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RESEARCH ARTICLE

Sole and sequential application of herbicides for economical weed management in blackgram

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ABSTRACT

A field experiment was conducted at Regional Research and Technology Transfer Station, Chiplima, Odisha, India during the winter *(Rabi)* seasons of 2019-20 and 2020-21 to study the effect of sole and sequential application of herbicides for weed management in blackgram (*Vigna mungo* L.). The treatment combinations consisted pre-emergence herbicides, *viz.* pendimethalin and oxyfluorfen and post-emergence herbicides, *viz.* imazethapyr and clodinafop-propargyl + acifluorfen (ready-mix) in different rates along with weed free and weedy check. The weed competition resulted in 37.6% yield loss in blackgram. The pre-emergence application (PE) of oxyfluorfen 200 g/ha at 1 days after seeding (DAS) followed by (*fb*) post-emergence application of imazethapyr75 g/ha at 20 DAS caused 89.5% reduction in weed biomass with higher weed control efficiency (89.4%) and blackgram yield (0.77 t/ha). The net return (₹ 24.9 x 10^3/ha) and benefit: cost ratios (2.0) were also higher with this treatment and hence be recommended in West Central Table Land Zone of Odisha for better weed control, seed yield and higher economic returns in blackgram.

Keywords: Blackgram, Clodinafop-propargyl + acifluorfen, Imazethapyr, Oxyfluorfen, Sequential application, Weed management

INTRODUCTION

Blackgram (*Vigna mungo* L.) a short duration pulse crop is grown over an area of 5.44 million hectares during of rainy and winter (*Kharif and Rabi*) season with a production of 3.56 million tonnes and productivity of 655 kg/ha, which is lower than the world average of 1808 kg/ha (Anon 2018), indicating wider scope for improving the yield potential in India. It is extensively grown in the states of Madhya Pradesh, Maharashtra, Andhra Pradesh, Tamil Nadu and Uttar Pradesh in India. In Odisha, it is grown in an area of 0.57 million ha with a production of 0.26 million tonnes and productivity of 456 kg/ha, which is below the national average (Anon 2016).

Heavy weed infestation in blackgram, due to slower crop growth during early stages and frequent irrigation during winter and summer season, is a major constraint causing lower blackgram yield. The uncontrolled weeds in blackgram cause yield loss up to 42-51% (Begum and Rao 2006, Malliswari *et al.* 2008). Pendimethalin, a pre-emergence herbicide is used at 750 to 1000 g/ha to control initial flush of weeds in most of pulses including blackgram. This alone is not sufficient to control the diverse weed flora of blackgram. Singh *et al.* (2014) discussed the need of post-emergence herbicide to control the second flush of weeds in pulse and to reduce human labour. Several pre and post – emergence herbicides have been reported (Kumar 2010) to provide a good degree of weed control. However, the information on the herbicide efficacy in managing weeds in *Rabi* blackgram under West Central Table Land Zone of Odisha is inadequate. Therefore, this study was conducted to find out the most selective, effective and economic herbicide and its optimum dose for minimizing the menace of weeds in blackgram.

