Indian Journal of Weed Science **53**(3): 300–304, 2021

Print ISSN 0253-8040 Online ISSN 0974-8164

Effect of different post-emergence herbicides on weeds, crop yield and economics of greengram grown in rainy season

Narayani Priyadarshini Panda*, K.N. Kalyana Murthy, Madam Vikramarjun[1] and Kommireddy Poojitha

College of Agriculture, UAS, GKVK, Bangalore, Karnataka 560 065, India

[1]*ICAR-Indian Agricultural Research Institute, New Delhi 110012, India*

Email: narayanipanda.agron@gmail.com

Article information

DOI: 10.5958/0974-8164.2021.00055.1

Type of article: Research note

Received : 5 May 2021
Revised : 26 September 2021
Accepted : 28 September 2021

January February

KEYWORDS

Fomesafen
Greengram
Hand weeding
Herbicides
Imazethapyr
Propaquizafop
Weed management

ABSTRACT

A field experiment was conducted at field unit of AICRP on Agro-forestry, University of Agricultural Sciences, GKVK, Bengaluru during *Kharif* (rainy season) 2018 to study the effect of different post-emergence herbicides on weeds, crop yield and economics of *Kharif* greengram. Eleven treatments including the application of three post-emergence herbicides (fomesafen, propaquizafop and imazethapyr) and their combinations at 25 days after seeding (DAS), hand weeding (HW) twice at 15 and 30 DAS, weed free check and un-weeded control were replicated thrice in randomized complete block design. The post-emergence application (PoE) of fomesafen + propaquizafop 294 + 91 g/ha and fomesafen + propaquizafop 252 + 78 g/ha resulted in significantly lower weed biomass at 45 DAS (11.65 and 12.78 g/m^2, respectively) and at harvest (15.59 and 18.69 g/m^2, respectively) due to reduced weed density at 45 DAS (21.5 and 23.4 no./m^2, respectively) and at harvest (15.90 and 18.01 no./m^2, respectively). These treatments have recorded higher weed control efficiency and lower weed index (71.6%, 6.21% and 69.09%, 10.73%, respectively). Among the various herbicide treatments, significantly, highest greengram seed yield (1058 kg/ha) was recorded with post-emergence application of fomesafen + propaquizafop 294 + 91 g/ha.

Greengram is second most important pulse crop in India after pigeon pea in the acreage. Weed infestation is one of the major biotic factor which is limiting growth and productivity of greengram crop. Yield reduction in greengram ranges from 35% (Raman and Krishnamoorthy 2005) to 80 % (Talnikar *et al.* 2008) depending on the type and weed flora associated with the crop. Critical period of crop weed competition for *Kharif* (rainy season) greengram crop is 20-40 DAS (Sheoran *et al*. 2008). In greengram, weed problem can be successfully managed by utilizing mechanical practices like hand weeding and inter-cultivation. But in the present scenario, timely availability of labour is a major constraint and continuous rainfall during the rainy season obstructs timely manual operations. Mechanical method being expensive, tedious and thus making farmers choose chemical weed control. Pendimethalin is the most widely used pre-emergence herbicide. Its effectiveness for late emerging weeds in *Kharif* greengram is less due to frequent rains of south- west monsoon. Moreover, the late emerged weeds pose severe competition to the crop and infest the land with weed seeds making it less productive in the successive seasons. Hence, post-emergence herbicide application (PoE) is alternative for effective weed control and increasing the growth and productivity of greengram. Herbicides like fomesafen and propaquizafop are characterized by broad spectrum weed control with an environmental benefit derived from their low application rates in the field (Tiwari and Mathew 2002).

A field experiment was conducted during *Kharif* 2018 to study the effect of different post-emergent herbicides on weed dynamics of *Kharif* greengram at field unit of AICRP on Agro-forestry, University of Agricultural Sciences, GKVK, Bengaluru. Eleven treatments including the application of three post-emergence herbicides and their combinations (fomesafen, propaquizafop and imazethapyr) at 25 days after seeding (DAS), hand weeding (HW) twice at 15 and 30 DAS, weed free check and unweeded control. A randomized complete block design with three replications was used. The soils of experimental site belongs to ferric luvisols. The soil was red sandy loam with slightly acidic in reaction (pH 6.2) with medium electrical conductivity (0.34 dS/m) and medium organic carbon content (0.55%). Greengram variety *'KKM-3'* was sown at a spacing of 30 x 10 cm and the recommended dose of fertilizer *i.e.*, 25:50:25 kg of N, P and K was applied at the time of sowing. All the post-emergence herbicides were applied using high volume spray to the weeds as per the treatment at 25 DAS.

