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Pre- and post-emergence herbicides effect on growth, nodulation and productivity of greengram

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ABSTRACT

A field experiment was conducted during *Kharif* season to study the efficacy of different pre- and post-emergence herbicides for weed management in greengram. Pre-emergence (PE) application of pendimethalin + imazethapyr at 0.75 kg/ha (pre-mix) effectively reduced both the density and dry matter of weeds whereas post-emergence (PoE) application of imazethapyr 10 SL at 55 g/ha significantly reduced *Cyperus rotundus*. All the PE and PoE herbicides significantly reduced the dry weight of weeds at 30 and 60 days after sowing (DAS) as compared to weedy check. The highest weed control efficiency was recorded in two hand weeding (90.2%), and was followed by pendimethalin + imazethapyr (pre-mix) 0.75 kg/ha applied as PE (86.8%). PoE herbicides (imazethapyr, imazamox+ imazethapyr and clodinafop-propargyl + aciflourfen-sodium) not only suppressed the crop growth, but also exhibited antagonistic effect on root nodulation. Significantly higher seed yields were recorded under two hand weeding and pendimethalin + imazethapyr at 0.75 kg/ha (PE). Two hand weeding also recorded the highest gross and net returns, and was followed by pendimethalin + imazethapyr (pre-mix) at 0.75 kg/ha (PE). Application of pendimethalin + imazethapyr at 0.75 kg/ha (PE) also gave the highest B:C ratio, and it was followed by two hand weeding. All the PoE herbicides fetched comparatively lower returns and B:C ratio.

INTRODUCTION

Greengram [*Vigna radiata* (L.) Wilczek] is an important pulse crop grown during both summer and *Kharif* (rainy) seasons in India. It occupied an area of 4.24 million hectares with a production of 2.03 million tonnes and productivity of 477 kg/ha in India during 2017-18 (Indiastat 2019). Weeds pose a serious threat to the productivity of greengram due to greater competition for nutrients, water, space and sunlight. Yield loss in greengram due to such competition may occur to the tune of 60-80% (Nandan *et al.* 2011, Kumar *et al.* 2017). Since weed infestation becomes more during rainy season, the rainy season crop gets infested with a large number of fast growing weeds. The critical period of weed competition in greengram is during first 30 days of sowing. Being a short duration crop, care should be taken on proper weed management to improve the productivity of greengram.

Pre-emergence herbicides like pendimethalin effectively control the grassy and broad-leaf weeds during early phase of crop growth. Post-emergence (PoE) application of imazethapyr has also been reported to provide effective weed control in greengram (Singh *et al.* 2014a, Singh *et al.* 2017). Combinations of PE and PoE herbicides or certain ready-mix formulations are commercially available which may be helpful to manage complex weed flora and reduce crop-weed competition.

Considering these facts in view, the present study was conducted to evaluate the effect of different PE and PoE herbicides on symbiosis, growth, phytotoxicity and productivity in greengram.

MATERIALS AND METHODS

A field experiment was conducted at Research Farm of Punjab Agricultural University, Ludhiana (30°54' N latitude, 75°48' E longitude and 247 m altitude), Punjab during *Kharif* 2016 and 2017 in a randomized complete block design with three replications. The soil of the experimental site was loamy sand, having pH 7.2, organic carbon 0.36%, available P 34.2 kg/ha and available K 195 kg/ha. A total of 217.5 mm (14 rainy days) and 219.4 mm (11

rainy days) rainfall was received during the crop season in 2016 and 2017, respectively. There were nine treatments (**Table 1**), including post-emergence (PoE) herbicides *viz.* imazethapyr 10 SL, imazamox 35 WG + imazethapyr 35 WG (pre-mix) and clodinafop propargyl 8% + aciflourfen sodium 16% (pre-mix) applied at 15-20 days after sowing (DAS); pre-emergence herbicides, *viz.* pendimethalin 30 EC and pendimethalin 30 EC + imazethapyr 2 EC (pre-mix) applied within 24 hours of sowing; two hand weeding (20 and 40 DAS); and weedy check. Herbicides were applied with knapsack sprayer fitted with flat fan nozzle using 500 L of water/ha. In case of hand weeding treatment, weeds were removed manually with the use of a *'Khurpa'* (hand spade). In weedy check plots, weeds were allowed to grow throughout the crop growing season.

