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Influence of new post emergent herbicides on weed densities and crop weed competition in blackgram (*Vigna mungo*)

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Abstract
The field experiment was conducted at University of Agricultural Sciences, Bangalore, during *kharif* 2018. Experiment consists of application of three post emergent herbicide molecules (Fomesafen, Propaquizafop and Imazethapyr) and their combinations at 20 DAS, Major weeds observed were, *Ageratum conyzoides*, *Achyranthes aspera*, *Alternanthra sessilis*, *Borreria articularis*, *Dactyloctenium aegyptium*, *Echinochloa colonum*, *Cynodon dactylon*, *Eleusine indica* and *Cyperus rotundus*. Post-emergent application of Fomesafen 18.8% SL+ Propaquizafop 5.83% EC @ (252+78) g a.i. ha^{-1} recoded significantly lower weed density, weed dry weight, and higher weed control efficiency at all stages of the crop, resulting in superior grain yield and lower weed index (1290 kg ha^{-1} and 10.23) and it was on par with Fomesafen 18.8% SL + Propaquizafop 5.83% EC @ (210+65) g a.i. ha^{-1} (1248 kg ha^{-1}, 13.15 respectively).

Keywords: Blackgram, weed density, weed dry weight and weed control efficiency

Introduction
Black gram (*Vigna mungo* L.). is third important short duration pulse grown in many parts of India. India is the largest producer and consumer of blackgram in the world. In India, it contributes to the total cultivated area of 5.44 M ha with the production of 3.56 MT with a productivity of 655 kg ha^{-1} (Anon, 2018) [1].

Among various factors of production, weeds play a vital role in influencing blackgram yield. Weeds compete with the resources like nutrient, moisture, and light. The critical period of crop-weed competition in blackgram is the first 20-40 days after sowing and season long weed competition has been found to reduce blackgram yield to the extent of 27-84 per cent depending on the kind and intensity of weed species (Singh, 2011 and Bhowmick *et al.*, 2015) [14, 2]. Hand weeding, which is usually preferred, adds to the cost of cultivation due to higher labour wages and does not ensure weed removal at critical stages of crop-weed competition (Duary *et al.*, 2015) [2]. At presently, Fomesafen (250 g ha^{-1}) is an effective post emergence herbicide for controlling non-grassy weeds in the soybean (Singh *et al.*, 2014) [13] and Tiwari and Mathew (2002) [15] found that Propaquizafop (50 g ha^{-1}) gave effective control of grassy weeds in soybean. However, the efficacy of fomesafen + propaquizafop (pre-mix) has not been evaluated for weed management in blackgram under Eastern dry zone of Karnataka as well as other parts of the country. Hence, the present investigation was undertaken.

Materials and Methods
A field experiment was conducted during rainy season (Kharif), 2018 at the Gandhi Krishi Vignana Kendra (GKVK), University of Agricultural Sciences, Bengaluru, Karnataka. The experimental site was situated in the Eastern dry zone (Zone-V) of Karnataka (12º51' N Latitude and 77º35' E Longitude with an altitude of 930 m above mean sea level). The soil of the experimental site was sandy loam in texture and slightly acidic in reaction (pH 5.8), medium in organic carbon content (0.50%), low available nitrogen (253.60 kg/ha), medium available phosphorus (32.24 kg/ha) and high available potassium (283.20 kg/ha) with electrical conductivity of 0.32 dS/m. The moisture content at field capacity was 18.63% with bulk density of 1.43 g/cc. Eleven treatments were assigned in a randomized complete block design with three replications. Treatments included fomesafen 25% SL 250 g/ha at 20 days after sowing (DAS), propaquizafop 10% EC 100 g/ha (20 DAS), imazethapyr 10% SL 100 g/ha (20 DAS), fomesafen 18.8% SL + propaquizafop 5.83% EC (pre-mix) 168 + 52, 210 + 65, 252 +

