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EVALUATION OF ENERGETICS OF BLACKGRAM (*Vigna mungo* L.) UNDER STALE SEEDBED AND HERBICIDE INTEGRATION

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ABSTRACT

Efficient energy utilization is an important component of sustainable crop production, particularly in pulse based cropping systems where weed management practices considerably influence energy consumption and productivity. A field experiment was conducted during *rabi* 2025-26 at the Regional Agricultural Research Station, Palem, Nagarkurnool, Telangana to evaluate the energetics of blackgram (*Vigna mungo* L.) under stale seedbed and herbicide integration. The experiment was laid out in a randomized block design with thirteen treatments and three replications. The treatments comprised normal sowing, stale seedbed established through shallow tillage or paraquat application before sowing, pre- and post-emergence herbicide combinations, weed free check and weedy check. Energy inputs from seed, fertilizers, herbicides, pesticides, human labour, machinery, diesel and irrigation along with energy outputs from seed and haulm yields were estimated using standard energy coefficients. Energy indices, total energy input, total energy output, net energy, energy use efficiency, energy productivity and specific energy were computed to assess the performance of different weed management practices. Stale seedbed (shallow tillage) + fluazifop-p-butyl 11.1% w/w + fomesafen 11.1% w/w SL @250 g a.i. ha^{-1} PoE at 20-25 DAS (T_8) recorded the highest total energy input and weed free check (T_{12}) recorded total energy output. Highest net energy, energy use efficiency, energy productivity and lowest specific energy recorded with weed free check and it was statistically on par with stale seedbed (paraquat spray @ 500 g a.i. ha^{-1} before sowing) + fluazifop-p-butyl 11.1% w/w + fomesafen 11.1% w/w SL @250 g a.i. ha^{-1} PoE at 20-25 DAS (T_9). The study demonstrated that integrating the stale seedbed technique with post-emergence herbicides significantly improved energetic performance and resource use efficiency suggesting that this approach is an energy efficient and sustainable weed management strategy for blackgram cultivation under the Southern Telangana agro climatic conditions.

***Key words*:** Blackgram, Stale seedbed, Energy productivity, Energy use efficiency, Specific Energy.

Introduction

Despite its agronomic advantages, blackgram cultivation is severely affected by weed infestation, one of the major constraints limiting crop productivity (Marimuthu *et al*., 2024). Due to their high adaptability, weeds establish rapidly and compete with the crop for nutrients, moisture, light and space particularly during the early growth stages when blackgram exhibits slow initial growth (Anusha *et al*., 2024). The critical period of crop-weed competition occurs between 15 and 45 DAS with yield losses ranging from 27% to 64% and reaching up to 79% under season-long weed infestation (Singh, 2011; Bhowmick *et al*., 2015; Sharma *et al*., 2024). Although hand weeding is effective, it is labour intensive and constrained by labour scarcity, while continuous reliance on herbicides has raised concerns about environmental pollution and herbicide resistance (Kumar *et al*., 2022; Owombo *et al*., (2014). Therefore, integrating stale

seedbed with herbicide application offers a promising and eco-friendly weed management approach. Since energy use and economics are closely linked in crop production, the present study was undertaken to evaluate the energy budgeting of weed management practices in blackgram.

