LR-5310
[1-8]

RESEARCH ARTICLE Legume Research- An International Journal

Bio-Efficacy of Pre-and Post-Emergence Herbicides on Growth, Productivity, Nodulation of Black Gram (*Vigna mungo* L.) under Coastal Plain of Odisha

Rabiratna Dash[1], Narmada Barik[1], Hrushikesh Patro[1], Bama Shankar Rath[1], Narayan Panda[2], S. Karubakee[1], M.A. Alim[1], Subhrashini Lenka[1], Anshuman Nayak[1]

10.18805/LR-5310

ABSTRACT

Background: Weeds compete with plants for resources during cultivation and the control of weeds during the critical period of crop-weed competition is crucial to avoid yield loss ranging from 50%-90% in black gram. The first 4-5 weeks are critical for black gram crop-weed competition. The composition of weed flora, the duration of crop-weed competition and its intensity significantly impact yield losses in black gram cultivation. Therefore, the current study aims to evaluate weed management practices in *rabi* black gram, with a focus on identifying herbicides that enhance weed control, increase productivity and profitability.

Methods: A field experiment was conducted during the *rabi* season of 2021-2022 and 2022-2023 consecutively at Odisha University of Agriculture and Technology, Bhubaneswar. The field experiment comprised of eight treatments on different herbicide applications as T_1- Fenoxaprop-p-ethyl @ 65 g a.i. ha^{-1}, T_2- Quizalofop-p-ethyl @ 50 g a.i. ha^{-1}, T_3-Cyhalofop-butyl @ 75 g a.i. ha^{-1}, T_4-Pendimethalin @ 750 g a.i. ha^{-1}, T_5- Oxyflourfen @ 50 g a.i. ha^{-1}, T_6- Tembotrione @ 120 g a.i. ha^{-1}, T_7- Weed check (control) and T_8-Weed free, which was laid under randomised block design. Collected samples were analyzed in the field and laboratory for crop-weed competition, herbicide phytotoxicity and yield attributes.

Result: The results revealed that weed-free treatment recorded the lowest weed population (5.27-5.45), weed dry weight (1.35g-2.20 g) and lowest weed index (0.00%) at all growth stages followed by pendimethalin (PE) application. Among yield attributes, weed-free treatment recorded the highest plant height (cm) which was at par with pendimethalin (PE) followed by cyhalofop-butyl (PoE) application. The magnitude of seed yield was increased under weed-free (1035.46 kg ha^{-1}) and pendimethalin (PE) and cyhalofop-butyl (PoE) applications by 53.62% and 48.40%, respectively over the weedy check. Application of tembotrione recorded the highest herbicide phytotoxicity (5.3-7.6) over the rest of the treatments. It can be concluded that the application of pendimethalin 30 EC 750 g ha^{-1} as PE at 2 DAS followed by cyhalofop-butyl 10 EC 75 g ha^{-1} can be advisable for better weed control, lower herbicide phytotoxicity and higher yield.

Key words: Black gram, Crop-weed competition, Herbicide phytotoxicity, Weed index, Weeds.

INTRODUCTION

Black gram or Urdbean (*Vigna mungo* L.) is a vital pulse crop in tropical and subtropical regions, promoting soil fertility through symbiotic nitrogen fixation and showing resilience to harsh weather cultivated year-round globally. Commercially and nutritionally, black gram, is a very important source of protein (12-42%) and is consumed as “dal” (Girish *et al.,* 2012). Black gram is gaining significance in North India as it plays a crucial role in meeting the escalating food and protein demands of the expanding population (Singh and Pandey, 2017). In India, the annual production is 22.29 lakh tonnes from 41.42 lakh hectares, averaging 538 kg per hectare in 2020-21. India leads in *rabi* black gram production, mainly in Andhra Pradesh and Telangana, covering 8.33 lakh hectares (DES, GoI, Min. of Agri. and FW, 2020-21). The low productivity of black gram in the country can be attributed to various factors, including cultivation on marginal lands and insufficient or imbalanced fertilization and crop-weed competition. Weeds compete with plants for resources during cultivation, producing an 55.4% reduction in urd bean yield (Ghosh *et al.*, 2023). The control of weeds during the critical period of crop-weed competition is crucial to avoid yield loss. The first 4-5 weeks are critical for black gram crop-weed competition (Patel *et al.*, 2015).

[1]Department of Agronomy, College of Agriculture, Odisha University of Agriculture and Technology, Bhubaneswar-751 003, Odisha, India.
[2]Department of Soil Science, College of Agriculture, Odisha University of Agriculture and Technology, Bhubaneswar-751 003, Odisha, India.

Corresponding Author: Rabiratna Dash, Department of Agronomy, College of Agriculture, Odisha University of Agriculture and Technology, Bhubaneswar-751 003, Odisha, India.
Email: rabiratnadash@ouat.ac.in

How to cite this article: Dash, R., Barik, N., Patro, H., Rath, B.S., Panda, N., Karubakee, S., Alim, M.A., Lenka, S. and Nayak, A., (2024). Bio-Efficacy of Pre-and Post-Emergence Herbicides on Growth, Productivity, Nodulation of Black Gram (*Vigna mungo* L.) Under Coastal Plain of Odisha. Legume Research. DOI: 10.18805/LR-5310.