78 and 294 + 91 g/ha (20 DAS), propaquizafop 2.5% EC + imazethapyr 3.7% SL (pre-mix) 50 + 75 g/ha (20 DAS), two hand weeding (15 and 30 DAS), weed free and weedy check. Seeds of blackgram variety 'LBG-625' (Rashmi) were sown in lines at the rate of 25 kg/ha and at a depth of 2-3 cm, maintaining 30 cm row spacing. The crop was fertilized with 25-50-25kg N-P-K/ha through urea, single super phosphate and muriate of potash, respectively. The crop was sown during 13th July and harvested at 24th October 2018. Weeds were counted at 25, 50 DAS and at harvest. Monocot and dicot weeds present within 0.5 m x 0.5 m random quadrant in each net plot were counted separately and expressed as number of weeds per 0.25 m^2. Weed dry weight was recorded at 25, 50 DAS and at harvest. Weeds in 0.5 m x 0.5 m quadrant in the net plot were cut close to the ground level and were dried at 70 ^oC to a constant weight and the weight was recorded. Based on this data, dry weight of weeds per 0.25 m^2 were worked out and expressed in g per m^2. The data on dry weight were subjected to square root transformation before statistical analysis to normalize their distribution. Gross returns, net returns and benefit cost ratio were worked out by using the following formulae and expressed in rupees per hectare.

Weed index and weed control efficiency were calculated as per the standard formulae.

$$\text{WCE (\%)} = \frac{\text{(Dry matter of weeds in un weeded plot - Dry matter of weeds in treated plot)}}{\text{Dry matter production of weeds in un weeded plot}} \times 100$$

$$\text{WI} = \frac{(X - Y)}{X} \text{ x } 100$$

Where

WI = Weed index (%)

X = Yield of weed free plot

Y = Yield from treated plot

Results and Discussion

The experiment results were discussed in the subsequent sub-headings:

Effect on weed growth

The major weed flora observed in the experimental plots were *Ageratum conyzoides*, *Achyranthes aspera*, *Borreria articularis*, *Alternanthra sessilis* and *Emilia sanchifolia.* Among the grassy weeds, *Digitaria marginata*, *Cynodon dactylon*, *Echinochloa colonum*, *Dactyloctenium aegyptium*, *Eleusine indica* and among sedges *Cyperus rotundus*.

Effect on weed density

Weed density m^{-2} at (50 and 70 DAS)

The data pertaining to weed densities at 50 and 70 DAS of blackgram is presented in Table 1. At 50 DAS, post emergence application of Fomesafen 18.8% SL+ Propaquizafop 5.83% EC @ (252+78) g a.i. ha^{-1} recorded significantly lower total weed density of 26.8 m^{-2} compared to other treatments which was on par with Fomesafen 18.8% SL+ Propaquizafop 5.83% EC @ (210+65) g a.i. ha^{-1} (37.5 m^{-2}) and two hand weedings at 15 and 30 DAS (23.2 m^{-2}). Whereas, unweeded check recorded significantly highest total weed density of 112.7 m^{-2} among all the treatments.

At 70 DAS, post emergence application of Fomesafen 18.8% SL+ Propaquizafop 5.83% EC @ (252+78) g a.i. ha^{-1} recorded significantly lower total weed density (33.27 m^{-2}) compared to other treatments but it was on par with Fomesafen 18.8% SL+ Propaquizafop 5.83% EC @ (210+65) g a.i. ha^{-1} (43.97m^{-2}) and two hand weedings at 15 and 30 DAS (23.3 m^{-2}). Whereas, unweeded check recorded a significantly higher total weed density (96.0 m^{-2}).

Effect on weed dry weight

Weed dry weight g m^{-2} at (50 and 70 DAS)

The data pertaining to weed dry weight at 50 and 70 DAS of blackgram is presented in Table 2.

