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

ABSTRACT

An 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, Stomp 30 % EC as PE *fb* straw mulch 5 t ha^{-1} recorded higher energy input. This treatment was followed by Goal 23.5 % EC as PE *fb* straw mulch 5 t ha^{-1} and Raft 6 % EC as 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 Raft 6 % EC as PE *fb* intercultivation at 30 DAS, Goal 23.5 % EC as PE *fb* intercultivation at 30 DAS and Stomp 30 % EC as PE *fb* intercultivation at 30 DAS.

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

INTRODUCTION:

"In terms of international trade, mustard is one of the most significant oilseed crops. Among the seven edible oilseeds, it is India's second-largest oilseed crop after groundnut. Oil content in mustard seeds ranges from 37 to 49%". (Bhowmik *et al.*, 2014). "Rapeseed and mustard grow on 6.23 million hectares of land in India, producing 9.34 million tonnes and 1499 kg ha^{-1}, respectively, in terms of output and productivity" (India stat 2019-20). The primary biotic stressor in mustard production is weeds. The usage of non-farm inputs including fertilisers, insecticides, herbicides, fungicides, and other chemicals has grown over time as a result of agriculture's intensification. Energy is needed in large quantities for these inputs. daily rise in the price of crude oil, which in turn drives up the cost of external inputs. As a result, the benefits of cultivation are limited while the expense increases. Therefore, it is necessary to calculate energy inputs and outputs. To determine the direction of a system's energy consumption pattern, energy balance is defined as the measurement of proportion and analysis of the energy input absorbed and output created by various activities. (Acharya *et al.*, 2013). Keeping this in view, the current experiment was conducted with the aim of analysing the energy balance of weed control techniques in mustard. Studies on the energy balance were conducted for the procedures used from the beginning of crop cultivation to the end of harvest.

METERIAL AND METHODS

A field study was carried out at the College Farm, College of Agriculture, Rajendranagar, Hyderabad, during the rabi season 2020–21. The soil in the experimental field had a loamy sand texture, a pH of 7.9, was moderately fertile, and had accessible nitrogen (223 kg ha^{-1}), phosphorus (30.87 kg ha^{-1}), potassium (375.72 kg ha^{-1}), and organic carbon (0.69%). The NRCHB-101 mustard variety was sown at a seed rate of 4 kg ha^{-1}. Manually, the seeds were spaced 40 cm apart by 10 cm. The recommended fertiliser dosage of 80:40:40 Kg ha^{-1} of N, P_2O_5, and K_2O was used. The experiment was laid in a randomised block design and replicated three times with twelve treatments:T_1**:** Stomp 30 % EC as PE *fb* Turga Super 5% EC as PoE, T_2: Raft 6% EC as PE *fb* Turga Super 5% EC as PoE, T_3: Goal 23.5 % EC as PE *fb* Turga Super 5% EC as PoE, T_4: Stomp 30 % EC as PE *fb* straw mulch 5 t ha^{-1}, T_5: Raft 6% EC as PE *fb* straw mulch 5 t ha^{-1}, T_6: Goal 23.5 % EC as PE *fb* straw mulch 5 t ha^{-1}, T_7: Stomp 30 % EC as PE *fb* intercultivation at 30 DAS, T_8: Raft 6% EC 0.09 kg ha^{-1} PE *fb* intercultivation at 30 DAS, T_9 : Goal 23.5 % EC as 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. Herbicides for pre-emergence were used 24 hours after sowing. All post-emergence herbicides were applied to weeds when they had 2–3 leaves. At 15 DAS, straw mulch was applied. Intercultivation was carried out with push hoe at 15 and 30 DAS. At 15 and 30 DAS, manual weeding was done. Energy input, energy output, net energy, energy efficiency, and energy productivity were all noted.

Direct and indirect energy were used to evaluate the energy input of various treatments. Indirect energy inputs are the energy necessary to convey machinery, synthetic fertilisers, pesticides, and seed. Direct energy inputs include the whole amount of fossil fuel used in land preparation, harvesting, human labour, and electricity.

Output energy

When determining output energy, the seed and stover yields were taken into account. By dividing the seed and stover yields by the associated energy coefficient, energy output was estimated. The energy intensities or efficiencies of the various weed management techniques were calculated as i) net energy and (ii) the output to energy input ratio (Energy use efficiency, EUE).