Submitted: 24-2-2024 **Accepted:** 8-05-2024 **Online**: 25-06-2024

However, challenges such as the unavailability of labor during critical periods and wet field conditions can hinder timely management of weeds. In rice-fallow black gram systems, farmers often avoid traditional weed management techniques like hand weeding due to concerns about crop trampling and the difficulty of removing dense rice crop stubble. Consequently, selective herbicides emerge as a practical and cost-effective solution for weed control in this system.

In this study, we compared the effects of different herbicides with weed-free and weedy check treatments to evaluate the reduction in weed dry weight and achieve high yields of black gram. The use of pre-emergence herbicides is a proven technique for weed management in black gram in the rainy season (Reddy *et al.,* 2023). Pre-emergence treatments with pendimethalin inhibit plant cell division and elongation in sensitive species and stop weeds from appearing especially during the crop's critical growth stage (Appleby and Valverde, 1988; Gilliam *et al*., 1993). Quizalofop ethyl 5% EC, a selective post-emergence herbicide controls annual grassy weeds effectively in black gram (Mundra and Maliwal, 2012). In legume crops, Quizalofop ethyl 5% EC as POST resulted in effective weed control and higher grain yield of lentil (Singh *et al*., 2018), groundnut (Tokasi *et al.,* 2023) and horse gram (Naik *et al*., 2022). Herbicides alone cannot achieve total weed control due to their selectivity. However, their effectiveness ought to be enhanced by supplementing them with hand 2 weeding or hoeing (Komal *et al*., 2015).

Keeping in view the importance of weeds in black gram and the higher cost involved in weed management, the present study was undertaken to formulate suitable weed management practices for improving the growth and yield of black gram.

MATERIALS AND METHODS

Site description

The present field experiment was conducted at the Agronomy Main Research Farm of the Orissa University of Agriculture and Technology, Bhubaneswar (20°15′N latitude and 85º52′E longitude with an elevation of 25.9 m above the mean sea level (MSL) and a distance of 64 km away from the Bay of Bengal), India. The study site falls under the East and South Eastern Coastal Plain Agro-climatic Zone of Odisha from November to February with a mean maximum temperature of 25-30°C and a mean minimum temperature of 15-20°C. There was no rainfall during the cropping season with 0 rainy days in both the years. The soil at the experimental field belongs to the order Inceptisol (Typic Ustochrept) with a sandy-loam texture. Chemical analysis of the upper 15 cm soil showed low organic carbon (3.39%), low nitrogen (186 kg ha^{-1}), medium P (P2O5: 26.9 kg ha^{-1}), K (K2O: 123.6 kg ha^{-1}) and slightly acidic soil reaction (pH 6.44, 1:2.5 soil: water).

Experimental details and crop management

The experiment was conducted in a randomized block design with three replications consecutively in the *rabi* season (November to February) for 2021-2022 and 2022-23. The field experiment comprised 8 treatments. The details of the treatment adopted in the experiment are presented in Table 1. The dimension of each experimental plot was 6 m × 4 m (24 m^2). Black gram was grown under conventional tillage after cultivator ploughing followed by two passes with a tractor-drawn rotavator to break up the clods. To achieve the proper leveling and pulverization, laddering proved efficient. Black gram cultivar OBG-33 (Shashi) was sown on 23rd November for 2021 and 26th November for 2022. The crop was sown with a seed rate of 25 kg ha^{-1} with a row geometry of 30 × 10 cm. Fertilizers were applied as basal with 20 kg N as Urea and 40 kg P2O5 ha^{-1} as DAP. The crop had two irrigations: the first at 21 DAS and the second during the blossoming stage. As plant protection chemical, chlorpyriphos (20 EC) solution was sprayed at the flowering stage to control pod borer infestation in the black gram in both the seasons. The crop was harvested on 13th February 2022 and 15th February 2023 respectively for both the years.

Herbicide description and management

All POST herbicides such as fenoxaprop-p-ethyl, cyhalofop-butyl, tembotrione and quizalofop-p-ethyl were applied at 21 days after sowing (DAS). Pendimethalin and oxyflourfenas PRE were applied on the next day of sowing. Required quantities of herbicides for 24 m2 of each experimental plot were applied with 500 L ha^{-1} water. Details of herbicide rate, formulation*and* trade name are given in Table 1. Herbicides were applied by a hand-operated knapsack sprayer (200 kPa pressure) of 16-liter capacity

Table 1: Treatment details adopted in the experiment.

