE *fb* imazethapyr (100 g/ha) at 20 DAS while minimum energy (63.39 MJ/ha) was required in plot treated with imazethapyr (100 g/ha) alone. Two hand weeded treatments required maximum energy (690.8 MJ/ha). It was due to maximum labor required (55 man days of 8 hours each) for two hand weeding operation.

Total input energy used in different treatments of soybean is presented in Table 4. Unweeded check required minimum total input energy (9.27×10^3 MJ/ha). Among the herbicidal treatments, maximum total input energy (9.58×10^3 MJ/ha) was required in plot treated with pendimethalin (750 g/ha) *fb* imazethapyr (100 g/ha), while minimum total input energy (9.33×10^3 MJ/ha) was required in plot treated with imazethapyr (100 g/ha) alone. Two hand weeded treatment required maximum total input energy (9.96×10^3 MJ/ha).

Energy input-output relationship: The total input energy (MJ/ha) consumed and total output energy produced (MJ/ha) in each treatment has been presented in Table 4. Based on the seed and haulm yield, treatment wise energy production was calculated. Minimum total output energy (29.15×10^3 MJ/ha) was recorded in unweeded check where weeds were allowed to grow throughout the crop season. However, its total input energy requirement was also minimum but in comparison to its total energy requirement, energy production was very less due to poor yield. Among the herbicidal treatment, lowest total output energy (45.61×10^3 MJ/ha) was produced in the plot treated with pendimethalin (750 g/ha) alone while its total input energy requirement was higher (9.52×10^3 MJ/ha) than alone application of imazethapyr (100 g/ha). It may be due to better control of weeds by alone application of imazethapyr

Table 2. Common input energy in soybean cultivation (mean of two years)

Particulars	Unit	Quantity/ha	Equivalent energy (MJ/unit)	Energy (MJ/ha)
Ploughing with cultivator including tractor	hr	2	22.8 + 303.6	652.80
Harrowing with disc harrow including tractor	hr	2	37.62 + 303.6	682.44
Pulverization with rotavator including tractor	hr	2	6.69 + 303.6	620.58
Sowing with seed-drill including tractor	hr	2	12.54 + 303.6	632.22
Fuel (Diesel)	l	24	56.31	1351.44
Driver	hr	8	1.96	15.68
Seed	kg	60	18.14	1088.4
Nitrogen	kg	20	60.60	1212
P_2O_5	kg	60	11.10	666
K_2O	kg	40	6.70	268
Bio-fertilizer	kg	0.5	10.0	5
Insecticide	kg *a.i*	0.089	237	21.09
Fungicide	kg *a.i*	0.06	196	11.76
Irrigation	m^3	100	1.02	204
Pump	h	4	2.4	9.6
Electricity	kWh	4	11.93	47.72
Water used for spraying insecticide	m^3	1	1.02	1.02
Sprayer	hrs	32	0.17	5.44
Labour: Fertilizer application-1 man days	hrs	8	1.96	15.68
Labour: Insecticide spray-4 man days	hrs	32	1.96	62.72
Labour: Seed treatment-0.5 man days	hrs	4	1.96	7.84
Labour: Harvesting, bundling and transportation-20 women + 5 man	hrs	160+40	1.57+1.96	329.6
Threshing and winnowing-3 man+3 women	hrs	24 + 24	1.57 + 1.96	84.72
Power thresher	hrs	6	200	1200
Electricity for threshing	kWh	6	11.93	71.58
Total	-	-	-	9267.33

Table 3. Energy used in different weed management treatments in soybean (mean of two years)

Treatment	Dose (g/ha)	Total energy used in the herbicide (MJ)	Labor used in hand weeding/ spraying	Energy used in the hand weeding/ spraying (MJ)	Knapsack sprayer used (hrs)	Energy used by knapsack sprayer in the spraying of herbicides (MJ)	Water used in the application of herbicides (m^3)	Energy used by water (MJ/ha)	Total energy (MJ/ha)
Pendimethalin 750 g/ha PE	750	216.0	16 man hours	31.36	16	2.72	0.50	0.51	250.59
Pendimethalin 750 g/ha PE *fb* imazethapyr 100 g/ha at 20 DAS	750 + 100	244.8	32 man hours	62.72	32	5.44	1.00	1.02	313.98
Pendimethalin 750 g/ha PE *fb* 1 HW at 20 DAS	750	216.0	16 man hrs+200 woman hours	345.36	16	2.72	0.50	0.51	564.59
Metribuzin 500 g/ha	500	144.0	16 man hours	31.36	16	2.72	0.50	0.51	178.59
Metribuzin 500 g/ha *fb* imazethapyr 100 g/ha at 20 DAS	500 + 100	172.8	32 man hours	62.76	32	5.44	1.00	1.02	242.02
Metribuzin 500 g/ha PE *fb* 1 HW at 20 DAS	500	144.0	16 man hrs+200 woman hours	345.36	16	2.72	0.50	0.51	492.59
Imazethapyr 100 g/ha at 20 DAS	100	28.8	16 man hours	31.36	16	2.72	0.50	0.51	63.39
Imazethapyr 100 g/ha at 20 DAS *fb* 1 HW at 40 DAS	100	28.8	16 man hrs+200 woman hours	345.36	16	2.72	0.50	0.51	377.39
2 HW at 20 and 40 DAS	-	-	440 woman hours	690.8	-	-	-	-	690.8
Unweeded control	-	-	-	-	-	-	-	-	0