Among herbicide treatments, post emergence application of Fomesafen 18.8% SL+ Propaquizafop 5.83% EC @ (252+78) g a.i. ha^{-1} recorded lower sedge, grass, broad leaf weeds and total weed dry weight (0.53, 7.03, 9.07 and 16.63 g m^{-2}, at 50 DAS) and (0.0, 10.43, 15.47 and 25.90 g m^{-2}, respectively at 70 DAS) it was at par with two hand Weedings at 15 and 30 DAS (0.33, 6.63, 5.40 and 12.37 g m^{-2}, at 50 DAS) and (0.17, 6.93, 11.80 and 18.91 g m^{-2}, respectively) due to lowest weed density. Unweeded check recorded highest total weed dry weight at 50 and 70 DAS (74.80 and 85.0 g m^{-2}, respectively) due to highest weed density.

The combined application of Fomesafen 18.8% SL+ Propaquizafop 5.83% EC @ (252+78) g a.i. ha^{-1} as post emergence caused significant reduction in density of sedge, grassy and broad leaved weeds by achieving higher weed control efficiency during critical period of crop weed competition through broad spectrum weed control. Higher weed population and dry weight were recorded in unweeded check compared to the rest of the treatments. This was mainly due to higher density and dry weight of grasses, sedges and broad leaved weeds. Long interference of weed growth resulted in maximum utilization of resources (moisture, nutrient, light and space). Various earlier workers (Khot *et al*., 2013b; Dwivedi *et al.*, 2012 and Choudhary *et al.*, 2012) [10, 6, 3] also reported higher weed population and dry weight in unweeded check.

Weed control efficiency

The data on weed control efficiency as influenced by different post emergent herbicides are presented in Table 3.

At 25, 50, 70 DAS and at harvest, higher weed control efficiency was recorded in two hand weedings at 15 and 30 DAS (92.3, 83.5, 77.8 and 70.6%, respectively). Among herbicide treatments, higher weed control efficiency at 25, 50, 70 DAS and at the harvest was recorded in post emergence application of Fomesafen 18.8% SL @ 252 g a.i. ha^{-1} + Propaquizafop 5.83% EC @ 78 g a.i. ha^{-1} (91.1, 77.8, 69.5 and 60.7%, respectively), and lowest weed control efficiency was recorded in Imazethapyr @ 100 g ha^{-1} (61.7, 36.8, 35.9 and 37.0%, respectively).

However, maximum weed control efficiency (WCE) was noticed in two hand weedings at 15 and 30 DAS (92.3, 83.5, 77.8 and 70.6%, respectively) due to highest efficiency of human labour in removing all types of weeds followed by Fomesafen + Propaquizafop @ (252 + 78) and (210 + 65) g ha^{-1} recorded next higher weed control efficiency because both treatments restricted the growth of grassy and broad leaved weeds effectively and resulted in the lowest weed biomass during the critical period of crop weed competition was the main reason for higher WCE and confirming the views of Shete *et al.* (2007), Gupta *et al.* (2013) [8] and Kewat *et al.* (2014) [9]. Whereas, lower weed control efficiency in application of Imazethapyr 10% SL @ 100 g a.i. ha^{-1} was due to the lower dose of chemical which is insufficient to control

all the weeds. Similar results were reported by Lal *et al.* (2017) [12] and Kumar *et al.* (2018) [11].

Effect on yield

Among different weed management treatments, two hand weedings at 15 and 30 DAS recorded significantly higher grain yield and weed index (1348 kg ha^{-1} and 6.19%) compared to all the treatments. However, it was statistically on par with post emergence application of Fomesafen 18.8% SL+ Propaquizafop 5.83% EC @ (252+78) g a.i. ha^{-1} (1290 kg ha^{-1} and 10.23) and Fomesafen 18.8% SL+ Propaquizafop 5.83% EC @ (210+65) g a.i. ha^{-1} (1248 kg ha^{-1}, 13.15% respectively). This was mainly due to higher yield attributing characters due to better control of different kinds of weed flora of critical growth periods of between 15 to 35 days after sowing, which otherwise were quite notorious for imposing competition for light, space and nutrients with crop. Whereas, the lower grain yield (456 kg ha^{-1}) was noticed in weedy check. It is mainly due to severe competition by weeds which affected the growth, nutrient uptake and yield parameters of the crop drastically. These results are in conformity with the findings of Goverdhan (2018) [7], Mundra and Maliwal (2012), Khot *et al*. (2015) [10] (Table 4).