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MATERIALS AND METHODS

The study was undertaken at Regional Research and Technology Transfer Station, Odisha University of Agriculture and Technology, Chiplima, Sambalpur, Odisha during winter *(Rabi)* seasons 2019-20 and 2020-21. The soil of the experimental field was sandy loam with pH 6.6, organic carbon 0.43 % and available N ($KMnO_4$ method), P (Olsen) and K (NH_4OHC method) content of 268, 13.4 and 132 kg/ha, respectively. Eight treatments consisting of pre-emergence application (PE) of oxyfluorfen 200 g/ha at 1 days after seeding (DAS); pendimethalin 750 g/ha PE at 1 DAS; pendimethalin 750 g/ha PE at 1 DAS followed by (*fb*) post-emergence application (PoE) imazethapyr 75 g/ha at 20 DAS; oxyfluorfen 200 g/ha PE at 1 DAS *fb* imazethapyr 75 g/ha PoE at 20 DAS; pendimethalin 75 g/ha PE at 1 DAS *fb* clodinafop-propargyl + acifluorfen 240 g/ha PoE at 20 DAS; oxyfluorfen 200 g/ha PE at 1 DAS *fb* clodinafop-propargyl + acifluorfen 240 g/ha PoE at 20 DAS; weed free (hand weeding twice at 20 and 40 DAS) and weedy control. A randomized block design with 3 replications was used. Blackgram cultivar '*LBG 787*' was sown on 15 October, 2019 and 25 October, 2020 at a spacing of 30 x 10 cm and was harvested on 18 January, 2020 and 28 January, 2021. A common fertilizer dose of 20 kg N + 40 kg P + 20 kg K/ha was applied. Full dose of N, P and K was applied as basal. Required quantities of herbicides were applied as per treatment with manually operated knapsack sprayer fitted with flat-fan nozzle using a spray volume of 500l of water/ha. Weed density (number/m^2) and weed biomass (g/m^2) were taken from random sampling at 2 places in the field with the help of 1 m^2 quadrat at 40 DAS.

The weed samples collected in paper bags were air dried in shade initially followed by oven drying at 65^0C for 48 hours till they attain constant weight to determine biomass in g/m^2. Data on individual and total weed density and biomass were subjected to square root transformation $\sqrt{x+0.5}$. Weed control efficiency (WCE) and Weed index (WI) were calculated based on the weed biomass and blackgram seed yield, respectively. At the harvest, yield and yield-attributes of blackgram were recorded.

The nutrients like N, P and K content in seed and stover were determined by modified Kjeldahl method, vanadomolybdophosphoric yellow colour method and flame photometer, respectively (Jackson 1973). The nutrients uptake by seed and stover were calculated by multiplying nutrient content with seed and stover yield (kg/ha). All data were analyzed through analysis of variance (ANOVA) using standard variance techniques suggested by Gomez and Gomez (1984).

Economics was computed using the prevailing market prices for inputs and outputs such as blackgram seed (₹ 70/kg) and manual labour (₹ 287/day); input price (₹/kg): urea, 5.52; diammonium phosphate, 24.45; muriate of potash, 17.44; oxyfluorfen, ₹ 180/100 ml; pendimethalin ₹ 400/l; imazethapyr ₹ 300/250 ml; clodinafop propargyl + acifluorfen ₹ 174/100ml.

RESULTS AND DISCUSSION

The predominant weeds of the experimental field were *Echinochloa colona* and *Digitaria sanguinalis, Dactyloctenium aegyptium, Brachiaria reptans* among the grasses; *Cyperus rotundus, Cyperus difformis* among the sedges and *Cleome viscosa*, *Euphorbia hirta* and *Boerhavia erecta, Euphorbia thymifolia, Celosia argentea, Commelina benghalensis, Phyllanthus niruri* among the broad-leaved weeds during both the years of study. The composition of grasses, sedges and broad-leaved weeds in weedy check plot was 18.7, 30.4 and 50.8%, respectively at vegetative stage of crop. The earlier emergence of sedges and broad-leaved weeds was noticed as compared to grasses as observed earlier by Bhowmick and Gupta (2005)