Number of weeds (grasses, broad-leaved, sedges) per 1 m^2 in net plot was recorded at 45 DAS and at harvest. Weeds cut up to ground level and were oven dried for 48 hrs at 60 ^{0}C until obtaining a constant weight and total dry weight of the weeds (biomass) were recorded at 45 DAS and at harvest.

Weed control efficiency shows how effectively the treatment controlled the weeds. The weed control efficiency of treatments was worked out using the formula given by Mani *et al.* (1973).

$$\text{Weed control efficiency} = \frac{X - Y}{X} \times 100$$

Where,

X = weed biomass in unweeded check plot

Y = weed biomass in the treated plot

Weed index indicates to what extent yield is reduced with respect to crop weed competition and for different treatments it was worked out by using the formula stated by Gill and Kumar (1969).

$$\text{Weed index} = \frac{X - Y}{X} \times 100$$

Where,

X = Yield from weed free plot

Y = Yield from treated plot

First the border plants were harvested and separated. Later, the crop from each net plot was harvested and sun dried for 3 days, bundled, tagged, weighed and transported to threshing floor. Threshing was done for each plot and yield was computed to kg/ha basis. The value of return on investment was calculated by converting increased seed yield over the weed control into monetary equivalent with market prices and cost involved for weed control operations.

The collected weed data on different traits was statically analyzed using the standard procedure and the results were tested at five per cent level of significance as given by Gomez and Gomez (1984).

Effect on weeds

Major weed species observed in the experimental field were *Borreria articularis, Alternanthera sessilis, Euphorbia geniculata, Acanthospermum hispidum, Parthenium hysterophorus, Amaranthus viridis* among broad leaved weeds, *Eleusine indica, Dactyloctenium aegyptium* and *Echinochloa colona* among the grassy weeds and *Cyperus rotundus* among sedges (**Table 1**).

The density and biomass of sedge, grasses and broad-leaf weeds differed significantly with tested weed management treatments. All the weed management treatments had significantly lower weed density and biomass than unweeded check at different stages of crop growth. The magnitude of reduction in weed biomass and density varied depending upon the weed control efficiency of the herbicide treatments.

Among the herbicide treatments, the density and biomass of sedges and grasses was observed to be the lowest with application of propaquizafop when compared to fomesafen and imazethapyr (**Table 2**

Table 1. The density (no./m^2) of dominant grasses, sedge and broad-leaved weeds and total weed density at 45 DAS in greengram as influenced by treatments tested

Treatment	Sedge	Grasses				Broad-leaved weeds							Total weed density
	Cr	Ei	Da	Ec	Total	Ba	As	Eg	Ah	P	Av	Total	
Fomesafen 250 g/ha	5.6	9.0	6.0	3.3	18.4	7.3	1.8	1.7	2.3	1.2	2.3	16.5	40.4
Propaquizafop 100 g/ha	3.9	2.5	2.7	0.8	6.0	14.9	2.1	3.5	3.5	1.8	2.3	28.3	38.1
Imazethapyr 100 g/ha	3.8	4.5	3.2	2.0	9.6	20.3	1.5	1.3	2.7	1.3	1.2	28.3	41.7
Fomesafen + propaquizafop 168 + 52 g/ha	3.1	3.9	2.1	1.3	7.3	11.8	0.9	2.4	2.3	0.4	3.1	20.9	31.3
Fomesafen + propaquizafop 210 + 65 g/ha	2.2	4.0	1.1	2.0	7.0	8.7	1.7	1.8	1.0	1.1	1.4	15.7	24.9
Fomesafen + propaquizafop 252 + 78 g/ha	2.2	3.6	1.3	1.7	6.6	6.8	1.3	1.5	1.7	2.0	1.2	14.6	23.4
Fomesafen + propaquizafop 294 + 91 g/ha	2.5	3.2	1.2	0.5	5.0	5.3	2.1	2.3	1.1	1.5	1.7	14.1	21.5
Propaquizafop + imazethapyr 50 + 75 g/ha	2.6	2.4	3.3	1.2	7.0	13.7	2.6	2.5	1.3	1.2	2.2	23.6	33.1
Hand weeding twice at 15 and 30 days after seeding	1.9	1.1	1.0	1.0	3.1	0.9	0.4	1.3	0.6	1.2	0.2	4.7	9.7
Weed free check	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Unweeded check	7.5	12.5	5.1	2.8	20.4	28.6	7.4	2.5	3.7	3.7	1.9	47.8	75.7

