



Integration of Weed Management Strategies for Economic Viability in Blackgram (*Vigna mungo* L.) Under North Gujarat Conditions

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ABSTRACT

A field experiment was conducted during July–October, 2023 at Agronomy Instructional Farm, Department of Agronomy, Chimanbhai Patel College of Agriculture, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar, Gujarat, India to study the efficacy of early post-emergence herbicides against weeds in blackgram crop. Twelve treatments replicated thrice were used in randomized block design. Among different weed management practices, weed-free recorded significantly higher seed and stover yield (1077 and 2657 kg ha⁻¹, respectively). Next to weed-free, significantly higher seed and stover yields were observed in interculturing followed by hand weeding at 20 and 40 DAS (960 and 2258 kg ha⁻¹, respectively) as a result of the markedly reduced densities of sedges, grasses, broadleaf weeds and overall weed population and was found at par with post-emergence application of imazethapyr+imazamox at 50 (25+25) g ha⁻¹ fb interculturing at 40 DAS (932 and 2224 kg ha⁻¹, respectively) and imazethapyr+imazamox at 60 (30+30) g ha⁻¹ fb interculturing at 40 DAS (916 and 2169 kg ha⁻¹, respectively). Whereas, imazethapyr+imazamox at 50 (25+25) g ha⁻¹ fb interculturing at 40 DAS recorded higher net returns (₹ 43941 ha⁻¹) followed by interculturing followed by hand weeding at 20 and 40 DAS (₹ 43111 ha⁻¹) and imazethapyr+imazamox at 60 (30+30) g ha⁻¹ fb interculturing at 40 DAS (₹ 42010 ha⁻¹). The same treatments were also witnessed remarkable improvements in energy-related parameters such as net energy returns, energy productivity and energy use efficiency.

KEYWORDS: Blackgram, economics, energetics, herbicides, post-emergence, regression, weeds, yield

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1. INTRODUCTION

Blackgram (*Vigna mungo* L.) is one of the important pulse crops of India, belonging to the *Fabaceae* or *Leguminosae* family and *Papilionaceae* subfamily. It is a self-pollinated crop having epigeal type of germination (Kumawat et al., 2024). India is considered as the primary centre and central Asia is a secondary centre of origin of blackgram. People in various regions of India use different names for the blackgram, for example, Urid or Kalai in Hindi; Mashkalai in Bengali; Manipapappu in Telugu; Ulathamparuppu in Tamil; Uddinabele in Kannada; Uzhunnu in Malayalam; Adad in Gujarati; Udid in Marathi and Mash in Punjabi. Blackgram seeds contain small fractions of isoflavones, namely glycitein, genistein, daidzein and formononetin. This leguminous crop is a nutritional powerhouse, comprising of 48.0% carbohydrates, 22.3% protein, 154 mg of calcium, 9.1 mg of iron, 1.4 g of fat, 0.37 g of riboflavin and 0.42 mg of thiamine per 100 g of blackgram (Marimuthu et al., 2024). It also has significant quantities of vitamin B₁, B₂ and niacin (Thongni et al., 2023). Blackgram is mainly cultivated in Asian countries, including Pakistan, Myanmar, Sri Lanka, Thailand, Burma, Bangladesh and parts of South Asia. India is the largest producer and consumer of blackgram, accounting for nearly 29% of the nation's total pulse cultivation area and contributing about 10.25% to its overall pulse production (Sreenivasulu et al., 2025). In India, during *kharif* 2022-23, the area covered by the blackgram was 39.6 lakh ha as against 38.27 lakh ha last year. The annual production of the blackgram is 28.4 lakh tonnes as against 22.3 mt in 2020-21, with an average productivity of 533 kg ha⁻¹ (Anonymous, 2022). It is a known crop for its hardiness, comparatively more resistance against the pests and diseases and its ability to withstand drought conditions. Hence, there is a great scope for increasing the productivity of this crop with the adoption of high-yielding varieties and agrotechnologies such as optimum plant population, proper management of water, fertilizer, along with weed, pest and disease. Among various biotic and abiotic factors, weed infestation is the major biotic factor responsible for the low productivity of blackgram (Priyadarshini et al., 2023). Weed emergence in blackgram begins almost with the crop emergence, leading to crop-weed competition from the initial stages and reducing yields to a greater extent of 27 to 100% (Taku et al., 2023). Such losses can have a severe economic impact on farmers and food production. Weed management with conventional hand weeding was observed to be highly expensive among different weed control methods due to the non-availability and increased cost of labour at some of the most important and critical stages of the crop weed competition. Moreover, continuous rainfall often prevents timely hand weeding because of excessive soil moisture.

Consequently, delayed weeding results in poor weed control and reduced crop yield efficiency. Hence, the timely control of weeds in blackgram using herbicides would be preferable and the use of post-emergent herbicides could be a better option for the control of weeds during the early stages of the crop growth (Thimmegowda et al., 2022) and provides a potentially more effective and economical solution (Nihal et al., 2025). So that, the chemical weed control method is becoming popular among farmers. The use of post-emergence herbicides alone or in combination may broaden the window of weed management by broad-spectrum weed control. Considering the above facts and views, the present experiment is planned using the following materials and methods.

2. MATERIALS AND METHODS

A field experiment was conducted during July-October of 2023 at the Agronomy Instructional Farm, Department of Agronomy, Chimanbhai Patel College of Agriculture, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar, Banaskantha (385506) (North Gujarat Agro-climatic region (AES IV) of Gujarat) at a 24° 19' North latitude and 72° 19' East longitude with an elevation of 154.52 meters above the mean sea level. The experiment was laid out in a randomized block design with twelve treatments and three replications. The soil of the experimental plot was loamy sand in texture and slightly alkaline in reaction (pH=7.40), low in organic carbon (0.24%) and available nitrogen (149.0 kg ha⁻¹) and medium in available phosphorus (39.3 kg ha⁻¹) and potassium (267.45 kg ha⁻¹). The experimental field was ploughed by tractor-drawn cultivator and was followed by harrowing and planking to obtain a fine seedbed. The blackgram cultivar "GU 1" was sown manually at a spacing of 45×10 cm² at a depth of 4–5 cm on 15 July, 2023 with a seed rate of 17.5 kg ha⁻¹. The gross plot size and net plot size of the experiment were 5.0×4.5m² and 3.6×2.7m², respectively. The crop was fertilized with the application of well-decomposed FYM @ 5 t ha⁻¹ ten days before sowing and 20:40:00 kg N: P₂O₅: K₂O ha⁻¹ at sowing. The sources of fertilizers used were DAP and urea, which were commonly applied to the soil for all treatments just before sowing of seeds in the furrow. The blackgram seeds were treated with *Rhizobium* @ 4 ml kg⁻¹ seeds. The experiment was laid out in randomised block design with three replications having twelve treatments viz., T₁: Pendimethalin at 750 g ha⁻¹ (PE) *fb* interculturing at 40 DAS, T₂: Quizalofop-p-ethyl at 38 g ha⁻¹ (PoE) *fb* interculturing at 40 DAS, T₃: Quizalofop-p-ethyl at 50 g ha⁻¹ (PoE) *fb* interculturing at 40 DAS, T₄: Imazethapyr at 50 g ha⁻¹ (PoE) *fb* interculturing at 40 DAS, T₅: Imazethapyr at 75 g ha⁻¹ (PoE) *fb* interculturing at 40 DAS, T₆: Fenoxaprop-p-ethyl at 56.25 g ha⁻¹ (PoE) *fb* interculturing

