Energy Balance Studies of Weed Management Practices in Mustard (*Brassica juncea* (L.) Czerj and Cosson)

ABSTRACT

A field experiment was conducted at College Farm, College of Agriculture, Rajendranagar, Hyderabad during *rabi* 2020-21 on loamy sand soils to study energy balance of weed management practices in mustard. The energy balance studies were determined by using direct and indirect energy. Among the different weed management practices, pendimethalin 30 % EC 1.0 kg ha^{-1} PE *fb* straw mulch 5 t ha^{-1} recorded higher energy input. This treatment was followed by oxyfluorfen 23.5 % EC 0.1 kg ha^{-1} PE *fb* straw mulch 5 t ha^{-1} and oxadiargyl 6 % EC 0.09 kg ha^{-1} PE *fb* straw mulch 5 t ha^{-1}. Maximum energy output, net energy, energy use efficiency and energy productivity were noticed under intercultivation and hand weeding at 15 and 30 DAS and it was statistically on par with oxadiargyl 6 % EC 0.09 kg ha^{-1} PE *fb* intercultivation at 30 DAS, oxyfluorfen 23.5 % EC 0.1 kg ha^{-1} PE *fb* intercultivation at 30 DAS and pendimethalin 30 % EC 1.0 kg ha^{-1} PE *fb* intercultivation at 30 DAS.

Key words: Energy input, Energy output, Energy efficiency, Energy Productivity and Intercultivation,

INTRODUCTION:

Mustard is one of the most important oilseed crops in terms of worldwide trade. It is a member of the Cruciferae family. It is the second most important oilseed crop in India, after groundnut, among the seven edible oilseeds. Mustard seeds have an oil content ranging from 37 to 49% (Bhowmik *et al.*, 2014). In India, rape seed and mustard occupy 6.23 million ha area with production and productivity of 9.34 million tonnes and 1499 $kgha^{-1}$ respectively (India stat 2019-20). Weeds are the major biotic stress in mustard production. With the intensification of agriculture, the use of non-farm inputs such as fertilizes, insecticides, herbicides, fungicides and various other chemicals has been increased with the time. The requirement of the energy for these inputs is high. With the increasing

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crude oil prices day by day which in turn increases the price of the external inputs. Thus the cost of cultivation multiplies with the benefits being limited. Hence the calculation of energy inputs and outputs is inevitable. Energy balance is defined as the measurement of proportion as well as analysis of the energy input consumed and output produced out of different activities to find out the direction of energy consumption pattern of a system (Acharya *et al.*, 2013). Keeping this in view, the present experiment was carried out with the objective to study energy balance of weed management practices in mustard. The energy balance studies were carried out for the practices adopted from the start of crop cultivation to the end of harvest.

METERIAL AND METHODS

A field experiment was conduct during *rabi* season 2020-21 at College Farm, College of Agriculture, Rajendranagar, Hyderabad. The experimental field's soil had a loamy sand texture and a pH of 7.9 with available nitrogen (223 kg ha^{-1}), available phosphorus (30.87 kg ha^{-1}), available potassium (375.72 kg ha^{-1}) and organic carbon (0.69%), it was medium fertile. Mustard variety NRCHB-101 was sown with seed rate of 4 kg ha^{-1}. The seeds were sown manually with spacing of 40×10 cm. Recommended dose of fertilizers 80:40:40 Kg ha^{-1} N, P_2O_5 K_2O were applied. The experiment was laid out in randomised block design replicated thrice with twelve treatments *viz.*, T_1**:** Pendimethalin 30 % EC 1.0 kg ha^{-1} PE *fb* quizalofop ethyl 5% EC 0.05 kg ha^{-1} PoE, T_2: Oxadiargyl 6% EC 0.09 kg ha^{-1} PE *fb* quizalofop ethyl 5% EC 0.05 kg ha^{-1} PoE, T_3: Oxyfluorfen 23.5 % EC 0.1 kg ha^{-1} PE *fb* quizalofop ethyl 5% EC 0.05 kg ha^{-1} PoE, T_4: Pendimethalin 30 % EC 1.0 kg ha^{-1} PE *fb* straw mulch 5 t ha^{-1}, T_5: Oxadiargyl 6% EC 0.09 kg ha^{-1} PE *fb* straw mulch 5 t ha^{-1}, T_6: Oxyfluorfen 23.5 % EC 0.1 kg ha^{-1} PE *fb* straw mulch 5 t ha^{-1}, T_7: Pendimethalin 30 % EC 1.0 kg ha^{-1} PE *fb* intercultivation at 30 DAS, T_8: Oxadiargyl 6% EC 0.09 kg ha^{-1} PE *fb* intercultivation at 30 DAS, T_9 : Oxyfluorfen 23.5 % EC 0.1 kg ha^{-1} PE *fb* intercultivation at 30 DAS, T_{10}: Intercultivation and hand weeding at 15 and 30 DAS (weed free), T_{11}: Intercultivation at 15 and 30 DAS, T_{12}: Unweeded control. Pre-emergence herbicides were applied within in 24 hours after sowing. All post-emergence herbicides were sprayed at 2-3 leaf stage of weeds. Straw mulch was laid at 15 DAS. Intercultivation was done with push hoe at 15 and 30 DAS. Hand weeding was done at 15 and 30 DAS. The observations were noticed on energy input, energy output, net energy, energy efficiency, energy Productivity.