Treatments	Herbicide name	Rate (g a.i. ha^{-1})	Formulation	Trade name
T_1	Fenoxaprop-p-ethyl	65 g a.i. ha^{-1}	9.3 EC	Whip super, Bayer
T_2	Quizalofop-p-ethyl	50 g a.i. ha^{-1}	5 EC	Targa Super, Dhanuka
T_3	Cyhalofop-butyl	75 g a.i. ha^{-1}	10 EC	Tata cyclo, Tata
T_4	Pendimethalin	750 g a.i. ha^{-1}	30 EC	Dhanutop, Dhanuka
T_5	Oxyflourfen	50 g a.i. ha^{-1}	23.5 EC	Galigan, Adama
T_6	Tembotrione	120 g a.i. ha^{-1}	34.4 SC	Laudis, Bayer
T_7	Weed check (control)	-	-	-
T_8	Weed free	-	-	-

with a flat fan nozzle. In weed-free check treatment, three hand weedings at 15 DAS, 30 DAS and 45 DAS were performed to create the weed-free condition. While in the unweeded control treatment, no-weeding operation was undertaken and weeds were allowed to emerge to assess dominant weed flora and yield loss.

Crop growth and yield estimation

Nodule number, dry weight of the plant and nodules were estimated at 40 DAS and then after the harvest. Five plants were randomly selected from each plot and nodules were counted. Plants and nodules were sun-dried and kept in an electric oven at 70°C for 72 h for dry weight. Plant dry weight was expressed as g plant 1, while nodule dry weight was expressed as mg plant 1. Black gram was harvested manually from the net area for yield estimation (576 m^2). Manual threshing of black gram was performed and seed yield was recorded from dried and cleaned produce after shelling. The seed yield of black gram was expressed as kg ha^{-1}.

Crop phytotoxicity score, density and dry weight of weeds and control index

Visual scoring for crop phytotoxic symptoms was undertaken after post herbicides application at 7-day intervals up to 21 days of application of herbicides on a 0-10 scale. In black gram, 0 means no phytotoxicity and 10 stands for complete death of the plant*and* a score of <3 is considered acceptable (Rao, 2000). Species-wise density and dry weight of weeds were assessed at 35 DAS and harvested from each plot using a quadrate size of 0.25 m^2 (0.5 m × 0.5 m). Two quadrants were selected randomly in each plot. Weeds collected from a 0.25 m^2 area were identified, counted species-wise and expressed as No. m^{-2}. Identified weeds were sun-dried for 3 days and then kept in an electric oven at 70°C. Dry weight was expressed as g m^{-2}. Weeds were categorized as broad-leaved and narrow-leaved (grasses + sedges). After the weed dry weight, the weed index (Gill and Kumar, 1969) was calculated using the following formula:

$$\text{Weed index} = \frac{\text{Ywf - Yt}}{\text{Ywf}} \times 100$$

Here,
Ywf: Yield from weed free plot
Yt: Yield from treated plot.

Weed control efficiency was calculated by using the following formula as suggested by Mani *et al.* (1973).

$$\text{WCE (\%)} = \frac{\text{WDc - WDt}}{\text{WDc}} \times 100$$

Here,
WCE = Weed control efficiency, WDc = Dry matter of weed in unweeded control, WDt = Dry matter of weeds in treated plot

Statistical analysis

Data were analyzed for randomized block design (Gomez and Gomez, 1984). Before analysis of variance estimation, all data were subjected to test for homogeneity of error variances. Given that there was a linear relationship between the means and variance, Bartlett (1947) recommended that the data on weed count be transformed by a factor to enable proper analysis of variance ($\sqrt{x+0.5}$) for species and category-wise weed density and dry weight because of larger variability. Treatment means were compared using a protected least significant difference test at p d≤ 0.05.

RESULTS AND DISCUSSION

Dominant weed species and category-wise weed density

Dominant weed flora under different herbicides comprised 12 species of weeds including 6 grasses, 1 sedge and 5 broadleaf weeds. Among the grassy weeds *Echinochloa colonum, Eleusine indica* and *Cynodon dactylon* were the most observed species. *Cyperus iria* was the dominant sedge. The broadleaf weeds such as *Phyllanthus niruri, Cleome viscosa, Ageratum conyzoides, Amaranthus viridis* and *Heliotropium indcum* were more evident during different stages of growth. The lowest grass weed population at 20 DAS was recorded from the weed-free treatment which remains statistically at par with pendimethalin 30 EC 750 g/ha as PE at 2 DAS. However, cyhalofop-butyl 10 EC 75 g/ha invariably reduced the density of grassy weed species compared with the weedy check (Table 3). The category wise distribution (%) at 40 DAS showed the dominance of grassy and broadleaved weeds in the weedy check plot (Fig 1). At 40 DAS tembotrione 34.4 SC 120 g/ha as PoE at 21 DAS recorded a lower weed population that was at par with pendimethalin 30 EC 750 g/ha as PE at 2 DAS in comparison to other treatments. At 40 DAS lowest broadleaf m^{-2} was recorded in weed free plot followed by tembotrione