Cr- *Cyperusrotundus,* Ei- *Eleusine indica,* Da- *Dactylocteniumaegyptium,* Ec- *Echinochloacolona,* Ba- *Borreriaarticularis,* As- *Alternanthera sessilis,* Eg- *Euphorbia geniculate,* Ah- *Acanthospermumhispidum,* P- *Parthenium hysterophorus,* Av- *Amaranthus viridis* and **3**). At 45 DAS and at harvest, significantly lower density and biomass of grasses and sedges were recorded with post-emergence application of fomesafen + propaquizafop 294 + 91 g/ha, fomesafen + propaquizafop 252 + 78 g/ha and propaquizafop 100 g/ha compared to the unweeded check. Similar observations were made in soybean by Kumar *et al.* (2018) and Bhimwal *et al.* (2018).

Density and biomass of broad-leaved weeds was observed to be the lowest with the application of fomesafen when compared to propaquizafop and imazethapyr. At 45 DAS and at harvest significantly lower density and biomass of broad-leaved weeds were recorded with post-emergence application of fomesafen + propaquizafop 294 + 91 g/ha, fomesafen + propaquizafop 252 + 78 g/ha and fomesafen 250 g/ha as compared to the unweeded check and were statistically on par with hand weeding at 15 and 30 DAS. Similar observation was also reported in common bean (Santos 2006) and in tomato (Mohsen and Doohan 2017).

Post-emergence application of fomesafen + propaquizafop 294 + 91 g/ha and fomesafen + propaquizafop 252 + 78 g/ha resulted in significantly lower total weed biomass at 45 DAS (11.65 and 12.78 g/m^2, respectively) and at harvest (15.59 and 18.69 g/m^2, respectively) due to reduced total weed density at 45 DAS (21.5 and 23.4 no./m^2, respectively) and at harvest (15.90 and 18.01 no./m^2, respectively). This is due to control of broad-spectrum weeds as a result of different mode of action of herbicides *i.e.*, fomesafen which inhibited the protoporphyrinogen oxidase (PROTOX) enzyme was effective in controlling the dicot weeds and propaquizafop, which inhibits fatty acid synthesis (ACCase) was effective in killing the monocot weeds (Tiwari and Mathew, 2002). Hence, combined application of fomesafen + propaquizafop was more effective for weed control in greengram as compared to application of fomesafen or propaquizafop alone. Whereas, application of fomesafen alone controlled only the broad-leaved weeds and application of propaquizafop alone controlled only the grassy weeds. Combination

Table 2. Weed density and biomass at 45 days after seeding (DAS) in greengram as influenced by weed management treatments

Treatment	Weed density (no./m^2)				Weed biomass (g/ m^2)			
	BLW	Grasses	Sedges	Total	BLW	Grasses	Sedges	Total
Fomesafen 250 g/ha	4.18(16.5)	4.40 (18.4)	2.56(5.6)	6.44 (40.4)	3.52(11.39)	4.44(18.71)	1.15(0.32)	5.61(30.42)
Propaquizafop 100 g/ha	5.41(28.3)	2.64(6.0)	2.21(3.9)	6.25 (38.1)	4.62(20.86)	2.07(3.28)	1.07(0.15)	5.02(24.29)
Imazethapyr 100 g/ha	5.41(28.3)	3.26(9.6)	2.17(3.8)	6.53 (41.7)	4.88(22.61)	2.38(4.77)	1.31(0.29)	5.35(28.67)
Fomesafen + propaquizafop 168 + 52 g/ha	4.67(20.9)	2.87(7.3)	2.36(3.1)	5.68 (31.3)	4.40(18.38)	2.19(3.82)	1.19(0.42)	4.85(22.56)
Fomesafen + propaquizafop 210 + 65 g/ha	4.07(15.7)	2.83(7.0)	1.79(2.2)	5.09(24.9)	3.97(14.62)	2.41(4.85)	1.16(0.34)	4.56(19.81)
Fomesafen + propaquizafop 252 + 78 g/ha	3.95(14.6)	2.76(6.6)	1.78(2.2)	4.83 (23.4)	3.41(10.35)	1.77(2.13)	1.13(0.29)	3.71(12.78)
Fomesafen + propaquizafop 294 + 91 g/ha	3.88(14.1)	2.38(5.0)	1.86(2.5)	4.74 (21.5)	3.28(9.46)	1.76(2.09)	1.05(0.10)	3.56(11.65)
Propaquizafop + imazethapyr 50 + 75 g/ha	4.96(23.6)	2.82(7.0)	2.22(2.6)	5.84(33.1)	4.43(18.05)	2.11(3.45)	1.21(0.47)	4.79(21.97)
Hand weeding twice at 15 and 30 DAS	2.38(4.7)	2.03(3.1)	1.69(1.9)	3.27(9.7)	2.60(5.43)	1.42(1.07)	1.02(0.06)	2.79(7.09)
Weed free check	1.00(0.0)	1.00(0.0)	1.00(0.0)	1.00(0.0)	1.00(0.00)	1.00(0.00)	1.00(0.00)	1.00(0.00)
Unweeded check	6.99(47.8)	4.62(20.4)	2.92(7.5)	8.76(75.7)	6.13(37.21)	2.79(6.71)	1.24(0.56)	6.74(44.48)
LSD (p=0.05)	0.35	0.75	0.51	1.72	0.94	0.65	0.12	1.11