Table 1: Category wise weed density (number m^{-2}) at 50 and 70 DAS in blackgram as influenced by different post emergent herbicides

Treatments	50 DAS				70 DAS			
	Sedge^{+}	Grasses$^{\#}$	BLWs$^{\#}$	Total$^{\#}$	Sedge^{+}	Grasses^{+}	BLWs$^{\#}$	Total$^{\#}$
T_1	1.91 (2.67)	1.49 (29.53)	1.29 (17.67)	1.71 (49.8)	2.20 (3.87)	5.72 (31.80)	1.40 (23.40)	1.78 (59.07)
T_2	1.63 (1.67)	1.19 (13.73)	1.60 (37.67)	1.74 (53.0)	1.99 (3.00)	4.38 (18.40)	1.65 (43.07)	1.82 (64.47)
T_3	1.79 (2.33)	1.41 (23.93)	1.49 (29.10)	1.76 (55.3)	2.11 (3.53)	5.56 (30.00)	1.54 (32.83)	1.83 (66.37)
T_4	1.99 (3.00)	1.31 (18.73)	1.41 (24.00)	1.68 (45.7)	2.27 (4.20)	4.80 (22.13)	1.48 (28.73)	1.76 (55.07)
T_5	1.63 (1.67)	1.27 (16.73)	1.32 (19.10)	1.60 (37.5)	1.96 (2.87)	4.33 (17.93)	1.40 (23.17)	1.66 (43.97)
T_6	1.52 (1.33)	1.09 (10.53)	1.23 (14.93)	1.46 (26.8)	1.88 (2.53)	3.66 (12.40)	1.31 (18.33)	1.55 (33.27)
T_7	1.82 (2.33)	1.28 (17.33)	1.35 (20.43)	1.62 (40.1)	2.02 (3.13)	4.72 (21.40)	1.38 (22.30)	1.68 (46.83)
T_8	2.29 (4.33)	1.37 (21.67)	1.43 (25.53)	1.72 (51.5)	2.54 (5.53)	4.94 (23.40)	1.59 (37.27)	1.83 (66.20)
T_9	1.38 (1.00)	1.05 (10.33)	1.16 (12.6)	1.40 (23.2)	1.77 (2.20)	3.15 (9.43)	1.13 (11.67)	1.39 (23.30)
T_{10}	1.00 (0.00)	0.30 (0.00)	0.30 (0.00)	0.30 (0.00)	1.00 (0.00)	1.00 (0.00)	0.30 (0.00)	0.30 (0.00)
T_{11}	2.55 (5.67)	1.67 (45.07)	1.80 (62.03)	2.06 (112.7)	2.78 (6.87)	6.08 (36.20)	1.74 (53.00)	1.99 (96.0)
S.Em±	0.16	0.05	0.04	0.07	0.08	0.15	0.09	0.09
CD (p = 0.05)	0.48	0.16	0.13	0.21	0.25	0.75	0.27	0.27

Data within parentheses are original values; # - data analyzed using log (x+2) transformation, + - square root (x+1) transformation

T_1: Fomesafen 25% SL @ 250 g a.i. ha^{-1}
T_2: Propaquizafop 10% EC @ 100 g a.i. ha^{-1}
T_3: Imazethapyr 10% SL @ 100 g a.i. ha^{-1}
T_4: Fomesafen 18.8% SL+ Propaquizafop 5.83% EC @ (252+78) g a.i. ha^{-1}
T_5: Fomesafen 18.8% SL+ Propaquizafop 5.83% EC @ (210+65) g a.i. ha^{-1}
T_6: Fomesafen 18.8% SL+ Propaquizafop 5.83% EC @ (252+78) g a.i. ha^{-1}
T_7: Fomesafen 18.8% SL+ Propaquizafop 5.83% EC @ (252+78) g a.i. ha^{-1}
T_8: Propaquizafop 2.5% EC + Imazethapyr 3.7% SL@ (50 + 75) g a.i. ha^{-1}
T_9: Hand weeding at 15 and 30 DAS
T_{10}: Weed free
T_{11}: Weedy check

BLWs- Broad leaved weeds, DAS-Days after sowing.