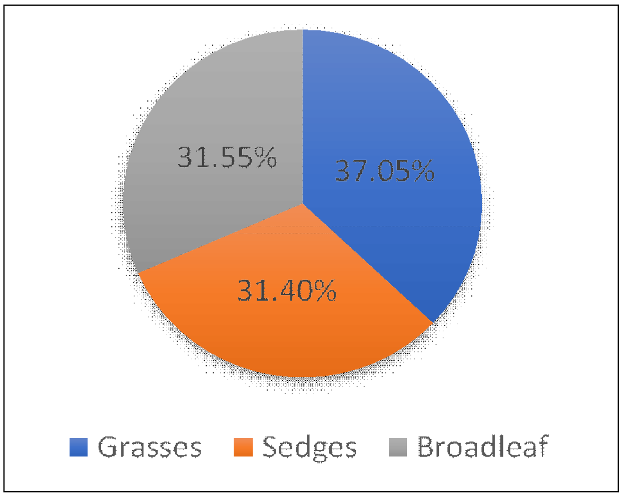
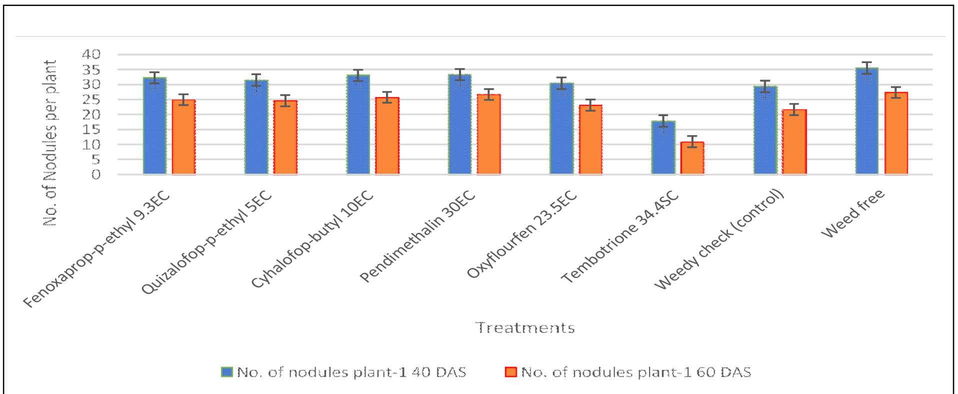


Fig 1: Occurrences of weed species (%) in black gram as influenced by weed management practices.

Table 2: Plant height and seed yield of black gram for different herbicides (Pooled data for 2021-22 and 2022-23).

Treatments	Plant height in cm				Seed Yield (kg ha^{-1})
	20 DAS	40 DAS	60 DAS	Harvest	Harvest
Fenoxaprop-p-ethyl 9.3 EC 65 g/ha as PoE (21DAS)	15.05	30.73	44.52	55.37	809.38
Quizalofop-p-ethyl 5 EC 50 g/ha as PoE (21DAS)	14.75	29.19	43.12	53.68	785.67
Cyhalofop-butyl 10 EC 75 g/ha as PoE (21DAS)	15.12	33.27	45.47	56.52	888.61
Pendimethalin 30 EC 750 g/ha as PE (2DAS)	18.05	31.83	46.02	57.13	919.87
Oxyflourfen 23.5 EC 50 g/ha as PE (2DAS)	17.53	28.21	42.13	51.06	705.71
Tembotrione 34.4 SC 120 g/ha as PoE (21DAS)	14.94	19.27	19.49	19.55	286.51
Weedy check (control)	14.47	26.29	37.20	45.62	598.79
Weed free	19.09	34.13	48.91	59.54	1035.46
SEm(±)	0.41	0.76	0.95	1.00	17.76
CD (p=0.05)	1.24	2.31	2.88	3.03	53.8



For details of treatment, see Table 1. DAS, days after sowing.

Fig 2: Nodule number (No. plant^{-1}) for each herbicide treatment at 40 and 60 days after sowing. Error bars represent standard error of mean.

34.4 SC 120 g/ha as PoE at 21 DAS which was at par with oxyflourfen 23.5 EC 50 g/ha as PE at 2 DAS. The dominance of these weeds was also earlier reported in this region (Nath *et al*., 2022; Patel *et al*., 2015 and Mohanty *et al*., 2020)

Black gram plant height and seed yield

Pendimethalin 30 EC 750 g/ha as PE increased 24%-26% of black gram plant height over the unweeded control across all the crop stages (Table 2). Nodule numbers in cyhalofop-butyl 10 EC 75 g/ha as PoE were significantly higher over tembotrione 34.4 SC as PoE and weedy-check (control). It resulted in 84.92% and 12.47% higher nodule numbers per plant over tembotrione 34.4 SC as PoE and weedy-check (control) respectively (Fig 2).Pendimethalin followed by cyhalofop-butyl has the potential to enhance weed control and black gram yield with effective control of weeds throughout the cropping period resulting in better environment for crop growth with reduced crop-weed competition for various plant growth resources. Similar results were reported by (Sharma and Yadav, 2006; Ghosh *et al*., (2016) and Kumar *et al*., 2016).