Materials and Methods

The field experiment was conducted at the Regional Agricultural Research Station, Palem, Nagarkurnool, Professor Jayashankar Telangana Agricultural University, Telangana. The experimental site is located at an altitude of 478 m above mean sea level, between 16°30' 49.98" N latitude and 78°15' 06.60" E longitude in the Southern Telangana agro-climatic Zone of Telangana. According to Troll's classification, the region falls under the semi-arid tropics. The experiment was laid out in a randomized block design with 13 treatments replicated thrice and consisted of normal sowing + pendimethalin 38.7% CS @ 677.25 g a.i. ha^{-1} (PE) (T_1), normal sowing + fluazifop-p-butyl 11.1 % w/w + fomesafen 11.1% w/w SL @ 250 g a.i. ha^{-1} (PoE) at 20-25 DAS (T_2), normal sowing + propaquizafop 2.5% + imazethapyr 3.75% w/w ME @ 50+75 g a.i. ha^{-1} (PoE) at 20-25 DAS (T_3), stale seedbed (shallow tillage) (T_4), stale seedbed (paraquat spray @ 500 g a.i. ha^{-1} before sowing) (T_5), stale seedbed (shallow tillage) + pendimethalin 38.7% CS @ 677.25 g a.i. ha^{-1} (PE) (T_6), stale seedbed (paraquat spray @ 500 g a.i. ha^{-1} before sowing) + pendimethalin 38.7% CS @ 677.25 g a.i. ha^{-1} (PE) (T_7), stale seedbed (shallow tillage) + fluazifop-p-butyl 11.1% w/w + fomesafen 11.1% w/w SL @ 250 g a.i. ha^{-1} (PoE) at 20-25 DAS (T_8), stale seedbed (paraquat spray @ 500 g a.i. ha^{-1} before sowing) + fluazifop-p-butyl 11.1% w/w fomesafen 11.1% w/w SL 250 g a.i. ha^{-1} (PoE) at 20-25 DAS (T_9), stale seedbed (shallow tillage) + propaquizafop 2.5% + imazethapyr 3.75% w/w ME @ 50+75 g a.i. ha^{-1} (PoE) at 20-25DAS (T_{10}), stale seedbed (paraquat spray @ 500 g a.i. ha^{-1} before sowing) + propaquizafop 2.5% + imazethapyr 3.75% w/w ME @ 50+75 g a.i. ha^{-1} (PoE) at 20-25 DAS (T_{11}), weed free check (hand weeding at 20 & 40 DAS) (T_{12}) and weedy check (T_{13}). Blackgram (Vigna mungo L.) variety MBG 1070 was sown on 11 December 2025 at a spacing of 30 × 10 cm using a seed rate of 20-25 kg ha^{-1}. Herbicides were applied with a knapsack sprayer fitted with a flat-fan nozzle calibrated to deliver 500 l of water ha^{-1}. All recommended agronomic practices for blackgram were followed throughout the crop growth period. The crop received the recommended fertilizer dose of 20 kg N and 50 kg P_2O_5 ha^{-1} supplied through urea and single superphosphate, respectively.

Methodology for Energy Budget Analysis

The inputs used and the energy requirement associated with each input in blackgram production, including weed management practices, were recorded, estimated, and presented. The major inputs considered for blackgram cultivation were machinery, human labour, chemical fertilizers, irrigation water, fuel, pesticides and seed, while the outputs comprised seed and haulm yield. The energy equivalents assigned to different inputs and outputs (Table 1) were used to estimate the total energy values. Human energy input was calculated by multiplying the total man hours (h ha^{-1}) by the corresponding energy equivalent of human labour (MJ h^{-1}) as given in Table 1. The energy contribution of female labour was converted into human energy using appropriate conversion factors.

Table 1: Energy conversion factors used in the present study in blackgram.

Energy source	Equivalent energy	References
Input energy		
Adult woman	1.57 MJ h^{-1}	Mittal and Dhawan, (1988)
Man	1.96 MJ h^{-1}	Mittal and Dhawan, (1988)
Tractor	64.80 MJ h^{-1}	Devasenapathy *et al.*, (2009)
Cultivator	22.80 MJ h^{-1}	Devasenapathy *et al.*, (2009)
Leveller	20.72 MJ h^{-1}	Devasenapathy *et al.*, (2009)
Power weeder	4.75 MJ kg^{-1}	Devasenapathy *et al.*, (2009)
Sprayer	0.94 MJ h^{-1}	Pimentel, (1993)
Disel	56.31 MJ L^{-1}	Devasenapathy *et al.*, (2009)
Chemical fertilizers		
N	60.6 MJ kg^{-1}	Devasenapathy *et al.*, (2009)
P_2O_5	11.1 MJ kg^{-1}	Devasenapathy *et al.*, (2009)
Pesticides		
Pendimethalin	421 MJ kg^{-1} a.i	Chaudary *et al.*, (2017)
Imazethapyr	518 MJ kg^{-1} a.i	Audsley *et al.*, (2009)
Propaquizafop	561 MJ kg^{-1} a.i	Audsley *et al.*, (2009)
Fluazifop-p-butyl	454 MJ kg^{-1} a.i	Green, (1987)
Fomesafen	454 MJ kg^{-1} a.i	Green, (1987)
Insecticides	184.63 MJ kg^{-1} a.i.	Parihar *et al.*, (2018)
Output energy		
Blackgram seed	14.7 MJ kg^{-1}	Devasenapathy *et al.*, (2009)
Blackgram haulm	12.5 MJ kg^{-1}	Devasenapathy *et al.*, (2009)