Table 2: Category wise weed dry weight (g m^{-2}) at 50 and 70 DAS in blackgram as influenced by different post emergent herbicides

Treatments	50 DAS				70 DAS			
	Sedge^{+}	Grasses$^{\#}$	BLWs^{+}	Total$^{\#}$	Sedge^{+}	Grasses$^{\#}$	BLWs^{+}	Total$^{\#}$
T_1	2.11 (3.47)	1.33 (19.80)	2.74 (6.57)	1.50 (29.84)	1.29 (0.72)	1.40 (23.20)	3.73 (12.97)	1.58 (36.89)
T_2	1.14 (0.33)	0.93 (6.60)	5.05 (24.57)	1.52 (31.50)	1.11 (0.27)	1.07 (10.00)	5.14 (25.50)	1.57 (35.77)
T_3	1.80 (2.27)	1.39 (23.03)	4.79 (22.00)	1.69 (47.30)	1.87 (2.50)	1.44 (25.80)	5.21 (26.17)	1.75 (54.47)
T_4	1.11 (0.25)	1.32 (18.97)	3.83 (13.87)	1.54 (33.08)	1.46 (1.18)	1.38 (22.37)	4.41 (18.50)	1.64 (42.05)
T_5	1.30 (0.73)	1.22 (14.73)	3.68 (12.57)	1.47 (28.03)	1.24 (0.57)	1.30 (18.13)	4.47 (18.97)	1.59 (37.67)
T_6	1.20 (0.53)	0.95 (7.03)	3.17 (9.07)	1.27 (16.63)	1.00 (0.00)	1.09 (10.43)	4.06 (15.47)	1.44 (25.90)
T_7	1.57 (1.52)	1.11 (11.07)	3.72 (12.87)	1.43 (25.45)	1.40 (1.07)	1.21 (14.47)	4.50 (19.27)	1.56 (34.80)
T_8	1.86 (2.47)	1.39 (22.93)	4.10 (15.87)	1.63 (41.27)	1.55 (1.43)	1.40 (23.23)	4.66 (20.80)	1.67 (45.47)
T_9	1.14 (0.33)	0.93 (6.63)	2.51 (5.40)	1.15 (12.37)	1.08 (0.17)	0.95 (6.93)	3.57 (11.80)	1.32 (18.91)
T_{10}	1.00 (0.00)	0.30 (0.00)	1.00 (0.00)	0.30 (0.00)	1.00 (0.00)	0.30 (0.00)	1.00 (0.00)	0.30 (0.00)
T_{11}	1.99 (3.07)	1.66 (44.67)	5.28 (27.07)	1.88 (74.80)	2.10 (3.47)	1.69 (48.07)	5.86 (33.47)	1.93 (85.00)
S.Em±	0.16	0.07	0.22	0.11	0.13	0.12	0.17	0.04
CD (p = 0.05)	0.48	0.20	0.65	0.33	0.39	0.37	0.53	0.13

Data within parentheses are original values; # - data analyzed using log (x+2) transformation, + - square root (x+1) transformation