Unweeded control resulted in seed yield loss of 53.62% in comparison with the pendimethalin 30EC 750 g/ha as PE and 35.16% in comparison with fenoxaprop-p-ethyl 9.3 EC 65 g/ha as PoE (Table 5). The highest black gram seed yield (1035.46 kg ha^{-1}) was recorded in the weed-free check. Cyhalofop-butyl 10 EC 75 g/ha as PoE had a seed yield advantage of 9.7% over the fenoxaprop-p-ethyl 9.3 EC 65 g/ha as PoE. Among the PoE, tembotrione 34.4 SC as PoE had the lowest seed yield (286.51 kg ha^{-1}). The highest yield and yield attributes were obtained from weed-free plot which might be due to absence of crop-weed competition for entire crop season resulting in a better micro-climate for higher crop growth, nodule number and seed yield. The results are in conformity with the findings of (Yadav *et al.* (2015); Painkra *et al.* (2021) and Mansoori *et al.* (2015).

Category-wise weed density, dry weight and weed index

All herbicides resulted in a significant reduction in weed density and weed dry weightcompared with the weedy check (Table 3 and 4). Lower weed density and higher weed index were observed with the application of pendimenthalin 30 EC 750 g/haas PE and cyhalofop-butyl 10 EC 75 g a.i./ha as PoE ($p<0.05$) creating a more favorable micro-climate for black gram growth with a reduction in crop-weed competition for light, space and nutrients at critical stages

Table 3: Density (No. m-2) of category-wise weed population in different treatments at 20, 40, 60 days after sowing (DAS) and at harvest (Pooled data for 2021-22 and 2022-23)

Treatments	No. of grassy weed m^{-2}				No. of sedges m^{-2}				No. of broadleaf m^{-2}			
	20DAS	40DAS	60DAS	Harvest	20DAS	40DAS	60DAS	Harvest	20DAS	40DAS	60DAS	Harvest
Fenoxaprop-p-ethyl 9.3 EC	8.12	4.69	7.35	8.22	4.76	5.29	7.78	7.91	3.84	6.55	8.31	8.64
65 g/ha as PoE (21 DAS)	(65.43)	(21.52)	(53.56)	(67.09)	(22.18)	(27.52)	(60.05)	(62.11)	(14.23)	(42.45)	(68.62)	(74.23)
Quizalofop-p-ethyl 5 EC	8.33	4.85	7.69	8.86	5.01	5.97	7.85	7.97	3.89	6.80	8.39	8.69
50 g/ha as PoE (21 DAS)	(68.87)	(23.04)	(58.60)	(78.09)	(24.61)	(35.21)	(61.21)	(63.03)	(14.65)	(45.70)	(69.82)	(74.99)
Cyhalofop-butyl 10 EC	7.84	3.78	6.13	7.05	4.63	4.72	7.40	7.52	3.79	5.87	8.06	8.37
75 g/ha as PoE (21 DAS)	(61.21)	(13.88)	(37.33)	(49.50)	(21.02)	(21.93)	(54.43)	(56.39)	(13.87)	(34.05)	(64.51)	(69.59)
Pendimethalin 30 EC	3.89	4.62	5.22	6.17	3.52	4.01	5.62	5.95	3.51	3.89	5.72	6.52
750 g/ha as PE (2 DAS)	(14.63)	(20.96)	(26.92)	(37.77)	(11.94)	(15.70)	(31.23)	(35.14)	(11.86)	(14.63)	(32.25)	(42.11)
Oxyflourfen 23.5 EC	5.57	7.81	10.01	11.32	4.24	6.13	8.03	8.51	3.36	3.68	5.33	6.13
50 g/ha as PE (2 DAS)	(30.55)	(42.57)	(99.73)	(127.84)	(17.50)	(37.14)	(63.98)	(71.97)	(10.80)	(13.04)	(27.90)	(37.06)
Tembotrione 34.4 SC	7.86	5.69	9.34	10.02	4.88	3.26	4.46	7.22	3.97	3.65	6.05	7.05
120 g/ha as PE (21 DAS)	(61.59)	(32.18)	(87.26)	(100.43)	(23.53)	(10.23)	(19.54)	(52.01)	(15.26)	(12.89)	(36.29)	(49.42)
Weedy check (control)	8.51	11.71	12.25	12.59	5.22	6.93	8.66	8.92	4.03	7.01	8.54	8.95
	(72.24)	(137.21)	(150.08)	(158.59)	(26.96)	(47.86)	(74.81)	(79.60)	(15.73)	(48.68)	(72.44)	(79.62)
Weed free	3.21	3.23	3.18	3.25	3.17	3.20	3.05	3.19	3.20	3.21	3.05	3.12
	(9.86)	(9.98)	(9.65)	(10.12)	(9.60)	(9.76)	(8.85)	(9.71)	(9.76)	(9.85)	(8.81)	(9.29)
SEm(±)	0.23	0.28	0.31	0.34	0.20	0.25	0.27	0.32	0.08	0.11	0.15	0.18
CD (p=0.05)	0.71	0.84	0.93	1.04	0.61	0.75	0.82	0.96	0.25	0.32	0.46	0.54