Energy use efficiency parameters were computed using the formulae proposed by Morad *et al*., (2018).

Input energy (MJ ha^{-1})

Input energy was estimated by multiplying the quantity of each input used with its corresponding energy equivalent.

Input energy (MJ ha^{-1}) = Quantity of various inputs × Energy equivalent

Output energy (MJ ha^{-1})

Energy output from the produce, including grain and

Table 2: Effect of stale seedbed and herbicide integration on total input (MJ ha^{-1}), output (MJ ha^{-1}) and net energy (MJ ha^{-1}) in blackgram.

Treatment	TIE	TOE	NE
T_1: Normal sowing + pendimethalin 38.7% CS @ 677.25 g a.i. ha^{-1} (PE)	8417	32244	23827
T_2: Normal sowing + fluazifop-p-butyl 11.1 % w/w + fomesafen 11.1% w/w SL @ 250 g a.i. ha^{-1} (PoE) at 20-25 DAS	8449	46214	37764
T_3: Normal sowing + propaquizafop 2.5% + imazethapyr 3.75% w/w ME @ 50+75 g a.i. ha^{-1} (PoE) at 20-25 DAS	8403	36686	28284
T_4: Stale seedbed (shallow tillage)	9980	39534	29555
T_5: Stale seedbed (paraquat spray @ 500 g a.i. ha^{-1} before sowing)	8586	38738	30153
T_6: Stale seedbed (shallow tillage) + pendimethalin 38.7% CS @ 677.25 g a.i. ha^{-1} (PE)	10081	44090	34009
T_7: Stale seedbed (paraquat spray @ 500 g a.i. ha^{-1} before sowing) + pendimethalin 38.7% CS @ 677.25 g a.i. ha^{-1} (PE)	8687	42171	33485
T_8: Stale seedbed (shallow tillage) + fluazifop-p-butyl 11.1% w/w + fomesafen 11.1% w/w SL @ 250 g a.i. ha^{-1} (PoE) at 20-25 DAS	10113	53855	43742
T_9: Stale seedbed (paraquat spray @ 500 g a.i. ha^{-1} before sowing) + fluazifop-p-butyl 11.1% w/w + fomesafen 11.1% w/w SL 250 g a.i. ha^{-1} (PoE) at 20-25 DAS	8719	53016	44297
T_{10}: Stale seedbed (shallow tillage) + propaquizafop 2.5% + imazethapyr 3.75% w/w ME @ 50+75 g a.i. ha^{-1} (PoE) at 20-25DAS	10066	49188	39122
T_{11}: Stale seedbed (paraquat spray @ 500 g a.i. ha^{-1} before sowing) + propaquizafop 2.5% + imazethapyr 3.75% w/w ME @ 50+75 g a.i. ha^{-1} (PoE) at 20-25 DAS	8672	48472	39799
T_{12}: Weed free check (Hand weeding at 20 & 40 DAS)	8944	54939	45995
T_{13}: Weedy check	8316	22703	14387
SEm±	-	1631	1631
CD (P=0.05)	-	4760	4760

TIE: Total input energy (MJ ha^{-1}); TOE: Total output energy (MJ ha^{-1}); NE: Net energy(MJ ha^{-1})

stover yield, was determined by multiplying the respective yield quantities by their corresponding energy equivalents.

Output energy (MJ ha^{-1}) = Total produce × Energy equivalent

Net energy (MJ ha^{-1})

It denotes the net energy gain per hectare obtained after subtracting all energy inputs, where a positive value indicates that the system generates more energy than it consumes.