fb- Followed by, PE- Pre-emergence, HW-Hand weeding, DAS-Days after sowing

(100 g/ha) than pendimethalin (750 g/ha) which resulted in better growth and development of crop plants thereby higher seed and haulm yield and ultimately higher total output energy. Among the herbicidal treatments, maximum total output energy (71.90×10^3 MJ/ha) was recorded with sequential application of pendimethalin 750 g/ha *fb* imazethapyr 100 g/ha. None of the herbicidal treatments surpassed hand weeding twice which produced highest total output energy (80.86×10^3 MJ/ha).

Energy indices: Energy ratio, specific energy, energy intensiveness / intensity (total energy used to produce 1 kg of grain (MJ/kg), energy profitability, net energy return (production), specific energy, and human energy profitability were calculated for each treatment separately (Table 5). This enabled comparing different management options in terms of energy use with reference to seed and haulm yield, in order to identify the most energy efficient weed management system.

Energy ratio: Energy ratio indicates the energy output under particular treatment with each unit of energy used. Energy output-input ratio varied across management scenarios depending upon the biomass production (Table 5). Energy ratio was minimum (3.15) with unweeded check because of lower output energy produced. However, this ratio was increased significantly when weed control measures were adopted. Among the different herbicidal treatments, minimum energy ratio (4.79) was in plot treated with pendimethalin (750 g/ha) alone. Maximum energy ratio was obtained with sequential application of pendimethalin (750 g/ha) *fb* imazethapyr (100 g/ha) at 20 DAS. Among all the treatments, maximum energy ratio (8.12) was gained by hand weeding twice (at 20 and 40 DAS).

Energy intensiveness/intensity: Energy intensity increased with the improvement in management practices which was significantly affected by seed and haulm productivity (Table 5). Energy intensity required to produce 1 kg soybean seed was highest (0.59) under unweeded check. Among the herbicidal treatments, energy intensity (0.54) was maximum under alone application of pendimethalin (750 g/ha) and metribuzin (500 g/ha) while it was minimum (0.48) under sequential application of pendimethalin (750 g/ha) *fb* imazethapyr (100 g/ha) and metribuzin (500 g/ha) *fb* imazethapyr (100 g/ha). Among all the treatments, energy intensity (0.40) was minimum under two hand weeding (20 and 40 DAS).

Energy profitability: Energy profitability increased with the decrease in management intensity and was highly correlated with total biomass productivity. Weed management practices had significant effect on this index (Table 5). Unweeded check gave lowest energy profitability (2.14). Among the herbicidal treatments, energy profitability was highest (6.50) with pendimethalin (750) PE *fb* imazethapyr (100 g/ha) closely followed by metribuzin (500 g/ha) *fb* imazethapyr (100 g/ha) (6.25). However, none of the herbicidal treatments surpassed hand weeding twice (20 and 40 DAS) which gave highest energy profitability *i.e.* 7.11.

Net energy return: There was marginal profit of 19.89 x 10^3 MJ/ha when the crop was not weeded throughout the growing season. However, it increased identically (62.32 x 10^3 MJ/ha) when weeds were controlled with the pre-emergence application of pendimethalin (750 g/ha) *fb* imazethapyr (100 g/ha). Among all the treatments, highest net energy (70.90 x 10^3 MJ/ha) was recorded with two hand weeding (20 and 40 DAS).