After pre-sowing irrigation, the field was prepared at an optimum soil moisture and ploughed twice followed by planking. The varieties taken for the study were '*ML 818*' and '*ML 2056*' during 2016 and 2017, respectively. The crop was sown on 18 July, 2016 and 21 July, 2017 in rows of 30 cm apart using a seed rate of 20 kg/ha in the individual plot size of 7.0 × 4.5 m. The crop was harvested in first week of October during both the years.

Data on weed species count were recorded at 30 and 60 DAS from a randomly selected area, measuring 50 × 50 cm from each plot, and then converted as weed density in terms of no./m^2. After counting, all the weeds were oven-dried for taking dry weight of weeds (g/m^2) at 30 and 60 DAS. At harvest, weeds from the whole plot were harvested, dried and weighed (kg/ha). Weed control efficiency (WCE) was recorded at harvest and calculated by using the following formula:

$$\text{WCE (\%)} = \frac{X - Y}{X} \times 100$$

[Where, WCE= Weed control efficiency (%), X= Dry weight of weeds (kg/ha) in weedy check and Y= Dry weight of weeds (kg/ha) in treated plot]

Data on nodulation parameters, *viz.* number and dry weight of nodules were recorded at 40 DAS. Five plants in each plot were randomly selected to record the total number and dry weight of nodules, and the values were averaged to work out nodule number and dry weight/plant. Data on plant height, number of branches/plant and number of pods/plant were recorded at maturity from five plants selected randomly from each plot, and number of seeds/pod from randomly selected 20 pods. Biological yield and seed yield were recorded on the basis of whole plot area and expressed in t/ha. Harvest index (HI) was also calculated. The weight of 100 seeds was recorded from the economic produce of each plot. Gross return, net return as well as benefit:cost (B:C) ratio were worked out using prevailing prices of inputs and output. Two-year pooled data were subjected to analysis of variance (ANOVA) in a randomized complete block design as per standard procedure.

RESULTS AND DISCUSSION

Effect on weed parameters

The major weed flora at the experimental site (**Table 1**) comprised of *Cyperus rotundus* (purple nutsedge), *Eleucine aegyptiacum* (crow foot grass) and *Commelina benghalensis* (day flower). Of these, *C. rotundus* was the most dominant weed, followed by *E. aegyptiacum* and *C. benghalensis.* The highest weed density was recorded in weedy check at 30 and 60 DAS (**Table 1**). Application of pendimethalin 750 g/ha (PE) did not control *Cyperus rotundus*, which was, however, effectively controlled by either the PE application of pendimethalin + imazethapyr (pre-mix) 750 g/ha or the PoE application of imazethapyr 55 g/ha. Density of *Eleucine aegyptiacum* and *Commelina benghalensis* was increased at 60 DAS in comparison to 30 DAS, whereas that of *Cyperus rotundus* was reduced.

Two rounds of hand weeding recorded the lowest dry weight of weeds, and it was followed by pre-mix application of pendimethalin + imazethapyr at 750 g/ha as PE (**Table 1**). All the PE and PoE herbicides significantly reduced the dry weight of weeds at 30 and 60 DAS as compared to weedy check. There were reports on effective weed management with the PoE application of imazethapyr in soybean (Gare *et al.* 2016) and blackgram (Aggarwal *et al.* 2014). Reduction of weed dry weight with the application of pendimethalin was reported by several researchers (Singh 2011, Singh *et al.* 2017, Virk *et al.* 2018). Application of imazethapyr as PoE was reported to provide effective weed control in greengram (Singh *et al.* 2014a, Singh *et al.* 2015, Kumar *et al.* 2016), blackgram (Aggarwal *et al.* 2014) and lentil (Singh *et al.* 2014b).

Dry weight of weeds and weed control efficiency at harvest were significantly affected by different weed control treatments (**Table 2**). Weedy check recorded the highest dry weight of weeds, whereas it was the lowest under two rounds of hand weeding. Among the chemical treatments, pendimethalin + imazethapyr (pre-mix) at 750 g/ha

recorded the lowest dry weight of weeds at harvest. The highest WCE was recorded with two hand weeding (90.2%), followed by pendimethalin + imazethapyr (pre-mix) as PE at 750 g/ha (86.8%). All the PoE herbicides recorded low WCE due to more occurrence of rainfall during early phase of crop growth which might have resulted in more flushes of weeds.