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

Energy use efficiency (MJ ha^{-1})

Energy use efficiency is defined as the ratio of energy output to energy input and it serves as an indicator of the efficiency of the crop production system in terms of effective utilization of energy resources in agriculture.

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

Energy productivity (kg MJ^{-1})

Energy productivity is determined by dividing the total biological yield by the total energy input and it is expressed in MJ kg^{-1}.

$$\text{Energy productivity (kg MJ}^{-1}) = \frac{\text{Total (Gain + stover yield) (kg ha}^{-1})}{\text{Total input energy (MJ ha}^{-1})}$$

Specific energy (MJ kg^{-1})

This indicator reflects the amount of energy (MJ) required to produce one kilogram of crop yield, where lower values signify higher production efficiency and it is computed using the formula given below.

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

Results and Discussion

The energy requirements for crop production differ considerably depending on the farming practices employed. Modern agricultural production is highly dependent on fossil fuel based energy sources, which are utilized as direct inputs such as fuel and electricity and as indirect inputs through fertilizers, pesticides, machinery and other agricultural resources. Agricultural productivity and profitability are strongly influenced by the amount of energy consumed during crop production. Continuous improvements in crop yields have been achieved through the increased application of agrochemicals and the adoption of high yielding cultivars. Energetic analysis plays an important role in identifying opportunities to enhance production efficiency and

Table 3: Effect of stale seedbed and herbicide integration on energy use efficiency (MJ ha^{-1}) and energy productivity (kg MJ$^{-1)}$ in blackgram.

Treatment	EUP	EP
T_1: Normal sowing + pendimethalin 38.7% CS @ 677.25 g a.i. ha^{-1} (PE)	3.83	0.29
T_2: Normal sowing + fluazifop-p-butyl 11.1 % w/w + fomesafen 11.1% w/w SL @ 250 g a.i. ha^{-1} (PoE) at 20-25 DAS	5.47	0.41
T_3: Normal sowing + propaquizafop 2.5% + imazethapyr 3.75% w/w ME @ 50+75 g a.i. ha^{-1} (PoE) at 20-25 DAS	4.37	0.33
T_4: Stale seedbed (shallow tillage)	3.96	0.30
T_5: Stale seedbed (paraquat spray @ 500 g a.i. ha^{-1} before sowing)	4.51	0.34
T_6: Stale seedbed (shallow tillage) + pendimethalin 38.7% CS @ 677.25 g a.i. ha^{-1} (PE)	4.37	0.33
T_7: Stale seedbed (paraquat spray @ 500 g a.i. ha^{-1} before sowing) +Pendimethalin 38.7% CS @ 677.25 g a.i. ha^{-1} (PE)	4.85	0.37
T_8: Stale seedbed (shallow tillage) + fluazifop-p-butyl 11.1% w/w + fomesafen 11.1% w/w SL @ 250 g a.i. ha^{-1} (PoE) at 20-25 DAS	5.33	0.40
T_9: Stale seedbed (paraquat spray @ 500 g a.i. ha^{-1} before sowing) + fluazifop-p-butyl 11.1% w/w fomesafen 11.1% w/w SL 250 g a.i. ha^{-1} (PoE) at 20-25 DAS	6.08	0.46
T_{10}: Stale seedbed (shallow tillage) + propaquizafop 2.5% + imazethapyr 3.75% w/w ME @ 50+75 g a.i. ha^{-1} (PoE) at 20-25DAS	4.89	0.37
T_{11}: Stale seedbed (paraquat spray @ 500 g a.i. ha^{-1} before sowing) + propaquizafop 2.5% + imazethapyr 3.75% w/w ME @ 50+75 g a.i. ha^{-1} (PoE) at 20-25 DAS	5.59	0.42
T_{12}: Weed free check (Hand weeding at 20 & 40 DAS)	6.14	0.46
T_{13}: Weedy check	2.73	0.21
SEm±	0.18	0.01
CD (P=0.05)	0.54	0.04

EUP: Energy use efficiency (MJ ha^{-1}); EP: Energy productivity (kg MJ^{-1})

promote environmentally sustainable cropping systems.