at 40 DAS, T₇: Fenoxaprop-p-ethyl at 67.5 g ha⁻¹ (PoE) fb interculturaling at 40 DAS, T₈: Imazethapyr+imazamox at 50 (25+25) g ha⁻¹ (PoE) fb interculturaling at 40 DAS, T₉: Imazethapyr+imazamox at 60 (30+30) g ha⁻¹ (PoE) fb interculturaling at 40 DAS, T₁₀: Interculturaling followed by hand weeding at 20 and 40 DAS, T₁₁: Weed-free and T₁₂: Unweeded check. The spraying was done by using a knapsack sprayer with a flat fan nozzle having a 15-litre capacity. Pendimethalin was applied as pre-emergence at two DAS. While, quizalofop-p-ethyl, fenoxaprop-p-ethyl, imazethapyr and imazethapyr+imazamox were applied as post-emergence at 20 DAS. The prepared solutions were sprayed separately as per the treatments in respective plots. The herbicides were applied by mixing in 500 litres of water ha⁻¹. The sedges, grasses and broadleaf weeds were counted from 0.25 m² (50×50 cm quadrat) in the net area of plots at two spots at 15, 40 DAS and at harvest. Further, the data was multiplied by four to convert the data into no. m⁻². Since the weed density data do not follow a normal distribution, the weed density data were analyzed after being subjected to the $\sqrt{x+0.5}$ transformation. The species wise weed count data at different stages was not statistically analyzed. The

weed control efficiency was calculated by using the following formula (Kondap and Upadhyay, 1985). A total five plants were selected randomly from net plot and tagged in each plot for recording various observations. The data on seed and stover yield were recorded from net plot and converted on hectare basis.

3. RESULTS AND DISCUSSION

3.1. Effect on weed flora

The different species of weeds in blackgram crop at different crop growth stages (15, 40 DAS and harvest) are given in Tables 1 to 3 and Figure 1. The different weed species observed at 15, 40 DAS and harvest were *Cyperus rotundus* L. and *Bulbostylis barbata* Rottb. among sedges, *Cynodon dactylon* L., *Setaria viridis* L. and *Digitaria sanguinalis* L. among grasses and *Digera arvensis* L., *Amaranthus viridis* L., *Amaranthus spinosus* L., *Amaranthus polygonoides* L., *Portulaca oleracea* L., *Boerhavia erecta* L., *Tribulus terrestris* L., *Commelina benghalensis* L. and *Leucas aspera* L. among broadleaf weeds. Overall, the field was dominated by broadleaf weeds, which were followed by grasses and sedges. Among sedges, *Cyperus rotundus* L.,

Table 1: Major weed flora at 15 DAS in blackgram as influenced by weed management practices

Treat- ments	Weed density (No. m ⁻²)												Grand total
	Sedges		Grasses			Broadleaf weeds							
	Cr	Total	Cd	Sv	Total	Da	Av	Po	Be	Tt	Cb	Total	
T ₁	2.67	2.67	1.33	4.67	6.00	2.00	1.33	1.33	2.00	1.33	1.33	9.33	18.00
T ₂	5.33	5.33	5.33	8.00	13.33	5.33	3.33	2.67	2.67	2.67	4.00	20.67	39.33
T ₃	7.33	7.33	6.00	8.00	14.00	4.67	2.67	2.67	3.33	3.33	2.00	18.67	40.00
T ₄	6.67	6.67	6.00	8.67	14.67	4.67	4.00	2.67	2.67	3.33	2.00	19.33	40.67
T ₅	7.33	7.33	2.00	10.00	12.00	4.67	2.00	2.00	2.00	2.67	2.00	15.33	34.67
T ₆	8.00	8.00	4.00	7.33	11.33	5.33	4.00	2.00	3.33	2.67	2.00	19.33	38.67
T ₇	6.67	6.67	4.67	8.00	12.67	4.00	2.67	2.67	2.00	2.00	2.00	15.33	34.67
T ₈	6.00	6.00	4.67	8.67	13.33	3.33	3.33	3.33	2.00	2.00	2.00	16.00	35.33
T ₉	6.00	6.00	7.33	8.67	16.00	4.00	2.67	2.00	2.00	2.67	2.00	15.33	37.33
T ₁₀	7.33	7.33	7.33	8.00	15.33	6.00	2.67	2.67	2.67	2.00	2.67	18.67	41.33
T ₁₁	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T ₁₂	6.67	6.67	4.00	7.33	11.33	5.33	4.00	2.67	3.33	2.67	2.00	20.00	38.00

Data is statistically not analyzed, averaged over 2 spots/plot and over three replications; T₁: Pendimethalin at 750 g ha⁻¹ (PE) fb interculturaling at 40 DAS; T₂: Quizalofop-p-ethyl at 38 g ha⁻¹ (PoE) fb interculturaling at 40 DAS, T₃: Quizalofop-p-ethyl at 50 g ha⁻¹ (PoE) fb interculturaling at 40 DAS, T₄: Imazethapyr at 50 g ha⁻¹ (PoE) fb interculturaling at 40 DAS, T₅: Imazethapyr at 75 g ha⁻¹ (PoE) fb interculturaling at 40 DAS, T₆: Fenoxaprop-p-ethyl at 56.25 g ha⁻¹ (PoE) fb interculturaling at 40 DAS, T₇: Fenoxaprop-p-ethyl at 67.5 g ha⁻¹ (PoE) fb interculturaling at 40 DAS, T₈: Imazethapyr+imazamox at 50 (25+25) g ha⁻¹ (PoE) fb interculturaling at 40 DAS, T₉: Imazethapyr+imazamox at 60 (30+30) g ha⁻¹ (PoE) fb interculturaling at 40 DAS, T₁₀: Interculturaling followed by hand weeding at 20 and 40 DAS, T₁₁: Weed-free, T₁₂: Unweeded check; Sedge- Cr: *Cyperus rotundus* L.; Grasses- Cd: *Cynodon dactylon* L., Sv: *Setaria viridis* L.; Broadleaf weeds- Da: *Digera arvensis* L., Av: *Amaranthus viridis* L., Po: *Portulaca oleracea* L., Be: *Boerhavia erecta* L., Tt: *Tribulus terrestris* L., Cb: *Commelina benghalensis* L.

Table 2: Major weed flora at 40 DAS in blackgram as influenced by weed management practices

Treatments	Weed density (No. m ⁻²)						
	Sedges			Grasses			
	Cr	Bb	Total	Cd	Sv	Ds	Total
T ₁	16.67	14.00	30.67	5.33	13.33	4.00	22.67
T ₂	25.33	20.00	45.33	10.67	14.00	0.00	34.67
T ₃	24.67	20.00	44.67	7.33	14.67	11.33	33.33
T ₄	16.00	13.33	29.33	4.67	12.67	4.00	21.33
T ₅	17.33	8.67	26.00	2.67	11.33	4.67	18.67
T ₆	26.67	21.33	48.00	12.00	14.67	11.33	38.00
T ₇	25.33	21.33	46.67	9.33	14.67	12.67	36.67
T ₈	6.00	5.33	11.33	3.33	4.67	2.67	10.67
T ₉	5.33	5.33	10.67	2.67	4.00	2.67	9.33
T ₁₀	5.33	2.67	8.00	2.67	4.00	2.00	8.67
T ₁₁	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T ₁₂	33.33	30.00	63.33	18.67	26.67	20.00	65.33

Table 2: Continue...