Effect on weeds

Herbicidal treatments significantly influenced the weed density and biomass. The density and biomass of both broad-leaved and grassy weeds were significantly reduced by all weed control treatments compared to weedy check, however, weed free (two hand weedings) recorded lowest broad-leaved, grassy and total weeds than the rest of the treatments (**Table 1** and **2**). The application of pendimethalin at 750 g/ha PE and oxyfluorfen at 200 g/ha PE alone, effectively reduced density and biomass of the sedges and broad-leaved weeds than weedy check, and were at par. However, sequential application of oxyfluorfen at 200 g/ha PE *fb* imazethapyr at 75 g/ha PoE recorded the lowest total weed density and biomass (18.5/m^2, 9.5 g/m^2), the highest weed control efficiency (89.4%) with the lowest weed index (3.4%).The next best treatment was pendimethalin at 750 g/ha PE *fb* imazethapyr at 75 g/ha PoE. The high selectivity of herbicides to blackgram and non-selectivity to weeds was the reason for better control of weeds. Oxyfluorfen PE or pendimethalin PE caused reduction in germination of emerging weed during initial period of growth and sequential post-emergence application of imazethapyr as PoE has controlled the late emerging sedges and broad-leaved weeds. Imazethapyr inhibits the plastid enzyme acetolactate synthase (ALS) in plants which catalyses the first step in the biosynthesis of essential branched chain aminoacids (valine, leucine, isoleucine). The ALS inhibitors thus stop cell division and reduce carbohydrate translocation in the susceptible plants (Das 2008). Papierniks *et al.* (2003) also recommended use of imazethapyr in legumes. That is why sequential application of pendimethalin or oxyfluorfen PE *fb* imazethapyr or clodinafop propargyl + acifluorfen as PoE was more effective than that of sole application of pendimethalin at 750 g/ha PE and oxyfluorfen at 200 g/ha PE in controlling weeds. Weedy check registered higher total weed density.

Effect on crop

The weed infestation caused 35.2% reduction in mean seed yield of winter (*Rabi*) blackgram as was also reported by Chand *et al*. (2004) and Singh (2011). Weedy control recorded the lowest seed yield (507 kg/ha). The blackgram yield and yield parameters were higher under weed free treatments which were at par with treatment of oxyfluorfen at 200 g/ha PE *fb* imazethapyr 75 g/ha and was significantly superior to pendimethalin 750 g/ha PE at 1 DAS *fb* clodinafop-propargyl + acefluorofen 240 g/ha PoE at 20 DAS (**Table 3**). Pods/plant, seeds/pod and test weight in weed free and pendimethalin 750 g/ha PE *fb* imazethapyr 75 g/ha PoE was found at par with each other. This might be due to minimizing the competition of weeds with main crop for resources, *viz.* light, nutrients and moisture with adaption of effective weed control methods. Thus, reduced crop-weed competition resulted into overall improvement of crop growth as reflected by plant height and dry matter accumulation consequently resulted into better development of reproductive structure and translocation of photosynthates to the sink. The results corroborate with the findings of Yadav *et al.*

Table 1. Effect of weed management on weed density at 40 days after seeding in blackgram

Treatment	Weed density (no./m^2)											
	Grasses			Sedges			Broad- leaved weeds			Total		
	2020	2021	Mean	2020	2021	Mean	2020	2021	Mean	2020	2021	Mean
Oxyfluorfen PE	23.4 (4.9)	18.7 (4.4)	21.1 (4.6)	39.4 (6.3)	33.0 (5.8)	36.2 (6.1)	64.0 (8.0)	51.0 (7.2)	57.5 (7.6)	126.8 (11.3)	102.7 (10.2)	114.8 (10.7)
Pendimethalin PE	23.4 (4.9)	18.0 (4.3)	20.7 (4.6)	38.6 (6.3)	32.7 (5.8)	35.7 (6.0)	67.4 (8.2)	53.0 (7.3)	60.2 (7.8)	129.4 (11.4)	103.7 (10.2)	116.6 (10.8)
Pendimethalin PE *fb* imazethapyr PoE	2.0 (1.6)	3.4 (2.0)	2.7 (1.8)	3.3 (1.9)	10.9 (3.4)	7.1 (2.8)	8.3 (3.0)	11.5 (3.5)	9.9 (3.2)	13.6 (3.8)	25.7 (5.1)	19.7 (4.5)
Oxyfluorfen PE *fb* imazethapyr PoE	2.0 (1.6)	3.0 (1.9)	2.5 (1.7)	3.0 (1.9)	10.5 (3.3)	6.8 (2.7)	7.0 (2.7)	11.5 (3.5)	9.3 (3.1)	12.0 (3.5)	25.0 (5.0)	18.5 (4.4)
Pendimethalin PE *fb* clodinafop-propargyl + acifluorfen PoE	6.0 (2.5)	6.3 (2.6)	6.2 (2.6)	30.6 (5.6)	27.7 (5.3)	29.2 (5.4)	24.0 (4.9)	35.7 (6.0)	29.9 (5.5)	60.6 (7.8)	69.7 (8.4)	65.2 (8.1)
Oxyfluorfen PE *fb* clodinafop-propargyl + acifluorfen PoE	4.6 (2.3)	4.7 (2.3)	4.7 (2.3)	30.0 (5.5)	27.0 (5.2)	28.5 (5.4)	13.4 (3.7)	31.0 (5.6)	22.2 (4.8)	48.0 (7.0)	62.7 (7.9)	55.4 (7.5)
Weed free	0.0 (0.7)	0.0 (0.7)	0.0 (0.7)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Weedy check	40.6 (6.4)	26.0 (5.1)	33.3 (5.8)	58.6 (7.7)	50.0 (7.1)	54.3 (7.4)	105.4 (10.3)	76.0 (8.7)	90.7 (9.5)	204.6 (14.3)	152.0 (12.3)	178.3 (13.4)
LSD (p=0.05)	0.4	0.3	0.4	0.4	0.4	0.4	0.5	0.5	0.5	0.7	0.6	0.7