Energy input of different treatments was estimated by using direct and indirect energy. Direct energy inputs include total quantity of fossil fuel used in land preparation, harvesting, human labour and electricity whereas indirect energy inputs are energy used in transportation of machinery synthetic fertilizers, pesticides and seed. The indirect energy use of agricultural machinery was calculated by using an equation.

Eim = (MTR x M)/ (L x Ce)

Where, Eim = Machinery input energy (M) ha^{-1})

MTR = Energy used to manufacture, transport and repair

M = Mass of machinery (kg)

L = Life of machinery (h)

Ce = Effective field capacity of farm machinery (h ha^{-1}).

Output energy

The seed and stover yields were considered for calculating output energy. Energy output was calculated by multiplying the seed and stover yields with corresponding energy coefficient. Energy efficiencies or intensities of the different weed management treatments were estimated as i) net energy and ii) ratio of output to energy input (Energy use efficiency, EUE).

Total net energy

NEt = Energy Output-Energy input

Total energy use efficiency

Total energy output (MJ ha^{-1})

EUEt = --------------------------------

Energy input (MJ ha^{-1})

Total energy productivity

Total yield (kg ha^{-1})

EPt = --------------------------------

Energy input (MJ ha^{-1})

List 1: Energy conversion factors used in the present study

Input		Energy coefficient	References
Machinery	MB Plough	22.4 MJ kg^{-1}	Devasenapathy *et al.* (2009)
	Rotavator	23.2 MJ kg^{-1}	Devasenapathy *et al.* (2009)
	Cultivator	20.72 MJ kg^{-1}	Devasenapathy *et al.* (2009)
	Sprayer	3.76 MJ kg^{-1}	Pimentel (1993)
Irrigation	Diesel	56.31 MJ 1^{-1}	Devasenapathy *et al.* (2009)
	Water	1.02 m^3	Devasenapathy *et al.* (2009)
	Electricity	11.93 kW h	Devasenapathy *et al.* (2009)
	Pump	0.382 kW h ha^{-1}	Devasenapathy *et al.* (2009)
Manual labour	Men	1.96 MJ $man\text{-}h^{-1}$	Mittal and Dhawan (1988)
	Women	1.57 MJ $man\text{-}h^{-1}$	Mittal and Dhawan (1988)
Fertilizers	Nitrogen	60.0 MJ kg^{-1}	Devasenapathy *et al.* (2009)
	Phosphorus	11.30 MJ kg^{-1}	Devasenapathy *et al.* (2009)
	Potassium	6.70 MJ kg^{-1}	Devasenapathy *et al.* (2009)

Pesticides	Emamectin	228.8 MJ kg^{-1}	Green (1987)
	Propiconazole	175 MJ kg^{-1}	Guzman and Alanso (2008)
	Oxyfluorfen	551 MJ kg^{-1}	Chaudary *et al.* (2017)
	Oxadiargyl	121.5 MJ kg^{-1}	Jha *et al.* (2020)
	Quizalofop ethyl	518 MJ kg^{-1}	Chaudary *et al.* (2017)
	Pendimethalin	421 MJ kg^{-1}	Chaudary *et al.* (2017)
Seed	Seed	14.70 MJ kg^{-1}	Devasenapathy *et al.* (2009)
Output			
Grain		14.70 MJ kg^{-1}	Devasenapathy *et al.* (2009)
Stover		12.50 MJ kg^{-1}	Devasenapathy *et al.* (2009)

RESULTS AND DISCUSSION

Effect on weed flora

The experimental field was infested with grasses like *Digitaria sanguinalis, Chloris barbata, Echinochloa crusgalli, Cynodon dactylon, Dactyloctenium aegyptium, Dinebra retroflexa, Eleusine indica* and sedges like *Cyperus rotundus* and broad-leaved weeds like *Parthenium hysterophorus, Alternanthera sessilis, Trianthema portulacastrum, Cleome viscosa, Datura stramonium, Euphorbia hirta, Commelina benghalensis, Sonchus arevensis* and *Digera arvensis.*

Effect on weed control efficiency

Different weed management practices had impact on weed control efficiency (Table 1). Higher weed control efficiency was