Treatments	Weed density (No. m ⁻²)										Grand Total
	Broadleaf weeds										
	Da	Av	As	Ap	Po	Be	Tt	Cb	La	Total	
T ₁	4.00	2.00	2.00	2.67	2.00	3.33	2.67	2.67	2.67	24.00	77.33
T ₂	8.00	2.00	2.67	4.67	4.00	4.00	3.33	4.00	6.00	38.67	118.67
T ₃	5.33	3.33	2.00	4.00	4.00	4.00	4.00	5.33	5.33	37.33	115.33
T ₄	4.00	1.33	2.00	2.00	2.00	2.00	2.00	2.00	1.33	18.67	69.33
T ₅	2.67	1.33	1.33	2.00	2.00	2.00	2.00	2.00	2.00	17.33	62.00
T ₆	10.67	3.33	2.67	3.33	4.67	4.00	4.00	8.67	4.00	45.33	131.33
T ₇	10.00	3.33	5.33	4.67	3.33	4.67	2.67	4.67	5.33	44.00	127.33
T ₈	1.33	0.67	0.67	0.67	0.67	1.33	0.67	0.67	0.00	6.67	28.67
T ₉	1.33	0.67	0.00	0.67	0.00	1.33	1.33	0.67	0.00	6.00	26.00
T ₁₀	2.00	0.67	0.00	0.67	0.00	0.00	0.67	0.00	0.67	4.67	21.33
T ₁₁	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T ₁₂	14.67	6.67	5.33	3.33	5.33	6.67	10.67	9.33	7.33	69.33	198.00

Data is statistically not analyzed, averaged over 2 spots/plot and over three replications; Sedge; Cr: *Cyperus rotundus* L.; Bb: *Bulbostylis barbata* Rottb.; Grasses- Cd: *Cynodon dactylon* L.; Sv: *Setaria viridis* L.; Ds: *Digitaria sanguinalis* L.; Broadleaf weeds- Da: *Digera arvensis* L.; Av: *Amaranthus viridis* L.; As: *Amaranthus spinosus* L.; Ap: *Amaranthus polygonoides* L.; Po: *Portulaca oleracea* L.; Be: *Boerhavia erecta* L.; Tt: *Tribulus terrestris* L.; Cb: *Commelina benghalensis* L.; La: *Leucas aspera* L.

among grasses, *Setaria viridis* L. and among broadleaf weeds, *Digera arvensis* L. were dominant at all the stages. Numerous factors, including the region's predominant weed flora, soil weed seed bank, soil type, tillage intensity, previous cropping system, meteorological conditions and the congeniality of the soil environment, have been linked to the establishment of various weed species. Richardsan et

al. (2022) observed the following weeds in blackgram field, i.e., *Trianthema portulacastrum*, *Digera arvensis*, *Portulaca oleracea*, *Amaranthus viridis*, *Parthenium hysterophorus*, *Cleome viscosa* as broadleaf weeds, *Echinochloa colona*, *Echinochloa crusgalli* as grasses and *Cyperus rotundus* as sedges during 2021-22 at Coimbatore, Tamil Nadu.

Table 3: Major weed flora at harvest in blackgram as influenced by weed management practices

Treatments	Weed density (No. m ⁻²)						Total
	Sedges			Grasses			
	Cr	Bb	Total	Cd	Sv	Ds	
T ₁	17.33	6.00	23.33	5.33	6.00	4.67	16.00
T ₂	22.67	11.33	34.00	8.00	10.67	6.67	25.33
T ₃	20.00	12.67	32.67	6.00	10.67	8.00	24.67
T ₄	16.00	6.67	22.67	5.33	6.00	4.00	15.33
T ₅	14.67	6.00	20.67	2.67	8.00	3.33	14.00
T ₆	21.33	14.00	35.33	6.67	11.33	8.67	26.67
T ₇	21.33	13.33	34.67	5.33	12.67	8.00	26.00
T ₈	4.67	4.00	8.67	2.67	3.33	1.33	7.33
T ₉	6.00	2.00	8.00	1.33	2.67	2.67	6.67
T ₁₀	4.00	3.33	7.33	0.67	2.00	2.00	4.67
T ₁₁	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T ₁₂	29.33	16.67	46.00	13.33	20.00	15.33	48.67

Table 3: Continue...

Treatments	Weed density (No. m ⁻²)										Grand total
	Broadleaf weeds										
	Da	Av	As	Ap	Po	Be	Tt	Cb	La	Total	
T ₁	3.33	1.33	2.00	1.33	2.00	1.33	2.67	1.33	2.00	17.33	56.67
T ₂	6.67	3.33	2.67	2.67	2.67	2.67	2.67	2.67	2.00	28.00	87.33
T ₃	4.67	2.67	2.67	2.67	2.67	2.67	2.67	3.33	3.33	27.33	84.67
T ₄	4.00	0.67	0.67	0.67	1.33	1.33	1.33	1.33	2.00	13.33	51.33
T ₅	8.00	0.00	0.00	0.00	2.00	1.33	0.00	0.67	0.00	12.00	46.67
T ₆	6.00	1.33	2.00	2.67	3.33	2.00	4.00	3.33	6.00	30.67	92.67
T ₇	5.33	3.33	2.67	3.33	2.67	3.33	2.00	4.00	2.00	28.67	89.33
T ₈	1.33	0.00	0.00	0.00	1.33	1.33	0.00	0.00	0.67	4.67	20.67
T ₉	2.00	0.00	0.00	0.00	0.00	0.67	1.33	0.00	0.00	4.00	18.67
T ₁₀	2.00	0.00	0.00	0.00	0.67	0.00	0.00	0.67	0.00	3.33	15.33
T ₁₁	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T ₁₂	10.00	6.00	5.33	5.33	6.00	5.33	6.67	6.00	4.00	54.67	149.33

Data is statistically not analyzed, averaged over 2 spots/plot and over three replications; Sedge; Cr: *Cyperus rotundus* L.; Bb: *Bulbostylis barbata* Rottb.; Grasses- Cd: *Cynodon dactylon* L.; Sv: *Setaria viridis* L.; Ds: *Digitaria sanguinalis* L.; Broadleaf weeds- Da: *Digera arvensis* L.; Av: *Amaranthu sviridis* L.; As: *Amaranthus spinosus* L.; Ap: *Amaranthus polygonoides* L.; Po: *Portulaca oleracea* L.; Be: *Boerhavia erecta* L.; Tt: *Tribulus terrestris* L.; Cb: *Commelina benghalensis* L.; La: *Leucas aspera* L.

2.2. Effect on weed density

In blackgram at 15, 40 DAS and at harvest, the density of weed was significantly influenced by different weed management practices. Data related to the weed density are presented in Tables 4 and 5. Among different weed management practices at 15 DAS, weed-free treatment recorded significantly lower density of sedges, grasses,

broadleaf and total weeds. Next to weed-free treatment, pendimethalin at 750 g ha⁻¹ (PE) fb interculturing at 40 DAS recorded significantly lower density of sedges, grasses, broadleaf and total weeds. Whereas, all other post-emergence herbicides, interculturing and unweeded check treatment have recorded significantly higher density of sedges, grasses, broadleaf and total weeds. The zero density



Figure 1: Weed flora observed at experimental site

of weeds observed in the weed-free treatment was attributed to frequent and successful uprooting and removal of weeds throughout the season using mechanical and physical means, which in turn led to a decrease in sedges, grasses, broadleaf and total weeds. The minimum density of sedges, grasses, broadleaf weeds in pre-emergence herbicidal treatments, *i.e.*, pendimethalin at 750 g ha^{-1} (PE) *fb* interculturing at 40 DAS, is a result of killing of grasses, broadleaf weeds and sedges right before the emergence of weeds by the action of pendimethalin, which prevents the emergence of monocot and grassy weeds. Similar results were also noticed by Kumar et al. (2015). He concluded that pre-emergence application of pendimethalin was most effective in controlling weeds in pulses. While, a significantly higher density of sedges, grasses, broadleaf and total weeds was observed under all post-emergence herbicide treatments, the interculturing and unweeded check treatment was clearly due to no weed control measures taken till 15 DAS to curtail the weed growth in the earlier crop growth period. Balyan et al. (2016) also witnessed that weedy check treatment in blackgram has recorded significantly higher density of weeds and weed dry weight with lower efficiency of weed control.