Data were subjected to square root $\sqrt{x+0.5}$ transformation before analysis and original values are shown in parentheses

Table 2. Effect of weed management on weed biomass and weed control efficiency (WCE) and weed index (WI) at 40 days after seeding in blackgram (pooled data of 2 years)

Treatment	Weed biomass (g/m^2)												WCE (%)	WI (%)
	Grasses			Sedges			Broad- leaved weeds			Total				
	2020	2021	Mean	2020	2021	Mean	2020	2021	Mean	2020	2021	Mean		
Oxyfluorfen PE	10.6 (3.3)	11.8 (3.5)	11.2 (3.4)	11.8 (3.5)	13.9 (3.8)	12.9 (3.7)	34.6 (5.9)	33.1 (5.8)	33.9 (5.9)	57.0 (7.6)	58.8 (7.7)	57.9 (7.6)	36.2	22.9
Pendimethalin PE	10.6 (3.3)	11.4 (3.4)	11.0 (3.4)	11.6 (3.5)	13.7 (3.8)	12.7 93.6)	36.4 (6.1)	34.2 (5.9)	35.3 (6.0)	58.6 (7.7)	59.3 (7.7)	59.0 (7.7)	35.1	20.5
Pendimethalin PE *fb* imazethapyr PoE	0.8 (1.1)	2.1 (1.6)	1.5 (1.4)	1.0 (1.2)	5.0 (2.3)	3.0 (1.9)	4.5 (2.2)	7.6 (2.8)	6.0 (2.6)	6.3 (2.6)	14.7 (3.3)	10.5 (3.3)	88.4	6.0
Oxyfluorfen PE *fb* imazethapyr PoE	0.6 (1.0)	1.9 (1.5)	1.3 (1.3)	0.9 (1.2)	4.4 (2.2)	2.7 (1.8)	3.8 (2.1)	7.4 (2.8)	5.6 (2.5)	5.3 (2.4)	13.7 (3.8)	9.5 (3.2)	89.4	3.4
Pendimethalin PE *fb* clodinafop-propargyl + acifluorfen PoE	2.8 (1.8)	4.0 (2.1)	3.4 (2.0)	9.2 (3.1)	11.6 (3.5)	10.4 (3.3)	13.0 (3.7)	23.0 (4.8)	18.0 (4.3)	25.0 (5.0)	38.6 (6.3)	31.8 (5.7)	64.8	18.6
Oxyfluorfen PE *fb* clodinafop-propargyl + acifluorfen PoE	2.2 (1.8)	2.9 (1.8)	2.6 (1.7)	9.0 (3.1)	11.3 (3.4)	10.2 (3.3)	7.2 (2.8)	20.0 (4.5)	13.6 (3.8)	18.4 (4.3)	34.2 (5.9)	26.3 (5.2)	70.9	14.8
Weed free	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100	0.0
Weedy check	18.3 (4.3)	18.4 (4.3)	18.4 94.3)	17.6 (4.3)	19.8 (4.5)	18.7 (4.4)	56.8 (7.6)	50.8 (7.2)	53.8 (7.4)	92.7 (9.7)	89.0 (9.5)	90.9 (9.6)	0.0	37.9
LSD (p=0.05)	0.2	0.3	0.2	0.2	0.3	0.2	0.4	0.4	0.4	4.5	4.2	6.3		