Effect on nodulation parameters

Number and dry weight of root nodules/plant at 40 DAS were significantly affected by different weed control treatments (**Table 2**). Two hand weedings recorded the highest number and dry weight of nodules/plant. PoE herbicides recorded lower number of nodules/plant (excepting imazamox + imzathapyr at 40 g/ha) and nodule dry weight/plant (excepting imazethapyr at 55 g/ha) in comparison to the PE herbicides and two hand weedings. Reduction in dry weight of plant might be due to phytotoxic effect of PoE herbicides on crop plants.

Antagonistic effect of PoE herbicides on number and dry weight of nodules/plant might be due to either phytotoxic effect on crop plants or adverse effect on nodule forming rhizobia. Application of imazethapyr at 25, 40 and 75 g/ha showed negative effect on different symbiotic parameters such as nodule number, nodule dry weight and leghaemoglobin content as compared to two hand weeding in greengram (Singh *et al*. 2015). Imazethapyr not only caused a significant reduction of rhizobial growth in a medium amended with it under *in vitro* condition but also showed inhibitory effect on symbiotic interaction in field studies in pigeonpea (Khanna *et al.* 2012). Ahemad and Khan (2010) also reported the negative effect of quizalofop-p-ethyl and clodinafop on the symbiosis in greengram plants, and the effect was more pronounced with the increase in herbicide dose. Application of PoE herbicide imazethapyr + imazamox significantly reduced the nodulation of greengram (Khairnar *et al*. 2014). Similarly, PoE application of imazethapyr (70 and 80 g/ha) or

Table 1. Effect of different weed control treatments on weed parameters in greengram at 30 and 60 DAS (pooled data of two years)

Treatment	30 DAS				60 DAS			
	Weed density (no./m^2)			Dry weight of weeds (g/m^2)	Weed density (no./m^2)			Dry weight of weeds (g/m^2)
	Cyperus rotundus	*Eleucine aegyptiacum*	*Commelina benghalenesis*		*Cyperus rotundus*	*Eleucine aegyptiacum*	*Commelina benghalenesis*	
Pendimethalin 750 g/ha (PE)	6.9 (47)	2.2 (5)	2.8 (7)	82	8.1 (66)	2.6 (7)	2.7 (7)	97
Pendimethalin + imazethapyr 750 g/ha (PE)	3.9 (15)	1.5 (2)	1.0 (0)	19	3.6 (12)	3.0 (9)	1.5 (2)	14
Imazethapyr 55 g/ha (PoE)	4.5 (20)	4.5 (20)	2.5 (6)	115	5.4 (29)	5.0 (25)	2.9 (8)	117
Imazamox + imazethapyr 40 g/ha (PoE)	7.0 (49)	4.8 (23)	2.3 (5)	97	6.4 (40)	4.9 (24)	2.6 (6)	111
Imazamox + imazethapyr 60 g/ha (PoE)	6.0 (36)	5.3 (30)	2.5 (6)	86	4.6 (22)	4.5 (21)	3.4 (11)	93
Clodinafop-propargyl+ aciflourfen-sodium 125 g/ha (PoE)	5.9 (35)	6.1 (37)	2.6 (7)	153	4.3 (18)	5.1 (27)	2.7 (7)	181
Clodinafop-propargyl + aciflourfen-sodium 187.5 g/ha (PoE)	5.5 (30)	5.1 (26)	2.7 (7)	112	4.9 (24)	5.3 (28)	2.4 (5)	129
Two hand weeding	2.8 (8)	2.7 (7)	1.0 (0)	6	3.8 (15)	2.3 (5)	1.2 (1)	10
Weedy check	9.0 (91)	7.9 (63)	3.8 (14)	238	9.5 (92)	6.9 (48)	3.7 (13)	323
LSD (p=0.05)	1.1	0.9	1.2	32	0.8	0.7	0.7	35

Original data on weed density are in parentheses and subjected to square root transformation ($\sqrt{x+0.5}$). PE: Pre-emergence, PoE: Post-emergence