The density of weeds at 40 DAS as influenced by weed management practices is furnished in Table 4. The data depicted that, at 40 DAS among different treatments, the weed-free treatment has witnessed significantly lowest density of sedges, grasses, broadleaf and total weeds. Subsequently, interculturing followed by hand weeding at 20 and 40 DAS, perceived significantly lowest density of sedges, grasses, broadleaf and total weeds and was found at par with post-emergence application of imazethapyr+imazamox at $60 (30+30) \text{ g ha}^{-1} \text{ fb}$ interculturing at 40 DAS and imazethapyr+imazamox at $50 (25+25) \text{ g ha}^{-1} \text{ fb}$ interculturing at 40 DAS. However, some other post-emergence herbicides, *i.e.*, quizalofop-p-ethyl, imazethapyr and fenoxaprop-p-ethyl, have not witnessed significantly lower density of sedges, grasses, broadleaf and total weeds. However, significantly higher density of sedges, grasses, broadleaf and total weeds were observed under the unweeded check. The density of weeds recorded with lower magnitudes in the weed-free treatment was attributed to frequent removal of weeds through physical and mechanical methods, which provided a weed-free environment during the whole life cycle of the crop and hence witnessed zero weeds in the treatment. Furthermore, this conclusion was corroborated by Khairnar et al. (2014), who concluded that mungbean had a lower dry weight of weeds with higher weed control efficiency in a weed-free plot. Next to weed-free interculturing followed by hand weeding at 20 and 40 DAS displayed significantly lower density of sedges, grasses, broadleaf and total weeds was due to effective uprooting and removal of weeds through interculture action by cycle weeder which removed majority of inter row weeds and further removal of intra row weeds through hand weeding which ultimately resulted in lower sedges, grasses, broadleaf and total weeds. These findings were also supported by Manohar and Sushmita (2019) and Manohar et al. (2022). The lower density of sedges, grasses and broadleaf weeds noticed under PoE application of ready-mix combination of imazethapyr+imazamox at $60 (30+30) \text{ g ha}^{-1}$ (PoE) *fb* interculturing at 40 DAS and imazethapyr+imazamox at $50 (25+25) \text{ g ha}^{-1}$ (PoE) *fb* interculturing at 40 DAS was reasoned to broad spectrum action of imazethapyr+imazamox herbicide which effectively control the broadleaf weeds, sedges and grasses through its effect on inhibition of synthesis of amino acids (valine, leucine and isoleucine), that ultimately hampers the protein synthesis in the targeted weeds. This herbicide is effective in controlling broad-leaved weeds as compared to grasses and sedges. While a significantly higher density of sedges, grasses, broadleaf and total weeds was seen under the unweeded check, it was because of a lack of any weed control activity; thus, the density of all the weeds was increased. The similar reports were also explained by Mohanty et al. (2023) and Nayak and Singh (2023).

Table 4: Effect of weed management practices on category wise weed density at 15 and 40 DAS in blackgram

Treatments	At 15 DAS				At 40 DAS			
	Weed density (No. m ⁻²)				Weed density (No. m ⁻²)			
	Sedges	Grasses	Broadleaf weeds	Total	Sedges	Grasses	Broadleaf weeds	Total
T ₁	1.76 ^b (2.67)	2.53 ^b (6.00)	3.12 ^b (9.33)	4.30 ^b (18.00)	5.51 ^c (30.67)	4.81 ^c (22.67)	4.95 ^c (24.00)	8.80 ^c (77.33)
T ₂	2.41 ^a (5.33)	3.72 ^a (13.33)	4.60 ^a (20.67)	6.31 ^a (39.33)	6.74 ^b (45.33)	5.86 ^b (34.67)	6.19 ^b (38.67)	10.88 ^b (118.67)
T ₃	2.76 ^a (7.33)	3.81 ^a (14.00)	4.38 ^a (18.67)	6.36 ^a (40.00)	6.70 ^b (44.67)	5.82 ^b (33.33)	6.11 ^b (37.33)	10.74 ^b (115.33)
T ₄	2.67 ^a (6.67)	3.89 ^a (14.67)	4.44 ^a (19.33)	6.41 ^a (40.67)	5.43 ^c (29.33)	4.63 ^c (21.33)	4.37 ^c (18.67)	8.36 ^c (69.33)
T ₅	2.79 ^a (7.33)	3.50 ^a (12.00)	3.98 ^a (15.33)	5.93 ^a (34.67)	5.15 ^c (26.00)	4.37 ^c (18.67)	4.22 ^c (17.33)	7.90 ^c (62.00)
T ₆	2.88 ^a (8.00)	3.44 ^a (11.33)	4.31 ^a (19.33)	6.22 ^a (38.67)	6.96 ^b (48.00)	6.18 ^b (38.00)	6.74 ^b (45.33)	11.47 ^b (131.33)
T ₇	2.67 ^a (6.67)	3.63 ^a (12.67)	3.98 ^a (15.33)	5.93 ^a (34.67)	6.87 ^b (46.67)	6.09 ^b (36.67)	6.67 ^b (44.00)	11.31 ^b (127.33)
T ₈	2.53 ^a (6.00)	3.68 ^a (13.33)	4.06 ^a (16.00)	5.98 ^a (35.33)	3.42 ^d (11.33)	3.34 ^d (10.67)	2.58 ^d (6.67)	5.38 ^d (28.67)
T ₉	2.55 ^a (6.00)	4.05 ^a (16.00)	3.97 ^a (15.33)	6.15 ^a (37.33)	3.34 ^d (10.67)	3.12 ^d (9.33)	2.46 ^d (6.00)	5.13 ^d (26.00)
T ₁₀	2.79 ^a (7.33)	3.97 ^a (15.33)	4.37 ^a (18.67)	6.47 ^a (41.33)	2.90 ^d (8.00)	3.00 ^d (8.67)	2.26 ^d (4.67)	4.67 ^d (21.33)
T ₁₁	0.71 ^c (0.00)	0.71 ^c (0.00)	0.71 ^c (0.00)	0.71 ^c (0.00)	0.71 ^c (0.00)	0.71 ^c (0.00)	0.71 ^c (0.00)	0.71 ^c (0.00)
T ₁₂	2.65 ^a (6.67)	3.41 ^a (11.33)	4.53 ^a (20.00)	6.20 ^a (38.00)	7.98 ^a (63.33)	8.10 ^a (65.33)	8.35 ^a (69.33)	14.08 ^a (198.00)
SEm±	0.18	0.23	0.26	0.20	0.32	0.30	0.35	0.33
C.V.%	12.86	11.67	11.60	6.16	10.75	11.16	12.99	6.84

The data on the density of weeds at harvest (Table 5) revealed that, among various weed management practices, the weed-free plot recorded significantly lower weed density of sedges, grasses, broadleaf and total weeds. After weed-free, interculturing followed by hand weeding at 20 and 40 DAS witnessed significantly lower weed density of sedges, grasses, broadleaf and total weeds at harvest, which was found at par with post-emergence application of imazethapyr+imazamox at 60 (30+30) g ha⁻¹ *fb* interculturing at 40 DAS and imazethapyr+imazamox at 50 (25+25) g ha⁻¹ *fb* interculturing at 40 DAS. Significantly lower weed density both category wise and total weeds under weed-free was assigned for maintaining almost nil weed density in the plot by repeated intercultivation/hand weeding. Further, lower density of weeds in each category and overall, at harvest in the interculturing followed by hand weeding at 20 and 40 DAS was linked for physical removal of weeds through

cultivation and hand weeding actions, which reduced weed density more effectively. Further, the lower weed density observed under imazethapyr+imazamox at 60 (30+30) g ha⁻¹ *fb* interculturing at 40 DAS and imazethapyr+imazamox at 50 (25+25) g ha⁻¹ *fb* interculturing at 40 DAS applied plots was explained to selective killing of broadleaf weeds, grasses and sedges and subsequent removing of weeds through intercultivation (inter row weeds). These results are confirmed by the works of Sahoo et al. (2017) and Rajput et al. (2021). Whereas, higher density of sedges, grasses, broadleaf and total weeds were found under unweeded check was also due to uncontrolled weed growth due to no weed control actions.