Total energy input varied across the different weed management treatments. Among them stale seedbed (shallow tillage) followed by fluazifop-p-butyl 11.1% w/w + fomesafen 11.1% w/w SL @ 250 g a.i. ha^{-1} (PoE) applied at 20-25 DAS (T_8) recorded the highest energy input (10113 MJ ha^{-1}). The higher energy requirement was primarily due to the additional fuel and irrigation water used during the shallow tillage operation for stale seedbed preparation. This was followed by treatments T_6, T_{10}, T_4, T_{12}, T_9, T_7, T_{11}, T_5, T_2, T_1 and T_3 in decreasing order of energy input. The lowest energy input recorded with weedy check (8316 MJ ha^{-1}) owing to the absence of any weed control operations throughout the crop growth period.

The weed free check recorded the highest output energy (54939 MJ ha^{-1}) and it was statistically comparable with T_8 (53855 MJ ha^{-1}). The higher output energy under these treatments might be due to their superior seed and haulm yields. The highest net energy recorded with weed free check (45995 MJ ha^{-1}) which was statistically comparable with T_9 (44297 MJ ha^{-1}). The higher net energy observed under these treatments may be attributed to the greater seed and haulm yields obtained. Weedy check recorded lowest energy output and net energy because of its lower seed and haulm yields compared to the other treatments, resulting from severe weed competition during the crop growth period.

Energy use efficiency differed significantly among the treatments due to the various weed management practices adopted. The weed free check recorded the highest energy use efficiency (6.14 MJ ha^{-1}) and it was statistically at par with T_9 (6.08 MJ ha^{-1}). The superior energy use efficiency observed in these treatments due to their higher output energy resulting from increased seed and haulm yields. The lowest energy use efficiency was observed in the weedy check (2.73 MJ ha^{-1}) due to reduced crop productivity caused by severe weed competition.

Significantly higher energy productivity was recorded in T_9 (4.6 kg MJ^{-1}) which was statistically on par with T_{12} (4.6 kg MJ^{-1}). The higher energy productivity observed in these treatments might be associated with the greater seed yield obtained relative to the energy inputs utilized. Weedy check recorded the lowest energy productivity

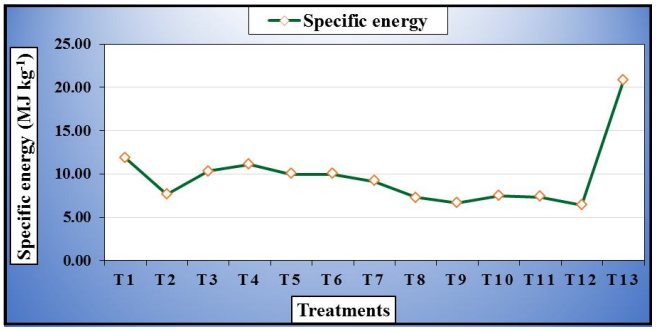

Fig. 1: Effect of stale seedbed and herbicide integration on specific energy (MJ kg^{-1}).

(0.21 kg MJ^{-1}) due to reduced crop yield resulting from severe weed competition.

Lower specific energy values indicate that less energy is required to produce a unit of yield. The lowest specific energy was recorded in T_{12} (6.41 MJ kg^{-1}), which was statistically on par with T_9 (6.63 MJ kg^{-1}) followed by T_8 (7.27 MJ kg^{-1}). The highest specific energy associated with weedy check (20.77 MJ kg^{-1}) as shown in Fig. 1.

Conclusion

In the energetics study, the maximum energy input was recorded with stale seedbed (shallow tillage) + fluazifop-p-butyl 11.1% w/w + fomesafen 11.1% w/w SL @ 250 g a.i. ha^{-1} (PoE) applied at 20-25 DAS. The same treatment also registered the highest energy output. Higher net energy, energy use efficiency, energy productivity and lower specific energy were recorded under the weed free check and it was statistically on par with stale seedbed (paraquat spray @ 500 g a.i. ha^{-1} before sowing) + fluazifop-p-butyl 11.1% w/w + fomesafen 11.1% w/w SL @ 250 g a.i. ha^{-1} (PoE) applied at 20-25 DAS.

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