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observed with intercultivation and hand weeding at 15 and 30 DAS and this treatment was followed by oxadiargyl 6 % EC 0.09 kg ha^{-1} PE *fb* intercultivation at 30 DAS, oxyfluorfen 23.5 % EC 0.1 kg ha^{-1} PE *fb* intercultivation at 30 DAS, pendimethalin 30 % EC 1.0 kg ha^{-1} PE *fb* intercultivation at 30 DAS, oxadiargyl 6 % EC 0.09 kg ha^{-1} PE *fb* straw mulch at 5 t ha^{-1}, oxyfluorfen 23.5 % EC 0.1 kg ha^{-1} PE *fb* straw mulch at 5 t ha^{-1} , pendimethalin 30 % EC 1.0 kg ha^{-1} PE *fb* straw mulch at 5 t ha^{-1}, intercultivation at 15 and 30 DAS, It might be due to effective control of weeds led to reduced weed dry matter resulted in higher weed control efficiency (Singh and Kumar, 2020).

Effect on yield

Data pertaining to yield presented in Table 1. Among weed management practices, Higher seed and stover yield were observed under intercultivation and hand weeding at 15 and 30 DAS and it was on par with oxadiargyl 6% EC 0.09 kg ha^{-1} PE *fb* intercultivation at 30 DAS. In turn oxadiargyl 6% EC 0.09 kg ha^{-1} PE *fb* intercultivation at 30 DAS on par with oxyfluorfen 23.5 % EC 0.1 kg ha^{-1} PE *fb* intercultivation at 30 DAS, pendimethalin 30 % EC 1.0 kg ha^{-1} PE *fb* intercultivation at 30 DAS. Effective control of weeds provided congenial environment for crop which resulted in higher yield attributes led to higher yield (Das, 2016).

Energy balance studies

Data pertaining to energy balance studies were presented in Table 2. Among the different weed management practices, pendimethalin 30 % EC 1.0 kg ha^{-1} PE *fb* straw mulch 5 t ha^{-1} recorded highest energy input. This treatment was followed by oxyfluorfen 23.5 % EC 0.1 kg ha^{-1} PE *fb* straw mulch 5 t ha^{-1} and oxadiargyl 6 % EC 0.09 kg ha^{-1} PE *fb* straw mulch 5 t ha^{-1} it might be due to more energy necessary to produce straw mulch.

Higher total energy output was observed with intercultivation and hand weeding at 15 and 30 DAS and it was statistically on par with oxadiargyl 6 % EC 0.09 kg ha^{-1} PE *fb* intercultivation at 30 DAS. Oxadiargyl 6 % EC 0.09 kg ha^{-1} PE *fb* intercultivation at 30 DAS in turn on par with oxyfluorfen 23.5 % EC 0.1 kg ha^{-1} PE *fb* intercultivation at 30 DAS and pendimethalin 30 % EC 1.0 kg ha^{-1} PE *fb* intercultivation at 30 DAS.

Intercultivation and hand weeding at 15 and 30 DAS was recorded significantly higher net energy and it was found to be on par with oxadiargyl 6 % EC 0.09 kg ha^{-1} PE *fb* intercultivation at 30 DAS. Oxadiargyl 6 % EC 0.09 kg ha^{-1} PE *fb* intercultivation at 30 DAS in turn on par with oxyfluorfen 23.5 % EC 0.1 kg ha^{-1} PE *fb* intercultivation at 30 DAS, pendimethalin 30 % EC 1.0 kg ha^{-1} PE *fb* intercultivation at 30 DAS.

Significantly superior energy use efficiency (EUE) of total output was recorded under intercultivation and hand weeding at 15 and 30 DAS and it was statistically on par with oxadiargyl 6 % EC 0.09 kg ha^{-1} PE *fb* intercultivation at 30 DAS, oxyfluorfen 23.5 % EC 0.1 kg ha^{-1} PE *fb* intercultivation at 30 DAS and pendimethalin 30 % EC 1.0 kg ha^{-1} PE *fb* intercultivation at 30 DAS.

Intercultivation and hand weeding at 15 and 30 DAS was recorded highest energy productivity (EP) of total output and it was statistically on par with oxadiargyl 6 % EC 0.09 kg ha^{-1} PE *fb* intercultivation at 30 DAS, oxyfluorfen 23.5 % EC 0.1 kg ha^{-1} PE *fb* intercultivation at 30 DAS and pendimethalin 30 % EC 1.0 kg ha^{-1} PE *fb* intercultivation at 30 DAS. Similar results were noticed by Jha *et al*. (2020).

CONCLUSONS

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In case of energy balance studies, maximum energy input was required for pendimethalin 30 % EC 1.0 kg ha^{-1} PE *fb* straw mulch 5 t ha^{-1}. Higher energy output, net energy, energy use efficiency and energy productivity were recorded under Intercultivation and hand weeding at 15 and 30 DAS.