Data within parentheses are original values; DAS: Days after seeding

Table 3. Weed density and biomass at harvest in greengram as influenced by weed management treatments

Treatment	Weed density (no./m^2)				Weed biomass (g/ m^2)			
	BLW	Grasses	Sedges	Total	BLW	Grasses	Sedges	Total
Fomesafen 250 g/ha	3.90 (14.22)	3.84 (13.78)	2.08 (3.36)	5.69 (31.36)	4.60 (20.22)	3.97(14.76)	1.89(2.57)	6.20(37.55)
Propaquizafop 100 g/ha	5.98 (34.78)	2.39 (4.69)	1.66 (1.77)	6. 50 (41.25)	3.95 (14.60)	2.18(3.75)	1.71(1.89)	4.6 (20.24)
Imazethapyr 100 g/ha	5.32 (27.35)	2.96 (7.76)	1.76 (2.12)	6.18 (37.22)	5.39 (28.08)	2.84(7.34)	1.78(2.17)	6.21 (37.59)
Fomesafen + propaquizafop 168 + 52 g/ha	4.50 (19.29)	2.54 (5.46)	1.71 (1.94)	5.26 (26.69)	4.67 (20.88)	2.91 (7.46)	1.59(1.57)	5.56 (29.91)
Fomesafen + propaquizafop 210 + 65 g/ha	3.97 (14.80)	2.46 (5.06)	1.70 (1.88)	4.77 (21.73)	4.14 (16.15)	2.19(3.98)	1.57(1.47)	4.75 (21.6)
Fomesafen + propaquizafop 252 + 78 g/ha	3.64 (12.29)	2.33 (4.44)	1.51 (1.28)	4.36 (18.01)	3.90 (14.20)	2.07(3.31)	1.47(1.18)	4.43 (18.69)
Fomesafen + propaquizafop 294 + 91 g/ha	3.52 (11.39)	2.15 (3.63)	1.39 (0.98)	4.11 (15.90)	3.68 (12.58)	1.91(2.75)	1.12(0.26)	4.07 (15.59)
Propaquizafop + imazethapyr 50 + 75 g/ha	4.68 (20.96)	2.34 (4.47)	1.73 (2.07)	5.34 (27.50)	4.91 (23.10)	2.17(3.76)	1.35(0.82)	5.35 (27.68)
Hand weeding twice at 15 and 30 DAS	2.97 (7.80)	2.04 (3.18)	1.33 (0.87)	3.60 (11.95)	3.05 (8.31)	1.57(1.58)	1.35(0.83)	3.42 (10.72)
Weed free check	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00(0.00)	1.00(0.00)	1.00 (0.00)
Unweeded check	7.32 (52.78)	4.45 (18.82)	3.02 (8.31)	8.99 (79.9)	7.59 (56.59)	3.12(8.94)	2.62(5.89)	8.51 (71.42)
LSD (p=0.05)	0.95	0.4	0.35	0.85	0.9	0.56	0.12	1.08

Data within parentheses are original values; DAS: Days after sowing of these both herbicides have longer effect on controlling weeds and brought significant reduction in weed biomass as compared to weedy check as also observed in field pea (Singh *et al.* 2014) and soybean (Kadam *et al.* 2018).

The unweeded check recorded the highest weed biomass at 45 DAS (44.48 g/m^2) and at harvest (71.42 g/m^2) as a result of higher weed density of 75.4 and 79.9 no./m^2, respectively. This could be attributed to higher density and biomass of grasses, sedges and broad-leaved weeds.

