Indian Journal of Agronomy **60** (4): 622–625 (December 2015)

Research Communicaiton

Efficacy of pre- and post-emergence herbicides with and without weeding in forage cowpea (*Vigna unguiculata*)

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Received : August 2015; Revised accepted : November 2015

ABSTRACT

A field experiment was conducted at Forage Research and Management Centre of the National Dairy Research Institute, Karnal, Haryana during the rainy season (*kharif*) of 2014 on sandy clay loam soils, to find out cost-effective weed-control method in forage cowpea [*Vigna unguiculata* (L.) Walp.]. Application of pendimethalin 1.0 kg/ha as pre-emergence followed by 1 hand-weeding (HW) 40 days after sowing (DAS) resulted in the lowest weed density, weed dry matter and the highest weed control efficiency, herbicide efficiency index and weed-management index and was followed by imazethapyr 0.075 kg/ha followed by hand-weeding (HW) at 40 DAS due to the efficient control of dominant weed *Trianthema monogyna*. Uncontrolled weeds reduced the seed yield by 43% compared to weed-free treatment. Pendimethalin @ 1.0 kg a.i./ha + 1 HW at 40 DAS recorded maximum seed yield, net returns and benefit: cost ratio.

Key words : Cowpea, Herbicides, Imazethapyr, Pendimethalin, Pre-emergence, Post-emergence, Weed management

In view of severe infestation of annual and perennial weeds in rainy season (*kharif*) cowpea, the potential yield is generally not realized. It has been observed that the sole application of pre-emergence herbicides, particularly pendimethalin is not enough to maintain weed-free environment throughout the crop growth of cowpea sown during *kharif* season (Gatechew *et al.,* 2015). Poor efficiency of the pre-emergence herbicides in controlling weeds, particularly *Echinochloa colona* and other grassy weeds emerging at later stages of crop growth emphasized the need for evaluation of some new, low dose herbicides for post-emergence application like imazethapyr and quizalofop. Evaluation of the post-emergence application of imazethapyr and quizalofop coupled with cultural practices and other herbicides needs to be explored as low-priced and quick method of weed management. Yield loss in cowpea due to weeds was 12.7–60.0% (Li *et al*., 2004). Keeping the above facts in view, the present investigation was undertaken to evaluate the efficacy of pre- and post-emergence application of herbicides with and without hand-weeding in *kharif* cowpea.

A field experiment was conducted during *kharif* season at Karnal. Efficacy of pre- and post-emergence application of pendimethalin (1.0 kg a.i./ha) and oxyfluorfen (0.2 kg a.i./ha), imazethapyr (0.075 kg a.i./ha) and quizalofop-*p*-ethyl (0.025 kg a.i./ha) as sole and followed by 1 hand-weeding at 40 days after sowing (DAS) was compared with weedy check (WC) and weed-free plots in randomized block design with 4 replications. The soil was sandy clay loam medium in organic carbon content 0.60%, low in available N 193 kg/ha, medium in available P (21.5 kg/ha) and K (260 kg/ha). The soil was slightly alkaline (*p*H 7.6). The crop cultivar 'C 152' (120 days duration) was sown 45 cm apart in the third week of June during 2014. A uniform application of 15 kg N and 40 kg P_2O_5 and 30 kg K_2O was used basal application. The harvesting was done in the third week of October. Pendimethalin (1.0 kg a.i./ha) and oxyfluorfen (0.2 kg a.i./ha) dissolved in 500 litres/ha of water were sprayed on the same day of sowing through sprayer fitted with flat-fan nozzle. The aqueous solution of imazethpyr (0.075 kg a.i. /kg) and quizalofop-*p*-ethyl (0.025 kg a.i./ha) was applied at 20 DAS. One hand-weeding was integrated with herbicidal treatments at

Based on a part of M.Sc. Thesis of the first author submitted to ICAR-National Dairy Research Institute, Karnal, in 2015 (unpublished)

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40 DAS. Weeds were recorded using quadrate 50 cm × 50 cm at 60 days after sowing and converted the values in m^2. The data on weed density and weed dry weight were subjected to transformation $\sqrt{X+1}$ before statistical analysis.