Table 1. Weed control efficiency (%) and yield (kg ha^{-1}) as influenced by integrated weed management practices in mustard

Treatments	Weed control efficiency (%)	Seed yield (kg ha^{-1})	Stover yield (kg ha^{-1})
T_1: Pendimethalin 30 % EC 1.0 kg ha^{-1} PE *fb* quizalofop ethyl 5 % EC 0.05 kg ha^{-1} PoE	80.63	895	2596
T_2: Oxadiargyl 6 % EC 0.09 kg ha^{-1} PE *fb* quizalofop ethyl 5 % EC 0.05 kg ha^{-1} PoE	82.12	917	2668
T_3: Oxyfluorfen 23.5 % EC 0.1 kg ha^{-1} PE *fb* quizalofop ethyl 5 % EC 0.05 kg ha^{-1} PoE	81.33	908	2634
T_4: Pendimethalin 30 % EC 1.0 kg ha^{-1} PE *fb* straw mulch 5 t ha^{-1}	85.46	1084	2878
T_5: Oxadiargyl 6 % EC 0.09 kg ha^{-1} PE *fb* straw mulch 5 t ha^{-1}	86.46	1104	2938
T_6: Oxyfluorfen at 23.5 % EC 0.1 kg ha^{-1} PE *fb* straw mulch 5 t ha^{-1}	85.97	1092	2897
T_7: Pendimethalin 30 % EC 1.0 kg ha^{-1} PE *fb* intercultivation at 30 DAS	90.29	1267	3098
T_8: Oxadiargyl 6 % EC 0.09 kg ha^{-1} PE *fb* intercultivation at 30 DAS	92.72	1349	3149
T_9: Oxyfluorfen 23.5 % EC 0.1 kg ha^{-1} PE *fb* intercultivation at 30 DAS	90.77	1320	3115
T_{10}: Intercultivation and hand weeding at 15 DAS and 30 DAS (weed free)	94.77	1483	3280
T_{11}: Intercultivation at 15 and 30 DAS	84.52	1070	2799
T_{12}: Unweeded control	-	641	2413
SE (m) ±		47.7	48.7
CD (P=0.05)		140.0	142.8

Table 2. Energetics as influenced by integrated weed management practices in mustard

Treatments	EI	Eot	Net	EUEt	Ept
	(MJ ha^{-1})				(kg MJ^{-1})
T_1: Pendimethalin 30 % EC 1.0 kg ha^{-1} PE *fb* quizalofop ethyl 5 % EC 0.05 kg ha^{-1} PoE	19423	45748	26325	2.36	0.180
T_2: Oxadiargyl 6 % EC 0.09 kg ha^{-1} PE *fb* quizalofop ethyl 5 % EC 0.05 kg ha^{-1} PoE	19013	46970	27958	2.47	0.189
T_3: Oxyfluorfen 23.5 % EC 0.1 kg ha^{-1} PE *fb* quizalofop ethyl 5 % EC 0.05 kg ha^{-1} PoE	19157	46422	27265	2.42	0.185
T_4: Pendimethalin 30 % EC 1.0 kg ha^{-1} PE *fb* straw mulch 5 t ha^{-1}	41944	52058	10114	1.24	0.094
T_5: Oxadiargyl 6 % EC 0.09 kg ha^{-1} PE *fb* straw mulch 5 t ha^{-1}	41534	53100	11566	1.28	0.097
T_6: Oxyfluorfen at 23.5 % EC 0.1 kg ha^{-1} PE *fb* straw mulch 5 t ha^{-1}	41578	52413	10835	1.26	0.096
T_7: Pendimethalin 30 % EC 1.0 kg ha^{-1} PE *fb* intercultivation at 30 DAS	19588	57483	37895	2.93	0.223
T_8: Oxadiargyl 6 % EC 0.09 kg ha^{-1} PE *fb* intercultivation at 30 DAS	19178	60338	41160	3.15	0.235
T_9: Oxyfluorfen 23.5 % EC 0.1 kg ha^{-1} PE *fb* intercultivation at 30 DAS	19223	58488	39266	3.04	0.231
T_{10}: Intercultivation and hand weeding at 15 DAS and 30 DAS (weed free)	19315	62945	43630	3.26	0.247
T_{11}: Intercultivation at 15 and 30 DAS	19202	50862	31660	2.65	0.202
T_{12}: Unweeded control	18988	22736	3748	1.20	0.161
SE (m) ±		1198.5	1200.3	0.13	0.01
CD (P=0.05)		3595.1	3602.0	0.40	0.03

EI: energy input, Eot: total energy output, Net: total net energy, EUEt: total energy use efficiency, Ept: total energy productivity

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Comment [h4]: Add 2-3 reference of International Journal of Environment and Climate Change

Comment [h5]: Only 3 references on mustard crop???

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