3.3. Effect on growth parameters

The data pertaining to effect of various weed management practices on plant population per net plot at harvest is given

Table 5: Effect of weed management practices on category wise weed density at harvest and growth parameters of blackgram

Treatments	At harvest				Plant population per net plot at harvest	Dry matter accumulation (g plant ⁻¹)		
	Weed density (No. m ⁻²)					At 15 DAS	At 40 DAS	At harvest
	Sedges	Grasses	Broadleaf weeds	Total				
T ₁	4.88 ^c (23.33)	4.06 ^c (16.00)	4.17 ^c (17.33)	7.55 ^c (56.67)	220.33	1.30	6.94	12.59
T ₂	5.87 ^b (34.00)	5.05 ^b (25.33)	5.33 ^b (28.00)	9.37 ^b (87.33)	226.00	0.90	5.66	9.65
T ₃	5.72 ^b (32.67)	5.01 ^b (24.67)	5.22 ^b (27.33)	9.21 ^b (84.67)	229.00	0.88	5.86	9.89
T ₄	4.81 ^c (22.67)	3.94 ^c (15.33)	3.72 ^c (13.33)	7.19 ^c (51.33)	201.00	0.87	7.01	13.99
T ₅	4.54 ^c (20.67)	3.78 ^c (14.00)	3.53 ^c (12.00)	6.86 ^c (46.67)	204.33	0.83	7.17	14.07
T ₆	5.95 ^b (35.33)	5.20 ^b (26.67)	5.58 ^b (30.67)	9.63 ^b (92.67)	222.00	0.85	5.34	9.19
T ₇	5.93 ^b (34.67)	5.15 ^b (26.00)	5.39 ^b (28.67)	9.47 ^b (89.33)	224.67	0.94	5.42	9.48
T ₈	3.02 ^d (8.67)	2.74 ^d (7.33)	2.26 ^d (4.67)	4.59 ^d (20.67)	208.00	0.95	8.34	16.48
T ₉	2.86 ^d (8.00)	2.64 ^d (6.67)	2.12 ^d (4.00)	4.34 ^d (18.67)	203.67	1.00	8.21	16.36
T ₁₀	2.79 ^d (7.33)	2.26 ^d (4.67)	1.79 ^d (3.33)	3.97 ^d (15.33)	198.00	0.86	8.63	17.52
T ₁₁	0.71 ^e (0.00)	0.71 ^e (0.00)	0.71 ^e (0.00)	0.71 ^e (0.00)	206.33	1.54	9.83	19.62
T ₁₂	6.82 ^a (46.00)	7.01 ^a (48.67)	7.42 ^a (54.67)	12.24 ^a (149.33)	210.00	0.98	4.32	7.29
SEm±	0.28	0.27	0.30	0.26	10.71	0.06	0.30	0.64
CD (<i>p</i> =0.05)	-	-	-	-	NS	0.18	0.88	1.87
C.V. %	10.76	11.86	13.25	6.23	8.71	10.60	7.52	8.51

in Table 5 and is revealed that different weed management practices did not significantly influenced plant population at harvest. Hence, whatever the variation observed in treatments are purely due to treatments effect only and not due to variation in plant population. Plant growth and yield are dependent on the rate of dry matter accumulation. Dry matter accumulation is the balance between photosynthesis and respiration. The rates of these physiological processes differ among organs, ages, cultural conditions etc. The situation of the relation between source and sink interacts with the rates of photosynthesis and respiration (Tanaka and Yamaguchi, 1972). Under high weed infestation, the crop plants are unable to express their genetic potential due to tough weed competition for all the inputs like moisture, light, nutrient and space (Mirjha et al., 2013). A glance of data asserted that different weed management practices significantly altered the dry matter accumulation per plant recorded at 15, 40 DAS and at harvest (Table 5). At 15 DAS, significantly higher dry matter accumulation per plant was recognized under weed-free treatment. Next to weed-free, pre-emergence application of pendimethalin at 750 g ha⁻¹ (PE) *fb* interculturing at 40 DAS recorded higher dry matter accumulation per plant due to better weed control by the application of pendimethalin that might killed weeds by inhibiting cell division in target

weeds and that created less crop-weed competition resulting in better plant growth as indicated by higher dry matter accumulation. Whereas, significantly lower dry matter accumulation per plant were noticed under all the post-emergence herbicides followed by interculturing treatments, interculturing followed by hand weeding at 20 and 40 DAS and unweeded check due to absence of any weed control activity till 15 DAS. Furthermore, the data on dry matter accumulation per plant at 40 DAS and at harvest was found superior under weed-free. Subsequently, significantly higher dry matter accumulation per plant were indicated under interculturing followed by hand weeding at 20 and 40 DAS and found at par with post-emergence application of imazethapyr+imazamox at 50 (25+25) g ha⁻¹ (PoE) *fb* interculturing at 40 DAS and imazethapyr+imazamox at 60 (30+30) g ha⁻¹ (PoE) *fb* interculturing at 40 DAS as compared to other treatments. Nevertheless, significantly lower dry matter accumulation per plant was found in unweeded check. Better dry matter accumulation per plant at 40 DAS and at harvest in blackgram observed under weed-free, interculturing followed by hand weeding at 20 and 40 DAS and other integrated treatments were recorded mainly ascribed due to better control of weeds as discussed in Tables 3 and 4 and as indicated by lower density of various categories of weeds which drastically lowered the crop-weed

competition that resulted in adequate availability of various growth factors such as nutrients, water, sunlight, space etc. and ultimately lead to enhanced dry matter accumulation. These findings are further supported by the correlation and regression analysis studies (Figure 4) which indicated perfect negative correlation between total weed density and dry matter production per plant at 15, 40 DAS and at harvest with a correlation coefficient of -0.9635^{**} , -0.9797^{**} and -0.9813^{**} , respectively. The regression analysis further envisaged that every 1 g m^{-2} increase in weed dry weight at 15, 40 DAS and at harvest shall reduce the dry matter production per plant to the tune of 0.016, 0.027 and 0.088 g plant^{-1} , respectively. Under post-emergence application of imazethapyr+imazamox at $50 (25+25) \text{ g ha}^{-1}$ (PoE) *fb* interculturing at 40 DAS and imazethapyr+imazamox at $60 (30+30) \text{ g ha}^{-1}$ (PoE) *fb* interculturing at 40 DAS treatments, the enhanced dry matter accumulation per plant were imputed to reduction in weed density of sedges, grasses and broadleaf weeds at 40 DAS and at harvest which contributed for better crop growth under low crop-weed competition in these treatments which cumulatively facilitated the crop to utilize more nutrients and water for better growth and development in terms of various growth attributing characters. The lower values of dry matter production per plant at harvest under unweeded check treatment might be cause of severe competition by weeds for resources, which made the crop plant less competent to take up required moisture and nutrients as well as competition for space, consequently growth was adversely affected. The findings are well supported by Choudhary et al. (2012) who noticed higher dry matter accumulation per plant in blackgram under weed-free treatments at Arunachal Pradesh. Similar outcomes were found by Komal et al. (2015) in greengram at Rajasthan. Jakhar et al. (2015) as well reported that weed-free treatment recorded higher dry matter accumulation at 25, 50 DAS and harvest in urdbean. The similar consequences were also witnessed by Barla and Upasani (2022) under application of imazethapyr+imazamox in chickpea crop.