Total net energy

NEt = Energy Output-Energy input

Total energy use efficiency

$$EUEt = \frac{\text{Total energy output (MJ ha}^{-1}\text{)}}{\text{Energy input (MJ ha}^{-1}\text{)}}$$

Total energy productivity

$$EPt = \frac{\text{Total yield (kg ha}^{-1}\text{)}}{\text{Energy input (MJ ha}^{-1}\text{)}}$$

Table 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-h^{-1}	Mittal and Dhawan (1988)
	Women	1.57 MJ man-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, 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, Euphorbia hirta, Commelina benghalensis* and *Digera arvensis". (Yernaidu et. Al. 2021)*

Effect on weed density and weed dry weight

Data pertaining to yield presented in Table 2. "Among weed management practices, Lower grasses, sedges and broad -leaved weed density were observed under intercultivation and hand weeding at 15 and 30 DAS recorded lower grass weed density and it was found to be on par with Raft 6 % EC as PE *fb* intercultivation at 30 DAS. In turn Raft 6 % EC as PE *fb* intercultivation at 30 DAS on par with Goal 23.5 % EC as PE *fb* intercultivation at 30 DAS, Stomp 30 % EC as PE *fb* intercultivation at 30 DAS. Similarly, Intercultivation and hand weeding at 15 and 30 DAS registered lower weed dry matter compared to other and it was statistically on par with Raft 6 % EC as PE *fb* intercultivation at 30 DAS. Goal 23.5 % EC as PE *fb* intercultivation at 30 DAS and Stomp 30 % EC as PE *fb* intercultivation at 30 DAS were on par with Raft 6 % EC as PE *fb* intercultivation at 30 DAS. These treatments followed by Raft 6 % EC as PE *fb* straw mulch 5 t ha^{-1}, Goal 23.5 % EC as PE *fb* straw mulch 5 t ha^{-1}, Stomp 30 % EC as PE *fb* straw mulch 5 t ha^{-1} and intercultivation at 15 and 30 DAS). Lower weed dry matter was observed in different treatments due to suppression of weeds resulted lesser weed dry matter" (Singh *et al*., 2020).

Effect on weed control efficiency

The effectiveness of weed control was impacted by several weed management techniques (Table 3). "Higher weed control efficiency was observed with intercultivation and hand weeding at 15 and 30 DAS and this treatment was followed by Raft 6 % EC as PE *fb* intercultivation at 30 DAS, Goal 23.5 % EC as PE *fb* intercultivation at 30 DAS, Stomp 30 % EC as PE *fb* intercultivation at 30 DAS, Raft 6 % EC as PE *fb* straw mulch at 5 t ha^{-1}, Goal 23.5 % EC as PE *fb* straw mulch at 5 t ha^{-1} , Stomp 30 % EC as 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" (Sharma and Jain, 2002, Singh and Kumar, 2020).

Effect on yield

Data pertaining to yield presented in Table 3. 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 Raft 6 % EC as PE *fb* intercultivation at 30 DAS. In turn Raft 6 % EC as PE *fb* intercultivation at 30 DAS on par with Goal 23.5 % EC as PE *fb* intercultivation at 30 DAS, Stomp 30 % EC as 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 4. Among the different weed management practices, Stomp 30 % EC as PE *fb* straw mulch 5 t ha^{-1} recorded highest energy input. This treatment was followed by Goal 23.5 % EC as PE *fb* straw mulch 5 t ha^{-1} and Raft 6 % EC as 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 Raft 6 % EC 0.09 as PE *fb* intercultivation at 30 DAS. Raft 6 % EC as PE *fb* intercultivation at 30 DAS in turn on par with Goal 23.5 % as PE *fb* intercultivation at 30 DAS and Turga Super 30 % EC as 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 Raft 6 % EC as PE *fb* intercultivation at 30 DAS. Raft 6 % EC as PE *fb* intercultivation at 30 DAS in turn on par with Goal 23.5 % EC as PE *fb* intercultivation at 30 DAS, Stomp 30 % EC as 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 Raft 6 % EC as PE *fb* intercultivation at 30 DAS, Goal 23.5 % EC as PE *fb* intercultivation at 30 DAS and Stomp 30 % EC as PE *fb* intercultivation at 30 DAS" (Rani *et al.*, 2016).

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 Raft 6 % EC as PE *fb* intercultivation at 30 DAS, Goal 23.5 % EC as PE *fb* intercultivation at 30 DAS and Stomp 30 % EC as PE *fb* intercultivation at 30 DAS. Similar results were noticed by Jha *et al.* (2020).