Table 2. Effect of different weed control treatments on weed growth, weed control efficiency at harvest and nodulation parameters at 40 DAS in greengram (pooled data of two years)

Treatment	Weed dry weight (t/ha)	WCE (%)	Nodule no./plant	Nodule dry weight/plant (mg)	Plant dry weight (g)
Pendimethalin 750 g/ha (PE)	2.36	36.5	25.7	26.9	7.2
Pendimethalin + imazethapyr 750 g/ha (PE)	0.93	86.8	26.1	26.8	7.4
Imazethapyr 55 g/ha (PoE)	2.31	37.8	23.1	26.8	5.8
Imazamox + imazethapyr 40 g/ha (PoE)	2.95	16.8	27.9	21.2	6.1
Imazamox + imazethapyr 60 g/ha (PoE)	2.85	20.2	19.8	23.2	5.4
Clodinafop-propargyl + aciflourfen-sodium 125 g/ha (PoE)	2.57	31.9	21.9	24.6	6.0
Clodinafop-propargyl + aciflourfen-sodium 187.5 g/ha (PoE)	2.41	36.5	23.6	24.0	6.0
Two hand weeding	0.36	90.2	28.5	31.4	6.8
Weedy check	3.77	-	16.6	21.4	5.6
LSD (p=0.05)	0.24	6.3	3.6	3.4	1.0

imazethapyr + imazamox as ready-mix (80 g/ha) also posed their negative impact on nodule number and plant dry weight in greengram (Mishra *et al.* 2017).

Effect on crop growth parameters, yield attributes and yield

Different weed control treatments significantly influenced the plant height, branches/plant, pods/ plant and seeds/pod (**Table 3**). Two hand weedings recorded the highest plant height, branches/plant and pods/plant whereas PoE application of imazethapyr (55 g/ha) and imazamox + imazethapyr (40 and 60 g/ ha) recorded significantly lower plant height than the other herbicides. It might be due to some sorts of phytotoxic effect of the herbicides on plant growth. PoE herbicides imazethapyr, imazamox + imazethapyr and clodinafop-propargyl + aciflourfen sodium caused similar reduction in branches/plant as recorded in weedy check plots with intense crop-weed competition. Application of imazethapyr + imazamox reduced the growth attributes of greengram (Khairnar *et al.* 2014).

Two hand weedings recorded the highest number of pods/plant, and it was followed by pendimethalin + imazethapyr (pre-mix) at 750 g/ha. Similarly, number of seeds/pod was the highest under two rounds of hand weeding and pendimethalin + imazethapyr (750 g/ha). The number of pods/plant and seeds/pod were the lowest in weedy check. Higher number of pods/plant and seeds/pod in two hand weeding and pendimethalin + imazethapyr (pre-mix at 750 g/ha) could be due to better weed control (**Table 1**) under these treatments. However, 100-seed weight was not significantly affected by different weed control treatments.

Biological yield and seed yield were significantly affected by different weed control treatments (**Table 4**). Two hand weeding recorded the highest biological yield and seed yield, whereas these were the lowest under weedy check. Among the herbicidal treatments, application of pendimethalin + imazethapyr (pre-mix) at 750 g/ha recorded significantly higher seed yield than the others. Higher seed yield was attributed to the production of more number of pods/plant (**Table 3**), owing to better weed management (**Table 1**) as evidenced from reduced weed dry weight and higher WCE at harvest (**Table 2**). Application of imazamox + imazethapyr at 60 g/ha (PoE) recorded the highest HI, and it was followed by two hand weeding although the said herbicidal combination recorded low seed yield. Khairnar *et al.* (2014) also reported low seed yield of greengram with the use of imazethapyr + imazamox as compared to two hand weeding. All the weed control treatments recorded significantly higher HI than the weedy check.

Better plant growth, higher values of yield attributes and less crop-weed competition might be the reasons behind the higher seed yield of greengram under treatment of pendimethalin + imazethapyr (pre-mix at 750 g/ha). Increase in seed yield due to efficient weed management practices was also reported in greengram (Singh *et al.* 2015), blackgram (Singh *et al.* 2018) and soybean (Virk *et al.* 2018).