The data pertaining to effect of various weed management practices on absolute growth rate (AGR), crop growth rate (CGR) and relative growth rate (RGR) is given in Figure 2. Among different weed management practices, weed-free treatment recorded higher AGR, CGR and RGR, which was closely followed by interculturing followed by hand weeding at 20 and 40 DAS. Whereas, unweeded check treatment recorded lower values of AGR, CGR and RGR. As the AGR is a direct reflection of dry matter accumulation per unit time, every unit increasing dry matter accumulation per plant from one stage to another stage will increase the AGR values. The CGR indicates dry matter accumulation per unit area and time, hence the increment in dry matter

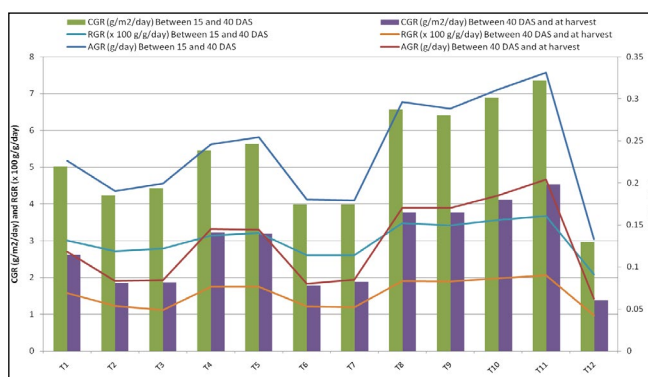


Figure 2: Effect of weed management practices on absolute growth rate (AGR), crop growth rate (CGR) and relative growth rate (RGR) of blackgram

accumulation from one stage to another stage per plant shall increase the CGR values. Further, the increase in dry matter accumulation per unit existing dry matter per unit time is expressed by RGR. Accordingly, every rise in dry matter accumulation per plant shall invariably enhance the RGR value. Thus, the AGR, CGR and RGR between two stages reflects the trend of dry matter accumulation per plant in blackgram. Kundu et al. (2011) also opined the same by witnessing higher CGR values under twice hand weeding at 15 and 30 DAS and lower CGR under weedy check. These findings are in accordance with Nayak and Singh (2023) who noticed lower value of CGR under unweeded check in blackgram.

The different weed control practices in blackgram have shown variation in chlorophyll content index (CCI), as furnished in Figure 3. At 15 DAS, the different weed management practices significantly affected the chlorophyll content index. The significantly higher chlorophyll content index was recorded under weed-free treatment. After weed-free, significantly higher chlorophyll content index was found under the pre-emergence application of pendimethalin at 750 g ha^{-1} (PE) *fb* interculturing at 40 DAS. However, significantly lower chlorophyll content index observed under all post-emergence applied treatments, interculturing followed by hand weeding at 20 and 40 DAS and unweeded check. The weed-free and pre-emergence application of pendimethalin at 750 g ha^{-1} (PE) *fb* interculturing at 40 DAS treatments showed a higher chlorophyll content index due to the lower weed density and higher nutrient availability of these treatments, so crops be able to use more available light for photosynthesis. This typically results in healthier plants with a higher chlorophyll content index. Lower chlorophyll content index was found under all post-emergence applied treatments, interculturing followed by hand weeding at 20 and 40 DAS and unweeded check might be due to severe crop-weed competition wherein weeds shaded the crop plant and hindered the light penetration into the

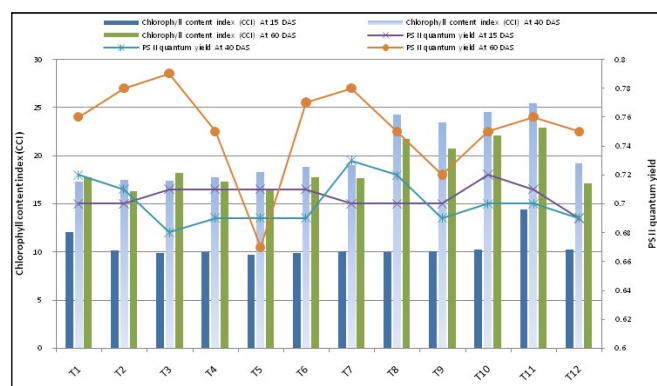


Figure 3: Effect of weed management practices on Chlorophyll content index (CCI) and PS II quantum yield of blackgram

crop canopy, which ultimately reduced the chlorophyll content. Among different weed management practices, at 40 and 60 DAS, weed-free recorded maximum chlorophyll content index, which was at par with interculturing followed by hand weeding at 20 and 40 DAS, post-emergence application of imazethapyr+imazamox at 50 (25+25) g ha⁻¹ fb interculturing at 40 DAS and imazethapyr+imazamox at 60 (30+30) g ha⁻¹ fb interculturing at 40 DAS. Wherein, significantly lower chlorophyll content index was found in the rest of the treatments due to the competition from weeds for essential resources like light, nutrients, and water. These factors collectively reduce the ability of crop plants to produce chlorophyll efficiently, leading to decreased chlorophyll content index. Weed-free plot quantified with a greater value of chlorophyll content index may be due to less competition for light and nutrients between crop and weeds as light and nitrogen have a major influence on chlorophyll development in the plant system. In greengram, Maji et al. (2020) also supported the findings of the present study through higher chlorophyll content under pre-emergence application of pendimethalin and hand weeding as compared to post-emergence herbicide applied plots at 30 DAS. Correspondingly similar outcomes were also witnessed by Murti et al. (2004).

The data related to the PS II quantum yield are presented in Figure 3. PS II quantum yield is indicator of plant stress, including stress caused by non-living environmental factors which can reduce the plant's natural metabolism (Murchie and Lawson, 2013). Various weed management practices did not significantly influenced the PS II quantum yield at 15, 40 and 60 DAS.

3.4. Effect on yield parameters and yield

The data pertaining to yield of blackgram as influenced by different weed management practices are presented in Table 6. Among different weed management practices, weed-free recorded significantly higher seed yield and stover yield. After weed-free, interculturing followed by hand weeding at 20 and 40 DAS realized significantly higher seed yield

and stover yield which became statistically at par with post-emergence application of imazethapyr+imazamox at 50 (25+25) g ha⁻¹ fb interculturing at 40 DAS and imazethapyr+imazamox at 60 (30+30) g ha⁻¹ fb interculturing at 40 DAS. Whereas, significantly lower seed yield and stover yield were observed under unweeded check. However, harvest index was not significantly differed due to weed management treatment effects. Significantly higher seed and stover yields recorded under T₁₁: weed-free, T₁₀: interculturing followed by hand weeding at 20 and 40 DAS, T₈: imazethapyr+imazamox at 50 (25+25) g ha⁻¹ fb interculturing at 40 DAS and T₉: imazethapyr+imazamox at 60 (30+30) g ha⁻¹ fb interculturing at 40 DAS was directly attributed to significantly higher yield parameters due to better growth parameters recorded under these treatments viz., dry matter accumulation per plant at harvest, chlorophyll content index at 60 DAS, number of pods per plant and number of seeds per pod due to creation of favourable conditions with lower crop-weed competition as a resultant of effective suppression of weeds which is indicated by significantly lower weed density of sedges, grasses, broadleaf weeds and total weeds in these treatments.

Weed-free and interculturing followed by hand weeding at 20 and 40 DAS effectively controlled all the category of weeds for a longer period. The better yield attributes were mainly due to effective suppression of weeds by uprooting and removal of weeds through physical and mechanical efforts which drastically reduced the densities and dry weights of sedges, grasses, broadleaf and total weeds. Subsequently these treatments also loosened the soil through mechanical soil disturbance which facilitated better crop growth by providing congenial environment for growth and development as evident from increase in plant height and dry matter accumulation which might be due to increased water and nutrient uptake, which might have accelerated photosynthetic rate, thereby increasing the supply of carbohydrates resulted in better cell division, multiplication and elongation as well as better partitioning of photosynthates leading to better yield parameters like number of pods plant⁻¹, number of seeds pod⁻¹ and ultimately enhanced the seed and stover yields of blackgram. These results are supported by studies of Gupta et al. (2013) who observed higher grain and biological yield of urdbean with hand weeding at 20 and 40 DAS, Anusha et al. (2024) who witnessed significantly higher seed yield of blackgram under hand weeding at 25-30 DAS and intercultivation at 45 DAS and Kaur et al. (2025) who recorded significantly higher grain yield of blackgram under hand weeding at 4 and 6 WAS.