Original values are given in parentheses, which were transformed to $\sqrt{(x+0.5)}$

of crop. In herbicidal treatments, pendimethalin 30 EC 750 g/ha minimized total weed density and dry weight more than cyhalofop-butyl due to its effectiveness of controlling both narrow- and broad-leaved weeds during the critical period of crop weed competition through inhibition of shoot and root growth of weeds. Oxyflourfen 23.5 EC 50 g a.i. ha^{-1} as PE significantly reduced the total dry weight of weeds (by 61.37%-64.72%) compared with weedy check across stages. In the case of PoE, cyhalofop-butyl 10 EC 75 g a.i. ha-1 reduced the total dry weight of weeds by 2.11%-35.41% in comparison with the weedy check plot ($p<0.05$) at all growth stages. Pendimethalin 30 EC 750 g/ha as PE (66.41% at harvest) and cyhalofop-butyl 10 EC 75 g a.i. ha^{-1} (59.31% at harvest) as PoE resulted in a higher ($p< 0.05$) weed control efficiency compared with remaining herbicides (Table 4). The weed control index followed an order of pendimethalin>clodinafop-butyl>fenoxaprop-p-ethyl>tembotrione>quizalofop-p-ethyl>oxyfluorfen for different herbicides. These findings validate the results (Mansoori *et al.*, 2015; Sashidhar *et al.,* 2020; Kumar and Chinnamuthu, 2014 and Naidu *et al.,* 2012). Among the post-emergence herbicidal treatments, cyhalofop-butyl 10 EC 75 g a.i. ha^{-1} could lead to increased weed control and grain yield of blackgram by inhibiting the cell division and the plant enzyme ACCase which prevents the production of essential fatty acids for the construction of cell membranes (Rao, 2008 and Kumar *et al.,* 2014).

Black gram phytotoxicity score

The PE and PoE herbicides resulted in variable black gram phytotoxicity at different crop growth stages (Table 5). In general, phytotoxicity increased at 14 days over days 7 and

Table 4: Category-wise weed dry weight (g m^{-2}) at 20, 40, 60 days after sowing (DAS) and at harvest, weed control efficiency at 40 DAS and weed index at harvesta (Pooled data for 2021 and 2022).

Treatments	Total weed dry weight g m^{-2}				Weed Control Efficiency	Weed Index
	20 DAS	40 DAS	60 DAS	Harvest	40 DAS	Harvest
Fenoxaprop-p-ethyl 9.3 EC 65 g/ha as PoE (21DAS)	4.09 (16.22)	3.90 (14.70)	5.64 (31.29)	5.79 (33.02)	40.33	21.83
Quizalofop-p-ethyl 5 EC 50 g/ha as PoE (21DAS)	4.18 (16.97)	3.97 (15.29)	5.72 (32.34)	6.01 (35.52)	36.90	24.49
Cyhalofop-butyl 10 EC 75 g/ha as PoE (21DAS)	3.97 (15.27)	3.21 (9.86)	5.29 (27.51)	5.57 (30.56)	59.31	14.82
Pendimethalin 30 EC 750 g/ha as PE (2DAS)	1.46 (1.64)	2.93 (8.14)	4.83 (22.89)	5.08 (25.34)	66.41	11.19
Oxyflourfen 23.5 EC 50 g/ha as PE (2DAS)	1.63 (2.17)	4.50 (19.80)	5.78 (32.97)	6.27 (38.89)	20.28	30.31
Tembotrione 34.4 SC 120 g/ha as PoE (21DAS)	4.13 (16.58)	3.79 (13.93)	5.39 (28.61)	5.69 (32.03)	39.51	72.33
Weedy check (control)	4.22 (17.30)	4.97 (24.23)	6.18 (37.75)	6.51 (41.94)	0.00	42.18
Weed free	1.35 (1.32)	1.69 (2.36)	1.95 (3.31)	2.20 (4.35)	90.26	0.00
SEm(±)	0.08	0.10	0.14	0.17	-	-
CD (p=0.05)	0.26	0.31	0.43	0.48	-	-

[a]Original values are given in parentheses, which were transformed to$\sqrt{(x+0.5)}$

Table 5: Effect of herbicides on black gram phytotoxicity score at 7, 14 and 21 days after application (DAA)[a]

Treatments	Phytotoxicity score		
	7 DAS	14 DAS	21 DAS
Fenoxaprop-p-ethyl 9.3 EC 65 g/ha as PoE (21DAS)	0.0	0.0	0.0
Quizalofop-p-ethyl 5 EC 50 g/ha as PoE (21DAS)	0.0	0.0	0.0
Cyhalofop-butyl 10 EC 75 g/ha as PoE (21DAS)	0.0	0.0	0.0
Pendimethalin 30 EC 750 g/ha as PE (2DAS)	0.0	0.0	0.0
Oxyflourfen 23.5 EC 50 g/ha as PE (2DAS)	1.0	1.5	0.0
Tembotrione 34.4 SC 120 g/ha as PoE (21DAS)	6.6	7.6	5.3
Weedy check (control)	0.0	0.0	0.0
Weed free	0.0	0.0	0.0

[a]The periodical phytotoxicity scores due to herbicides application are given in 0–10 scale.