(2014). Overall seed yield was lower in 2019-20 than 2020-21. Pod length did not vary significantly among the treatments.

Among different treatments, sequential application of oxyfluorfen 200 g/ha PE *fb* imazethapyr 75 g/ha PoE recorded higher seed yield (0.77 t/ha) with 53.1% yield advantages over weedy check. It was at par with pendimethalin 750 g/ha PE *fb* imazethapyr 75 g/ha PoE. Kantar *et al*. (1999) also observed 63.6% higher seed yield over unweeded check with application of imazethapyr. The reduced crop weed competition caused significant increase in growth and yield characters ultimately led to higher seed yield of blackgram. The significant improvement in seed yield as a result of hand weeding twice (weed free) and all herbicidal weed control treatments could be attributed to the fact that yield of crop depends on several yield components which are interrelated. Under weedy situation, at early crop growth stage a greater part of resources present in soil and environment are depleted by weeds for their growth. The crop plant thus, face stress which ultimately affects their growth, development and yield. Like seed yield, stover yield (1.17 t/ha) was also significantly increased due to application of oxyfluorfen 200 g/ha PE *fb* imazethapyr 75 g/ha PoE over weedy check. Increase in stover yield might be due to direct influence of various weed management treatments on the suppression of weeds. The results were in agreement with the earlier findings (Kumar *et al*. 2016 and Tiwari *et al*. 2014).

Nutrient uptake

Significant decrease in total N, P and K uptake by weeds were recorded due to all weed management treatments than weedy check (**Table 4**). Oxyfluorfen 200 g/ha PE *fb* imazethapyr 75g/ha PoE at 20 DAS caused the highest uptake of N, P and K (31.8, 3.9, 12.4 kg/ha) by seed and stover (19.3, 3.5, 14.0 kg/ha) and was at par with weed free check, owing to higher dry matter production of crop and corresponding nutrient contents in these treatments due to negligible competition offered by weeds for N, P and K uptake as also reported by Chhodavadia *et al*. (2013). The highest N, P and K depletion (31.5, 3.2 and 20.0 kg/ha, respectively) by weeds was recorded in weedy check plots as weeds were not controlled effectively and enabled them to absorb more nutrients (Singh *et al*. 2020).

Economics

The monetary returns were significantly influenced by different weed control treatments (**Table 4**). Sequential application of oxyfluorfen 200 g/ha PE *fb* imazethapyr 75g/ha PoE at 20 DAS recorded the highest net return (₹ 24.9 x 10^3/ha) and benefit: cost ratio (2.0) which was closely followed by pendimethalin 750 g/ha PE at 1 DAS *fb* imazethapyr 75 g/ha PoE at 20 DAS and significantly superior to the weed free check. In weed free treatment, the net return was maximum (₹ 21.3 x10^3/ ha), but benefit: cost ratio was less (1.7). This was due to engagement of greater number of laborer which enhanced the cost of cultivation (₹ 29.79x 10^3/ ha) in this treatment. Weedy check though involved the lowest cost of cultivation yet provided the lowest net monetary return (₹ 9.1 x 10^3/ha) and benefit: cost ratio (1.4). These findings are similar to those reported by Kalhapure *et al*. (2013) and Yadav *et al*. (2014).