T_1: Fomesafen 25% SL @ 250 g a.i. ha^{-1}
T_2: Propaquizafop 10% EC @ 100 g a.i. ha^{-1}
T_3: Imazethapyr 10% SL @ 100 g a.i. ha^{-1}
T_4: Fomesafen 18.8% SL+ Propaquizafop 5.83% EC @ (168+52) g a.i. ha^{-1}
T_5: Fomesafen 18.8% SL+ Propaquizafop 5.83% EC @ (210+65) g a.i. ha^{-1}
T_6: Fomesafen 18.8% SL+ Propaquizafop 5.83% EC @ (252+78) g a.i. ha^{-1}
T_7: Fomesafen 18.8% SL+ Propaquizafop 5.83% EC @ (294+91) g a.i. ha^{-1}
T_8: Propaquizafop 2.5% EC + Imazethapyr 3.7% SL@ (50 + 75) g a.i. ha^{-1}
T_9: Hand weeding at 15 and 30 DAS
T_{10}: Weed free
T_{11}: Weedy check

BLWs- Broad leaved weeds, DAS-Days after sowing.

Table 3: Weed control efficiency (%) at different stages in blackgram as influenced by different post emergent herbicides

Treatments	25 DAS	50 DAS	70 DAS	At harvest
T_1: Fomesafen 25% SL @ 250 g a.i. ha^{-1}	68.3	60.1	56.6	47.7
T_2: Propaquizafop 10% EC @ 100 g a.i. ha^{-1}	74.5	57.9	57.9	55.3
T_3: Imazethapyr 10% SL @ 100 g a.i. ha^{-1}	61.7	36.8	35.9	37.0
T_4: Fomesafen 18.8% SL+ Propaquizafop 5.83% EC @ (168+52) g a.i. ha^{-1}	75.1	55.8	50.5	48.6
T_5: Fomesafen 18.8% SL+ Propaquizafop 5.83% EC @ (210+65) g a.i. ha^{-1}	89.7	62.5	55.7	50.9
T_6: Fomesafen 18.8% SL+ Propaquizafop 5.83% EC @ (252+78) g a.i. ha^{-1}	91.1	77.8	69.5	60.7
T_7: Fomesafen 18.8% SL+ Propaquizafop 5.83% EC @ (294+91) g a.i. ha^{-1}	88.8	66.0	59.1	53.3
T_8: Propaquizafop 2.5% EC + Imazethapyr 3.7% SL@ (50 + 75) g a.i. ha^{-1}	78.0	44.82	46.1	49.4
T_9: Hand weeding at 15 and 30 DAS	92.3	83.5	77.8	70.6
T_{10}: Weed free Check	100.0	100.0	100.0	100.0
T_{11}: Weedy Check	0.0	0.0	0.0	0.0

Table 4: Effect of post emergent herbicides on seed yield, harvest index and weed index of blackgram

Treatments	Seed yield (kg ha^{-1})	Harvest index	Weed index (%)
T_1: Fomesafen 25% SL @ 250 g a.i. ha^{-1}	770	0.207	46.42
T_2: Propaquizafop 10% EC @ 100 g a.i. ha^{-1}	804	0.217	44.05
T_3: Imazethapyr 10% SL @ 100 g a.i. ha^{-1}	752	0.208	47.67
T_4: Fomesafen 18.8% SL+ Propaquizafop 5.83% EC @ (168+52) g a.i. ha^{-1}	948	0.241	34.03
T_5: Fomesafen 18.8% SL+ Propaquizafop 5.83% EC @ (210+65) g a.i. ha^{-1}	1248	0.245	13.15
T_6: Fomesafen 18.8% SL+ Propaquizafop 5.83% EC @ (252+78) g a.i. ha^{-1}	1290	0.246	10.23
T_7: Fomesafen 18.8% SL+ Propaquizafop 5.83% EC @ (294+91) g a.i. ha^{-1}	988	0.229	31.20
T_8: Propaquizafop 2.5% EC + Imazethapyr 3.7% SL@ (50 + 75) g a.i. ha^{-1}	1005	0.214	30.06
T_9: Hand weeding at 15 and 30 DAS	1348	0.246	6.19
T_{10}: Weed free Check	1437	0.254	0.00
T_{11}: Weedy Check	456	0.144	68.27
S.Em±	64.7	0.006	NA
CD (p = 0.05)	194.3	NS	NA

NS-Non significant, NA-Not analyzed

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