subsequently reduced at 21 days after the application. Herbicides such as oxyfluorfen 23.5 EC 50 g a.i. ha^{-1} as PE (2 DAS) and tembotrione 34.4 SC 120 g a.i. ha^{-1} as PoE (21 DAS) showed a higher black gram phytotoxicity with a score of 1-9. Fenoxaprop-p-ethyl 9.3 EC 65 g a.i. ha^{-1} as PoE (21 DAS), pendimethalin 30 EC 750 g a.i. ha^{-1} as PE (2 DAS) and cyhalofop-p-butyl 10 EC 75 g a.i. ha^{-1} as PoE (21 DAS) did not show any phytotoxicity. The degree of phytotoxicity experienced varied throughout different stages of crop development and over time. Notably, oxyfluorfen demonstrated more pronounced initial phytotoxic effects; however, these effects diminished gradually in black gram as time progressed.Fenoxaprop-p-ethyl and cyhalofop-p-butyl are recommended for controlling narrow-leaved weeds (Nath *et al.,* 2022). The selectivity of black gram for fenoxaprop-p-ethyl 9.3 EC, quizalofop-p-ethyl 5 EC, chalofop-butyl 10 EC and pendimethalin 30 EC was possible because of the inherent tolerance of the crop against these herbicides.For instance, tembotrione and oxyfluorfen belong to the pigment synthesis inhibitor herbicides and had chlorosis and bleaching effects on plants (Das, 2008). Among the herbicide treatments, tembotrione had the highest black gram phytotoxicity because of over-sensitivity to these herbicides and inhibiting the plant enzyme 4-hydroxyphenylpyruvate dioxygenase (HPPD). This enzyme is necessary to produce several important amino acids and carotenoid pigments. This results in the yellowing and chlorosis of plant tissues, which ultimately kills cells and restricts plant development (Dumas *et al.,* 2017).

CONCLUSION

Pendimethalin 30 EC 750 g ha^{-1} as PE at 2 DAS showed selectivity in black gram without any phytotoxicity on the crop. Cyhalofop-butyl 10 EC 75 g ha^{-1} at 21 DAS significantly reduced weed dry weight among PoE at all growth stages. It resulted in a lower weed index. It gave a comparable yield with weed-free check without any negative impact on nodulation. Pendimethalin 30 EC 750 g ha^{-1} as PE at 2 DAS followed by Cyhalofop-butyl 10 EC 75 g ha^{-1}as PoE at 21 DAS can be recommended for broad-spectrum weed control (reduced weed density and dry weight), as it provides a lower weed index and higher seed yield with weed-free check in black gram.

Conflict of interest

All authors declared that there is no conflict of interest.

REFERENCES

Appleby, A.P. and Valverdae, B. E. (1988). Behavior of dinitroaniline herbicides in plants. Weed Technology. 3: 198-206.

Bartlett, M.S. (1947). The use of transformations. Biometrics. 3*:* 39-52.

Das, T.K. (2008). Weed Science: Basics and Applications. New Delhi: Jain Brothers.

Directorate of Economics and Statistics (2020-21), Ministry of Agriculture, Cooperation and Farmers Welfare, Government of India.

Dumas, E., Giraudo, M., Goujon, E., Halma, M., Knhili, E., Stauffert, M., Batisson, I., Besse-Hoggan, P., Bohatier, J., Bouchard, P., CelleJeanton, H., Costa, M.G., Delbac, F., Forano, C., Goupil, P., Guix, N., Husson, P., Ledoigt, G., Mallet, C., Mousty, C., Prevot, C., Richard, V. and Sarraute, S. (2017). Fate and ecotoxicological impact of new generation herbicides from the triketone family: An overview to assess the environmental risks. Journal of Hazardous Materials. 325: 136-156.

Ghosh, P.K., Hazra, K.K., Nath, C.P., Das, A. and Acharya, C.L. (2016). Scope, constraints and challenges of intensifying rice (*Oryza sativa*) fallows through pulses. Indian Journal of Agronomy. 61: 122-128.

Ghosh, S., Das, T.K. and Upadhyaya, A. (2023). Sustaining pulses production through effective weed management options Indian Farming. 73 (07): 03-06.

Gill, G.S. and Kumar, V.K. (1969). Weed Index-A New Method of Reporting Weed Control Trials. Indian Journal of Agronomy. 14: 96-98.

Gilliam, C.H., Eakes, D.J. and Olive, J.W. (1993). Herbicide use during propagation affects root initiation and development. J. Environ. Hort. 11: 157-159.

Girish, T.K., Pratape, V.M.*and* Prasada Rao, U.J.S. (2012). Nutrient distribution, phenolic acid composition, antioxidant and Food Research International. 46(1): 370-377.

Gomez, K.A. and Gomez, A.A. (1984). Statistical Procedures for Agricultural Research. 2nd Edition, John Wiley and Sons, New York. pp: 680.

Komal, Singh, S.P. and Yadav, R.S. (2015). Effect of weed management on growth, yield and nutrient uptake of green gram. Indian Journal of Weed Science. 47(2): 206-210.

Kumar, B., Sharma, R., Singh, S., Shukla, L. and Khare, T. (2014). Effect of post-emergence application of cyhalofop-butyl for weed management in direct-seeded rice (*Oryza sativa*). Indian Journal of Agricultural Sciences. 84.