Specific energy: Specific energy requirement was minimum (9.38 x 10^3 MJ/ha) with two hand weedings done at 20 and 40 DAS while maximum (41.50 x 10^3 MJ/ha) in unweeded check where no weed control measures were adopted (Table 5). Among the herbicidal treatments, maximum specific energy (24.62 x 10^3 MJ/ha) was required by alone

Table 4. Total input and output energy of weed management in soybean (mean of two years)

Treatment	Seed yield (kg/ha)	Output energy by seed (x10^3 MJ/ha)	Haulm yield (t/ha)	Output energy by haulm (x10^3 MJ/ha)	Total output energy (x10^3 MJ/ha)	Total input energy used (x10^3 MJ/ha)
Pendimethalin 750 g/ha PE	387	07.01	3.09	38.60	45.61	9.52
Pendimethalin 750 g/ha PE *fb* imazethapyr 100 g/ha at 20 DAS	831	15.09	4.54	56.81	71.90	9.58
Pendimethalin 750 g/ha PE *fb* 1 HW at 20 DAS	773	14.03	4.47	55.95	69.98	9.84
Metribuzin 500 g /ha	460	08.34	3.25	40.69	49.03	9.45
Metribuzin 500 g/ha *fb* imazethapyr 100 g/ha at 20 DAS	807	14.64	4.35	54.38	69.01	9.51
Metribuzin 500 g/ha PE *fb* 1 HW at 20 DAS	810	14.70	4.30	53.76	68.45	9.76
Imazethapyr 100 g/ha at 20 DAS	750	13.61	3.68	46.02	59.62	9.33
Imazethapyr 100 g/ha at 20 DAS *fb* 1 HW at 40 DAS	870	15.79	4.58	57.23	73.01	9.64
2 HW at 20 and 40 DAS	1062	19.26	4.93	61.59	80.86	9.96
Unweeded control	223	04.05	2.01	25.10	29.15	9.27
LSD (P = 0.05)	117	2.13	0.40	5.02	5.88	-

Table 5. Effect of weed management on energy ratio, energy intensiveness, energy profitability, net energy return, specific energy and human energy profitability of soybean (mean of two years)

Treatment	Energy ratio	Energy intensiveness (MJ/` ha)	Energy profitability (MJ/ha)	Net energy return (x 10^3 MJ/ha)	Specific Energy (x 10^3 MJ/ha)	Human energy profitability
Pendimethalin 750 g/ha PE	4.79	0.54	3.79	36.09	24.62	112.08
Pendimethalin 750 g/ha PE *fb* imazethapyr 100 g/ha at 20 DAS	7.50	0.48	6.50	62.32	11.53	164.27
Pendimethalin 750 g/ha PE *fb* 1 HW at 20 DAS	7.12	0.45	6.11	60.15	12.72	123.52
Metribuzin 500 g /ha	5.19	0.54	4.19	39.58	20.54	120.48
Metribuzin 500 g/ha *fb* imazethapyr 100 g/ha at 20 DAS	7.26	0.48	6.25	59.50	11.79	157.67
Metribuzin 500 g/ha PE fb 1 HW at 20 DAS	7.01	0.45	6.01	58.69	12.05	120.83
Imazethapyr 100 g/ha at 20 DAS	6.39	0.52	5.38	50.29	12.45	146.50
Imazethapyr 100 g/ha at 20 DAS fb 1 HW at 40 DAS	7.57	0.44	6.56	63.36	11.09	128.87
2 HW at 20 and 40 DAS	8.12	0.40	7.11	70.90	9.38	109.65
Unweeded control	3.15	0.59	2.14	19.89	41.50	77.75

fb- Followed by, PE- Pre-emergence, HW-Hand weeding, DAS-Days after sowing

application of pendimethalin (750 g/ha). This index was minimum (11.53 x 10^3 MJ/ha) under sequential application of pendimethalin (750 g/ha) *fb* imazethapyr (100 g/ha).

Human energy profitability: Human energy profitability was calculated based on man power and its energy equivalent used to produce the output (Table 5). This index was lowest (77.75) under unweeded check. However, it increased appreciably when various weed control measures were adopted. Among the herbicidal treatments, this index was lowest (112.08) with pendimethalin (750 g/ha) alone. Human energy profitability was highest (164.27) with pendimethalin (750 g/ha) *fb* imazethapyr (100 g/ha) closely followed by metribuzin (500 g/ha) *fb* imazethapyr (100 g/ha) (157.67). Among all the weed management treatments, human energy profitability was lowest (109.65) under two hand weeding. It was due to maximum labor required for two hand weeding which resulted in increase in labor energy and finally human energy profitability was lowest.

Results indicated that among the herbicidal treatments, sequential application of pendimethalin 750 g/ha PE *fb* imazethapyr 100 g/ha at 20 DAS was the most energy efficient weed management practice in soybean and had maximum value of total output energy (71.90 x 10^3 MJ/ha) and net energy return (62.32 x 10^3 MJ/ha). Other parameters like energy ratio (7.50), energy profitability (6.50) and human energy profitability (164.27) were also higher under the same treatment whereas less specific energy (11.53 10^3 MJ/ha) and energy intensity (0.48) were recorded.

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