The improvement in number of pods per plant and number of seeds per pod under post-emergence application of imazethapyr+imazamox at 50 (25+25) g ha⁻¹ fb interculturing

Table 6: Effect of weed management practices on nodules, yield parameters and yield of blackgram

Treatments	No. of nodules plant ⁻¹	Fresh weight of nodules (mg plant ⁻¹)	No. of pods plant ⁻¹	Number of seeds pod ⁻¹	Test weight (g)	Seed yield (kg ha ⁻¹)	Stover yield (kg ha ⁻¹)	Harvest index (%)
T ₁	23.16	218.78	33.07	5.97	42.25	777	1808	30.07
T ₂	22.91	214.47	24.55	4.89	42.15	640	1402	31.34
T ₃	22.54	210.16	24.96	5.11	42.72	660	1443	31.32
T ₄	21.31	203.95	34.27	6.08	41.84	789	1824	30.32
T ₅	23.05	217.16	35.38	6.12	40.86	792	1857	29.91
T ₆	22.62	212.85	23.24	4.66	41.99	559	1356	29.21
T ₇	21.16	203.50	24.25	4.74	42.37	574	1391	29.25
T ₈	22.66	213.65	45.73	7.07	40.77	932	2224	29.46
T ₉	22.22	204.93	42.75	6.91	41.75	916	2169	29.64
T ₁₀	27.24	248.78	47.22	7.11	41.45	960	2258	29.86
T ₁₁	28.10	252.72	52.93	7.15	42.96	1077	2657	29.26
T ₁₂	20.14	203.03	16.77	4.55	41.99	432	999	30.26
SEm±	1.08	8.24	1.82	0.26	0.57	36.23	104.26	1.6
CD (<i>p</i> =0.05)	3.17	24.17	5.34	0.78	NS	106.25	305.77	NS
C.V. %	8.11	6.58	9.33	7.82	2.34	8.27	10.13	9.0

at 40 DAS and imazethapyr+imazamox at 60 (30+30) g ha⁻¹ *fb* interculturing at 40 DAS was attributed to the better control of weeds *viz.*, sedges, grasses and broadleaf weeds that resulted in lowered competition from upsurged weeds for growth resources in these treatments that resulted in increased crop growth, resource utilization by the crop, efficient partitioning and translocation of photosynthates which finally turned into higher seed and stover yield of blackgram. These improved yield parameters and yield in above treatments was due to higher weed control which is indicated by negative correlation between weed density (15, 40 DAS and at harvest) and seed yield with a correlation coefficients of -0.4792*, -0.9875** and -0.9813** between weed density (15, 40 DAS and at harvest) and stover yield with a correlation coefficient of -0.5278*, -0.9807** and -0.9765 (Figure 4). The regression equations also showcased that increase in weed density 1 number m⁻² shall decrease the seed yield of blackgram by 7.569, 3.245 and 4.367 kg ha⁻¹, respectively. In addition, regression equations explored that every 1 number m⁻² increase in weed density at 15, 40 DAS and at harvest reduced the stover yield of blackgram by 20.95, 8.105 and 10.93 kg ha⁻¹, respectively.

Thus, as the weeds were effectively killed in post-emergence application of imazethapyr+imazamox at 50 (25+25) g ha⁻¹ *fb* interculturing at 40 DAS and imazethapyr+imazamox at 60 (30+30) g ha⁻¹ *fb* interculturing at 40 DAS due to their physical action/mode of action of herbicides as discussed

earlier (Tables 4 and 5), these treatments have recorded significantly higher yield attributes, seed and stover yield. Patel et al. (2017) observed higher growth and yield attributing characters *i.e.*, plant height, branches plant⁻¹, pods plant⁻¹ and seeds pod⁻¹ and seed yield over weedy check in blackgram under weed-free. Singh et al. (2015) similarly outlined the similar findings as that of above results. Patel et al. (2016) further supported the findings of present study through higher seed and haulm yield of greengram under interculturing+hand weeding carried out at 20 and 40 DAS. On the other hand, unweeded check recorded significantly lower number of pods plants⁻¹ and seeds pod⁻¹ plant⁻¹ which ultimately reduced seed yield and stover yields due to severe and magnificent growth of weeds which drastically reduced growth and yield of blackgram as compared to all other weed control treatments. These findings were in close vicinity with those reported by Manohar et al. (2022) and Dhakad et al. (2023).

3.5. Effect on economics

The glimpse of data tabulated in Table 7 indicated that among different weed management practices, weed-free, interculturing followed by hand weeding at 20 and 40 DAS, post-emergence application of quizalofop-p-ethyl at 50 g ha⁻¹ (PoE) *fb* interculturing at 40 DAS and imazethapyr+imazamox at 60 (30+30) g ha⁻¹ (PoE) *fb* interculturing at 40 DAS treatments have recorded higher cost of cultivation. However, lower cost of cultivation

was observed under unweeded check. The higher cost of cultivation under weed-free and interculturing followed by hand weeding at 20 and 40 DAS were mainly due to higher cost of labourers and units of labour used for weeding operations. Other variation in cost of cultivation among herbicidal treatments was due to variation in the market price of the commercial herbicide products. Whereas, lower cost of cultivation under unweeded check was due to no cost involved in any weed management practice/input.

The higher gross returns were recorded under weed-free treatment which was closely followed by interculturing followed by hand weeding at 20 and 40 DAS, post-emergence application of imazethapyr+imazamox at 50 (25+25) g ha⁻¹ (PoE) *fb* interculturing at 40 DAS and imazethapyr+imazamox at 60 (30+30) g ha⁻¹ (PoE) *fb* interculturing at 40 DAS. Whereas, lower gross returns were observed under unweeded check. The differences in gross returns were purely ascribed to their respective seed and stover yields. The net returns of various weed management have also been worked out looking into gross returns and cost of cultivation. The data pertaining to net returns of blackgram under the influence of weed management practices explained that maximum net returns were obtained with imazethapyr+imazamox at 50 (25+25) g ha⁻¹ (PoE) *fb* interculturing at 40 DAS followed by interculturing followed by hand weeding at 20 and 40 DAS and post-emergence application of imazethapyr+imazamox at 60 (30+30) g ha⁻¹ (PoE) *fb* interculturing at 40 DAS. The

variation in net returns among these weed management practices was because of variation in the gross returns and cost of cultivation in these treatments. Whereas, lower net returns of were obtained in unweeded check treatment which indicates lower returns than cost of cultivation due to poor seed and stover yields recorded under unweeded check. It is evident from the data on BC ratio that, all the weed management practices have increased BC ratio as compared to weedy check treatment. A maximum BC ratio of 2.00 was obtained under post-emergence application of imazethapyr+imazamox at 50 (25+25) g ha⁻¹ (PoE) *fb* interculturing at 40 DAS which was closely followed by post-emergence application of imazethapyr+imazamox at 60 (30+30) g ha⁻¹ (PoE) *fb* interculturing at 40 DAS (1.95) and interculturing followed by hand weeding at 20 and 40 DAS (1.92). The higher BC ratio documented under imazethapyr+imazamox at 50 (25+25) g ha⁻¹ (PoE) *fb* interculturing at 40 DAS and imazethapyr+imazamox at 60 (30+30) g ha⁻¹ (PoE) *fb* interculturing at 40 DAS than interculturing followed by hand weeding at 20 and 40 DAS treatments were primarily due to lower cost of cultivation in these above herbicidal treatments. These results are in confirmatory with the findings of Manohar and Sushmita (2019) who described maximum yield under intercultural operation at 20 and 40 DAS and weed-free but lower net returns and BC ratio due to higher cost of cultivation than herbicidal treatments. Yadav et al. (2015) also observed maximum net returns (₹ 17135 ha⁻¹) and benefit-cost ratio