CONCLUSONS

In case of energy balance studies, maximum energy input was required for Stomp 30 % EC as 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 2. Effect of different weed management practices on Weed density and weed dry weight in mustard

Treatments	Weed density (No. m^{-2})			Weed dry weight
	Grasses	Sedges	Broad leaved	
T_1: Stomp 30 % EC as PE *fb* Turga Super 5 % EC as PoE	2.61 (5.80)	2.94 (7.65)	4.53 (19.52)	3.51 (11.29)
T_2: Raft 6 % EC as PE *fb* Turga Super 5 % EC as PoE	2.57 (5.59)	2.77 (6.66)	4.48 (19.06)	3.38 (10.43)
T_3: Goal 23.5 % EC as PE *fb* Turga Super 5 % EC as PoE	2.59 (5.71)	2.88 (7.32)	4.51 (19.36)	3.45 (10.88)
T_4: Stomp 30 % EC as PE *fb* straw mulch 5 t ha^{-1}	3.23 (9.46)	2.41 (4.85)	3.66 (12.39)	3.08 (8.48)
T_5: Raft 6 % EC as PE *fb* straw mulch 5 t ha^{-1}	3.19 (9.18)	2.26 (4.13)	3.59 (11.89)	2.98 (7.89)
T_6: Goal 23.5 % EC as PE *fb* straw mulch 5 t ha^{-1}	3.21 (9.28)	2.37 (4.66)	3.63 (12.21)	3.03 (8.18)
T_7: Stomp 30 % EC as PE *fb* intercultivation at 30 DAS	2.56 (5.58)	2.00 (3.01)	3.17 (9.06)	2.58 (5.66)
T_8: Raft 6 % EC as PE *fb* intercultivation at 30 DAS	2.17 (3.70)	1.79 (2.26)	2.97 (7.85)	2.29 (4.24)
T_9: Goal 23.5 % EC as PE *fb* intercultivation at 30 DAS	2.52 (5.44)	1.97 (2.90)	3.08 (8.49)	2.53 (5.38)
T_{10}: Intercultivation and hand weeding at 15 DAS and 30 DAS (weed free)	1.98 (2.92)	1.61 (1.71)	2.55 (5.53)	2.01 (3.05)
T_{11}: Intercultivation at 15 and 30 DAS	3.25 (9.56)	2.49 (5.21)	3.70 (12.71)	3.17 (9.03)
T_{12}: Unweeded control	5.86 (33.56)	4.63 (20.43)	9.08 (81.53)	7.70 (58.30)
SE (m) ±	0.16	0.11	0.15	0.11
CD (P=0.05)	0.48	0.33	0.44	0.35

Note: Values in the parenthesis are original and ($\sqrt{x+1}$) transformed. PE-Pre Emergence, PoE-Post Emergence.

Table 3. Effect of different weed management practices on Weed control efficiency and yield in mustard

Treatments	Weed control efficiency (%)	Seed yield (kg ha^{-1})	Stover yield (kg ha^{-1})
T_1: Stomp 30 % EC as PE *fb* Turga Super 5 % EC as PoE	80.63	895	2596
T_2: Raft 6 % EC as PE *fb* Turga Super 5 % EC as PoE	82.12	917	2668
T_3: Goal 23.5 % EC as PE *fb* Turga Super 5 % EC as PoE	81.33	908	2634
T_4: Stomp 30 % EC as PE *fb* straw mulch 5 t ha^{-1}	85.46	1084	2878
T_5: Raft 6 % EC as PE *fb* straw mulch 5 t ha^{-1}	86.46	1104	2938
T_6: Goal 23.5 % EC as PE *fb* straw mulch 5 t ha^{-1}	85.97	1092	2897
T_7: Stomp 30 % EC as PE *fb* intercultivation at 30 DAS	90.29	1267	3098
T_8: Raft 6 % EC as PE *fb* intercultivation at 30 DAS	92.72	1349	3149
T_9: Goal 23.5 % EC as 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 4. Effect of different weed management practices on Energetics in mustard

Treatments	EI	Eot	Net	EUEt	Ept
	(MJ ha^{-1})				(kg MJ^{-1})
T_1: Stomp 30 % EC as PE *fb* Turga Super 5 % EC as PoE	19423	45748	26325	2.36	0.180
T_2: Raft 6 % EC as PE *fb* Turga Super 5 % EC as PoE	19013	46970	27958	2.47	0.189
T_3: Goal 23.5 % EC as PE *fb* Turga Super 5 % EC as PoE	19157	46422	27265	2.42	0.185
T_4: Stomp 30 % EC as PE *fb* straw mulch 5 t ha^{-1}	41944	52058	10114	1.24	0.094
T_5: Raft 6 % EC as PE *fb* straw mulch 5 t ha^{-1}	41534	53100	11566	1.28	0.097
T_6: Goal 23.5 % EC as PE *fb* straw mulch 5 t ha^{-1}	41578	52413	10835	1.26	0.096
T_7: Stomp 30 % EC as PE *fb* intercultivation at 30 DAS	19588	57483	37895	2.93	0.223
T_8: Raft 6 % EC as PE *fb* intercultivation at 30 DAS	19178	60338	41160	3.15	0.235
T_9: Goal 23.5 % EC as 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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