Among the treatments tested, weed free check recorded complete control of weeds with weed control efficiency of 100 per cent at all the stages when compared to all other treatments (**Table 4**). The crop yield is directly proportional to weed control efficiency (WCE) and inversely related to weed index (WI). At harvest, higher weed control efficiency was observed in hand weeding twice at 15 and 30 DAS (87.19%) followed by post-emergent application of fomesafen + propaquizafop 294 + 91 g/ha (71.60%) and fomesafen + propaquizafop 252 + 78 g/ha (69.09%) due to reduction in the weed biomass as a result of effective weed management in these treatments.

Effect on greengram

The new herbicide molecules like fomesafen and propaquizafop did not cause any phytotoxic symptoms on greengram. In the present study, significant differences were noticed in yield of greengram as a consequence of weed control treatments involving post-emergence application of herbicides. All the herbicide treatments resulted in significantly higher seed yield compared to the unweeded check. Significantly, higher seed yield was recorded with post-emergence application of fomesafen + propaquizafop 294 + 91 g/ha (1058 kg/ha) and fomesafen + propaquizafop 252 + 78 g/ha (1007 kg/ha) and were statistically on par with hand weeding at 15 and 30 DAS (1094 kg/ha) (**Table 4**). The reduction in yield of unweeded check was mainly attributed to the reduction in the leaf area, which is an important factor that determines the photosynthetic ability, growth and dry matter production (Algotar *et al.* 2014, Mamatha *et al.* 2017).

Weed index, an indicator of yield reduction due to weed competition, was higher in unweeded control (64.6%). The lower weed index was noticed in hand weeding twice at 15 and 30 DAS (3.01%) followed by post- emergence application of fomesafen + propaquizafop 294 + 91 g/ha (6.21%) and fomesafen + propaquizafop 252 + 78 g/ha (10.73%) due to satisfactory control of weeds and reduction in the crop weed competition which enabled the crop to utilize available resources like light, nutrients, moisture and space resulting in higher yield (Gupta *et al.* 2013 and Kewat *et al.* 2014).

Return on investment on weed control

By manual hand weeding operations, yield loss can be minimized in the crop but it’s costly due to increased labour wages. The manual weeding method of weed management generated, on an average, 4 rupees returns over single rupee investment. While post-emergence herbicides use resulted in 22.5 rupees return over single rupee investment, on an average. Post-emergence application of fomesafen + propaquizafop 294 + 91 g/ha recoded highest greengram seed yield. However, the application of fomesafen + propaquizafop 168 +52 g/ha recorded higher return on investment of 34 rupees.

Table 4. Weed control efficiency and weed index at harvest in greengram as influenced by weed management treatments

Treatment	Seed yield (kg/ha)	Weed control efficiency (%)	Weed index (%)	Return on investment
Fomesafen 250 g/ha	728	46.63	35.46	11.4
Propaquizafop 100 g/ha	717	49.67	36.44	14.6
Imazethapyr 100 g/ha	681	44.91	39.63	21.6
Fomesafen + propaquizafop 168 + 52 g/ha	937	58.65	16.93	34.0
Fomesafen + propaquizafop 210 + 65 g/ha	959	67.11	14.98	28.3
Fomesafen + propaquizafop 252 + 78 g/ha	1007	69.09	10.73	25.6
Fomesafen + propaquizafop 294 + 91 g/ha	1058	71.60	6.21	23.8
Propaquizafop + imazethapyr 50 + 75 g/ha	844	56.27	25.18	20.6
Hand weeding twice at 15 and 30 DAS	1094	87.19	3.01	4.8
Weed free check	1128	100.00	0.00	4.2
Unweeded check	402	0.00	64.36	-
LSD (p=0.05)	72.00	-	-	-

Inputs cost (Rs./kg): seeds (KKM-3)= 120.00; FYM = 0.50; Urea = 5.62; MOP = 7.8; Fomesafen = 2000; Fomesafen + Propaquizafop = 1230; Propaquizafop + imazethapyr = 750; Carbendazim = 325.00; Carbandizim = 325; Output: greengram (Rs./Kg.) = 69.75

Conclusion

Post-emergence application of fomesafen + propaquizafop 294 + 91 g/ha recoded significantly lower weed density and biomass, higher weed control efficiency and highest greengram yield due to its efficacy in controlling broad spectrum of weeds with no crop phytotoxicity. Hence, it can be used for managing weeds and increasing greengram yield of *Kharif* greengram under current labour constraint conditions.

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