Kumar, N., Nath, C.P., Hazra, K.K. and Sharma, A.R. (2016). Efficient weed management in pulses for higher productivity and profitability. Indian Journal of Agronomy. 61: S93–S105.

Kumar, T.P. and Chinnamuthu, C.R. (2014). Performance of Pre-emergence herbicide on weeds and plant growth attributes of irrigated blackgram (*Vigna mungo* L.). trends in biosciences. 7(11): 1055-1058.

Mani, V.S., Chakraborty, T.K. and Gautam, K.C. (1973). Double hedge weed killers in peas. Indian Fmg. 26(2): 80-83.

Mansoori, N., Bhadauria, N. and Rajput, R.L. (2015). Effect of weed control practices on weeds and yield of black gram (*Vigna mungo*). Legume Research - An International Journal. 38(6). doi:10.18805/lr.v38i6.6736

Mohanty, T.R., Saha, P., Sahoo, K.C., Tudu, S., Ray, M., Sahoo, S.K., Das, S. and Mishra, N. (2020). Weed management in blackgram [*Vigna mungo* (L.) Hepper] during wet season in North Central Plateau Zone of Odisha. Journal of Food Legumes. 33(3): 191-194.

Mundra, S.L. and Maliwal, P.L. (2012). Influence of quizalofop-ethyl on narrow-leaved weeds in blackgram and its residual effect on succeeding crops. Indian Journal of Weed Science. 44(4): 231-234.

Naidu, K.R.K., Ramana, A.V. and De, B. (2012). Bio-efficacy and economics of herbicides against weeds of black gram [*Vigna mungo* (L.) Hepper] grown in rice-fallow. Journal of Crop and Weed. 8(1): 133-136.

Naik, G.R., Anand, M.R., Kushal, Sukanya, T.S., Kalyanamurthy, K.N., Prakasha, H.C. and Krishna, T.V. (2022). Bio-efficacy of post-emergent herbicides on weed dynamics, yield and economics of horsegram. Mysore J. Agric. Sci. 56 (3): 237-242

Nath, C.P., Kumar, N., Hazra, K.K. and Praharaj, C.C. (2022). Bio-efficacy of different post-emergence herbicides in mungbean. Weed Research. 62: 422-430.

Painkra, D., Gupta, D.K., Sinha, A.K., Paliwal, A.K., Chouksey, N. and Singh, S.K. (2021). Effective weed management strategy for blackgram [*Vigna mungo* (L.) Hepper] under north hill situation of Chhattisgarh. The Pharma Innovation Journal. 10(7): 85-88.

Patel, K.R., Patel, B.D., Patel, R.B., Patel, V.J. and Darji, V.B. (2015). Bio-efficacy of herbicides against weeds in blackgram. Indian Journal of Weed Science. 47(1): 78-81.

Rao, A.S. (2008). Effect of time and dose of post -emergence herbicides on *Echinochloa colona* (L.) Linn. in black gram grown as relay crop. Indian Journal of Weed Science. 40: 165-168.

Rao, V.S. (2000). Principles of Weed Science. Second Edition Published by Mohan Primlini for Oxford and IBH Publishing Co. Pvt. Ltd. pp: 84-85.

Reddy, N.R.M., Subramanyam, D., Sumathi, V. and Sagar, G.K. (2023). Weed management in blackgram with pre- and post-emergence herbicides. Indian Journal of Weed Science. 55(4): 461-463.

Sharma, Mohit and Yadava, M.S. (2006). Effect of Weed Management Practices on Urdbean (*Vigna mungo* L.) and Associated Weeds. Indian J. Weed Sci. 38 (1 and 2): 143-144.

Shashidhar, K.S., Jeberson, S., Premaradhya, M., Singh, N.A.K. and Bhuvaneswari, S. (2020). Weed management effect in blackgram under acidic soils of Manipur. Indian Journal of Weed Science. 52(2): 147-152.

Singh, A. and Pandey, A.K. (2017). Effect of Phosphorus, PSB and Pressmud on Total Phosphorus in Soil, Fertilizer Use Efficiency and Yield of Urd Bean. Int. J. Curr. Microbiol. App. Sci. 6(10): 1775-1779

Singh, K.M., Kumar, M. and Choudhary, S.K. (2018). Effect of weed management practices on growth and yield of lentil (*Lens esculenta* Moench). International Journal of Current Microbiology and Applied Sciences. 7: 3290-3295.

Singh, M., Shekhar, K.S., Ardeep and Datta, D. (2018). Herbicide combinations for weed management in Black gram *(Vigna mungo*) under tarai condition of Uttarakhand. International Journal of Chemical Studies. 6(4): 1594-1597.

Tokasi, S., Sharifzivah, P., Younesabadi, M., Habibian, L. and Moghanlo, G.D. (2023). The efficacy of quizalofop-P-ethyl herbicide to control of grass-weeds in groundnut fields. Crop Production. 15: 193-158.

Yadav, K.S., Dixit, J.P. and Prajapati, B.L. (2015). Weed management effects on yield and economics of blackgram. Indian Journal of Weed Science. 47(2): 136-138.