The broad-spectrum weed control throughout the crop growth period with sequential application of oxyfluorfen at 200 g/ha PE *fb* imazethapyr 75 g/ha at 20 DAS recorded maximum net returns and B:C ratio in winter (*Rabi*) blackgram under West Central Table Land Zone of Odisha.

Table 3. Yield attributes, yield and harvest index of blackgram as influenced by different treatments (pooled data of 2 years)

Treatment	Plant height (cm)	Dry matter /plant (g)	Pods/ plant	Pod length (cm)	Seeds/ pod	Test weight (g)	Seed yield (t/ha)			Stover yield (t/ha)		
							2020	2021	Mean	2020	2021	Mean
Oxyfluorfen PE	33.5	11.8	13.5	4.0	6.4	43.3	0.66	0.58	0.62	0.96	0.90	0.93
Pendimethalin PE	31.5	12.6	14.5	5.0	6.4	45.3	0.70	0.59	0.64	1.01	0.91	0.96
Pendimethalin PE *fb* imazethapyr PoE	34.5	13.7	16.5	6.0	6.6	45.3	0.76	0.65	0.70	1.14	1.13	1.13
Oxyfluorfen PE *fb* imazethapyr PoE	36	13.9	18.3	6.0	6.5	50.5	0.83	0.72	0.78	1.18	1.15	1.17
Pendimethalin PE *fb* clodinafop-propargyl + acifluorfen PoE	29.5	12.2	14	5.0	6.3	44.4	0.71	0.60	0.65	1.02	0.94	0.98
Oxyfluorfen PE *fb* clodinafop-propargyl + acifluorfen PoE	33	12.9	16	5.0	6.5	44.4	0.72	0.62	0.67	1.07	0.99	1.03
Weed free	39.5	14.9	18.5	6.0	7	52	0.87	0.75	0.81	1.22	1.195	1.21
Weedy check	28.5	9.3	11.5	4.0	6.4	41.5	0.51	0.50	0.51	0.79	0.71	70.5
LSD (p=0.05)	3.8	1.1	1.9	NS	1.1	7.5	0.18	0.06	0.11	0.17	0.18	0.17

Table 4. Nutrient uptake by seed, stover, weed and economics of blackgram as influenced by different treatment (pooled data of 2 years)

Treatment	Uptake by seed (kg/ha)			Uptake by stover (kg/ha)			Uptake by weed (kg/ha)			Cost of cultivation (x10³ ₹/ha)	Net returns (x10³ ₹/ha)	Benefit : cost ratio
	N	P	K	N	P	K	N	P	K			
Oxyfluorfen PE	25.1	2.57	10.3	14.4	2.88	11.5	21.5	2.1	13.2	23.29	16.0	1.7
Pendimethalin PE	26.1	2.61	10.44	9.83	1.97	10.8	18.9	2.4	13.4	23.49	17.1	1.7
Pendimethalin PE *fb* imazethapyr PoE	28.9	2.82	11.99	17.5	3.4	12.5	3.4	0.4	2.6	24.25	21.3	1.8
Oxyfluorfen PE *fb* imazethapyr PoE	31.8	3.88	12.41	19.3	3.5	14	3.4	0.4	2.3	24.03	24.9	2.0
Pendimethalin PE *fb* clodinafop-propargyl + acifluorfen PoE	26.1	2.68	11.39	17.5	3.09	11.3	10.2	1.2	7.1	25.25	15.8	1.6
Oxyfluorfen PE *fb* clodinafop-propargyl + acifluorfen PoE	28	2.73	10.93	17	3.39	13.6	9.3	1.1	6.1	25.49	16.8	1.7
Weed free	34.1	4.06	13.81	21.7	3.62	14.5	0.0	0.0	0.0	29.79	20.3	1.7
Weedy check	19.8	2.26	7.34	14	2.63	7.88	31.5	3.2	20.0	22.87	9.1	1.4
LSD (p=0.05)	4.8	0.3	1.6	4.6	1.2	0.64	0.54	0.2	0.52		11.8	0.3

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