Effect on economics

Gross returns, net returns and B:C ratio were significantly affected by different weed control treatments (**Table 4**). Two hand weeding recorded the highest gross returns and net returns, and was followed by application of pendimethalin + imazethapyr (pre-mix) at 750 g/ha. Application of pendimethalin + imazethapyr (pre-mix) at 750 g/ha gave the highest B:C ratio, and was followed by two hand weeding. Two rounds of hand weeding and pendimethalin + imazethapyr at 750 g/ha proved to be more economical due to better B:C ratio as a result of effective weed management. All the PoE herbicides fetched lower gross and net returns as well as B:C ratio as compared to that of hand weeding and

Table 3. Effect of different weed control treatments on plant characters and yield attributes of greengram at harvest (pooled data of two years)

Treatment	Plant height (cm)	Branches/ plant	Pods/ plant	Seeds/ pod	100-seed weight (g)
Pendimethalin 750 g/ha (PE)	66.6	5.2	19.1	11.8	3.21
Pendimethalin + imazethapyr 750 g/ha (PE)	67.5	6.0	21.2	12.2	3.19
Imazethapyr 55 g/ha (PoE)	59.5	4.9	16.4	11.7	3.21
Imazamox + imazethapyr 40 g/ha (PoE)	60.7	4.2	15.3	11.8	3.10
Imazamox + imazethapyr 60 g/ha (PoE)	60.8	4.3	17.8	11.9	3.22
Clodinafop-propargyl+ aciflourfen-sodium 125 g/ha (PoE)	64.6	4.0	13.2	11.4	3.14
Clodinafop-propargyl+ aciflourfen-sodium187.5 g/ha (PoE)	65.6	4.0	12.8	11.6	3.20
Two hand weeding	68.2	6.1	22.1	12.2	3.20
Weedy check	66.1	4.2	9.7	11.2	3.26
LSD (p=0.05)	2.2	0.5	1.3	0.4	NS

Table 4. Effect of different weed control treatments on yield, harvest index and economics of greengram (pooled data of two years)

Treatment	Biological yield (t/ha)			Seed yield (t/ha)			Harvest index (%)	Gross return (x10^3 `/ha)	Net return (x10^3 `/ha)	B:C ratio
	2016	2017	Mean	2016	2017	Mean				
Pendimethalin 750 g/ha (PE)	3.41	3.24	3.33	0.81	0.72	0.77	23.2	42.98	22.10	2.06
Pendimethalin + imazethapyr 750 g/ha (PE)	4.02	5.47	4.75	0.91	1.17	1.04	22.0	58.25	36.12	2.63
Imazethapyr 55 g/ha (PoE)	3.92	3.06	3.49	0.85	0.54	0.70	19.8	39.05	18.68	1.92
Imazamox + imazethapyr 40 g/ha (PoE)	3.24	2.92	3.08	0.76	0.58	0.67	21.8	37.59	16.72	1.80
Imazamox + imazethapyr 60 g/ha (PoE)	3.44	2.94	3.19	0.93	0.65	0.79	24.8	44.50	23.13	2.08
Clodinafop-propargyl+ aciflourfen-sodium 125 g/ha (PoE)	3.23	2.91	3.07	0.65	0.60	0.63	20.5	35.09	14.47	1.70
Clodinafop-propargyl+ aciflourfen-sodium187.5 g/ha (PoE)	3.13	2.88	3.01	0.52	0.61	0.56	18.9	31.56	10.44	1.49
Two hand weeding	4.76	5.74	5.25	1.08	1.22	1.15	22.1	64.37	37.24	2.37
Weedy check	3.06	1.91	2.49	0.48	0.20	0.34	13.3	19.01	-0.11	0.99
LSD (p=0.05)	0.54	0.41	0.33	0.11	0.09	0.07	1.7	4.06	4.06	0.19

pendimethalin + imazethapyr (pre-mix) at 0.75 kg/ha. Lower monetary returns were also earlier reported with imazethapyr + imazamox in greengram (Khairnar *et al*. 2014).

It was concluded that PE application of pendimethalin + imazethapyr (pre-mix) at 750 g/ha can effectively control the major weeds and provide higher net return and B:C ratio in greengram.

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