Table 7: Effect of weed management practices on economics and energetics of blackgram

Treat- ments	Economics				Energetics					
	Cost of cultivation (₹ ha ⁻¹)	Gross returns (₹ ha ⁻¹)	Net returns (₹ ha ⁻¹)	BC ratio	Input energy (MJ ha ⁻¹)	Output energy (MJ ha ⁻¹)	Net energy returns (MJ ha ⁻¹)	Energy use efficiency	Energy productivity (kg MJ ⁻¹)	Specific energy (MJ kg ⁻¹)
T ₁	40905	72741	28837	1.66	7450	33450	26000	4.490	0.104	9.588
T ₂	40925	59215	15290	1.35	7035	26458	19423	3.761	0.091	10.993
T ₃	41405	61044	16603	1.37	7093	27251	20159	3.842	0.093	10.746
T ₄	40005	73764	30826	1.72	6974	33809	26836	4.848	0.113	8.839
T ₅	40305	74256	30995	1.72	7033	34268	27235	4.872	0.113	8.880
T ₆	40614	52772	9180	1.21	6998	24753	17754	3.537	0.080	12.519
T ₇	40856	54181	10328	1.24	7027	25405	18377	3.615	0.082	12.242
T ₈	40761	87691	43941	2.00	6872	40810	33938	5.939	0.136	7.373
T ₉	41033	86052	42010	1.95	6875	39990	33025	5.804	0.133	7.505
T ₁₀	43741	90060	43111	1.92	7038	41620	34582	5.914	0.136	7.331
T ₁₁	58936	102029	38771	1.61	7513	48244	40731	6.421	0.143	6.976
T ₁₂	37876	40391	-263	0.99	6759	18516	11757	2.739	0.064	15.647

1US\$= INR 83.23 (Average value for Oct, 2023)

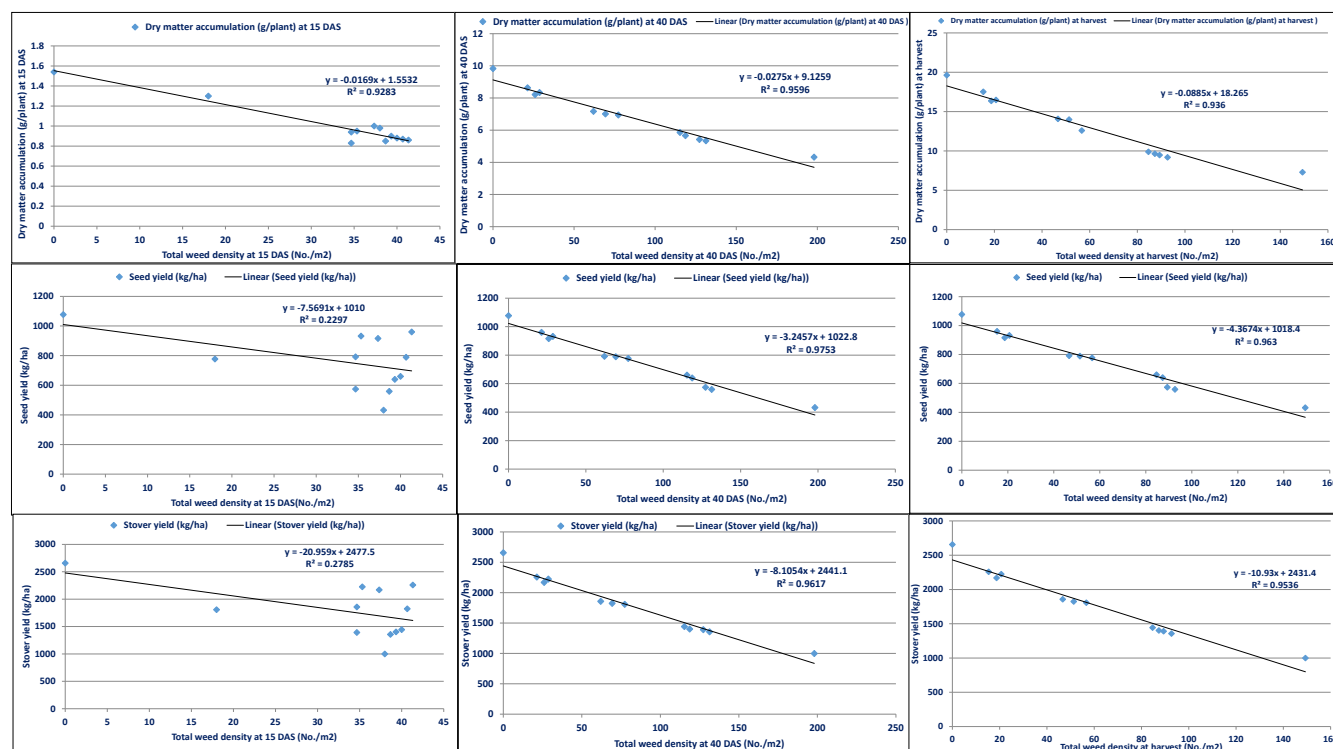


Figure 4: Regression analysis between different dependent and independent parameters of balckgram as influenced by weed management practices

(2.35) with PoE application of imazethapyr+imazamox (pre-mix) @ 0.05 kg ha⁻¹ in blackgram over other treatments on sandy loam soils of Gwalior, Madhya Pradesh.

3.6. Effect on energetics

The different weed management practices varied in terms of input energy, output energy, net energy returns, energy use efficiency, energy productivity and specific energy as indicated in Table 7. Among various weed management practices, weed-free recorded higher input energy, output energy, net energy returns, energy use efficiency, energy productivity and lower specific energy which was followed by interculturing followed by hand weeding at 20 and 40 DAS, post-emergence application of imazethapyr+imazamox at 50 (25+25) g ha⁻¹ (PoE) *fb* interculturing at 40 DAS and imazethapyr+imazamox at 60 (30+30)g ha⁻¹ (PoE) *fb* interculturing at 40 DAS. Wherein, unweeded check recorded lower input energy, output energy, net energy returns, energy use efficiency, energy productivity and higher specific energy. The higher input energy witnessed under weed-free and interculturing followed by hand weeding at 20 and 40 DAS treatments was due to the maximum input energy required as the manual labourers were used for hand weeding and interculturing operations. Whereas, comparatively lower energies recorded under herbicidal treatments is ascribed to a lower dose of herbicide and their lower energy equivalents. Nevertheless, lower energy input under unweeded check revealed the direct impact of

no/nil energy used for weed control operations. Whereas, elevated values of output energy, net energy returns, energy use efficiency, energy productivity and lower specific energy under weed-free, interculturing followed by hand weeding at 20 and 40 DAS, post-emergence application of imazethapyr+imazamox at 50 (25+25) g ha⁻¹ (PoE) *fb* interculturing at 40 DAS were solely attributed to their respective higher seed and stover yields. These higher yields were attributed to better crop growth conditions due to effective control of weeds and resultant improved growth, yield parameters and yields. These less crop-weed competition and favourable growing environments have led to more energy returns per unit of energy input used, hence was reflected in terms of higher net energy returns, energy use efficiency, energy productivity and lower specific energy. Whereas, lower output energy revealed under unweeded check was because of witnessed lower seed and stover yields due to no weed control activity/operations undertook in the treatment. These findings are further supported by Lal et al. (2016), Kumar et al. (2021) and Malhi et al. (2021).

4. CONCLUSION

The interculturing followed by hand weeding at 20 and 40 DAS or post-emergence application of imazethapyr+imazamox at 50 (25+25) g ha⁻¹ (PoE) *fb* interculturing at 40 DAS, proved most effective in

controlling sedges, grasses and broadleaf weeds. These practices significantly improved crop growth resulting in higher seed and stover yields and increased net returns and energy use efficiency in blackgram cultivation under field conditions.

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