Herbicide efficiency index (HEI) was calculated by using the following expression (Krishnamurthy *et al.*, 1975)

$$HEI = \frac{\frac{YT - YC}{YC} \times 100}{\frac{DMT}{DMC} \times 100}$$

where YT, Yield from treatment; YC, yield from control; DMT, dry-matter of weeds in treatment, DMC, dry matter of weeds in control.

Weed-management index (WMI) was worked out using the following expression (Gupta *et al.*, 2013).

$$\text{Weed Management Index (WMI)} = \frac{\text{\% yield over control}}{\text{\% control of weed}}$$

The experimental crop was infested with *Trianthema monogyana, Commelina benghalensis, Digera arvensis, Echinocloa colona* and *Cyperus rotundus* during the crop season. The most dominated weed was *Trianthema monogyana* in experimental field. Pendimethalin (1.0 kg a.i./ha) and imazethpyr (0.075 kg a.i./ha) integrated with 1 hand-weeding caused the mortality of *T. monogyana* 81.4% and 67.7%, respectively, over weedy check (Table 1). Oxyfluorfen (0.2 kg a.i./ha) and quizalofop-*p*-ethyl (0.025 kg a.i./ha) recorded significantly higher weed density of *Trianthema monogyna* than pendimetalin and imazethapyr followed by 1 hand-weeding. Pendimethalin did not allow the emergence and growth of weed seedling, particularly of *T. monogyana* because of reduced hypertrophy and hyperplasia (Singh and Angiras, 2004). Imazethapyr translocated freely in plants through roots and shoots could effectively controlled broad-leaf as well as grassy weeds (Ram *et al*., 2012). The lowest density of *Echinochloa colona* was recorded with quizalofop-*p*-ethyl 0.025 kg a.i./ha post-emergence (PoE) at 20 DAS with 1 hand-weeding at 40 DAS which was 60.8% lower than weedy check (Table 1). The results confirm the findings of Ali *et al.* (2011). Pendimethalin (1.0 kg a.i./ha) and imazethpyr (0.75 kg a.i./kg) followed by 1 hand-weeding (HW) reduced the density of *Commelina benghalensis* to the extent of 73.5 and 76.5% respectively (Table 1). Application of pendimethalin 1.0 kg a.i./ha pre-emergence (PE) + 1 HW at 40 DAS and imazethapyr 0.075 kg a.i./ha PoE at 20 DAS + 1 HW at 40 DAS reduced the total density of weeds by 56.0%, 47.8% and 44.7%, 34.6%, against weed control (WC) and quizalofop-*p*-ethyl 0.025 kg a.i./ha PoE at 20 DAS respectively. The highest weed dry weight was obtained under weedy check and the minimum under pendimethalin 1.0 kg a.i./ha PE + 1 HW at 40 DAS followed by imazethapyr 0.075 kg a.i./ha PoE at 20 DAS + 1 HW at 40 DAS. There was reduction of 72.0%, 63.3% and 65.2%, 54.4%, in total weed dry weight with application of pendimethalin 1.0 kg a.i./ha PE + 1 HW at 40 DAS and imazethapyr 0.075 kg a.i./ha PoE at 20 DAS + 1 HW at 40 DAS as compared to WC and quizalofop-*p*-ethyl 0.025 kg a.i./ha PoE at 20 DAS respectively. Similar results were reported by Usman (2013) with pendimathalin + weeding and by Tiwari *et al.* (2007) with imazethapyr at 0.075 kg/ha best treatment in soybean. The maximum weed-control efficiency was witnessed with pendamethalin 1.0 kg a.i./ha PE + 1 HW at 40 DAS which was at par with imazethapyr 0.075 kg a.i./ha PoE at 20

Table 1. Effect of pre- and post-emergence herbicides on weed density (m^2) of different weed species in forage cowpea

Treatment	*Trianthema monogyana*	*Echinochloa colona*	*Commelina benghalensis*	*Cyperus rotundus*	*Digera arvensis*
Pendimethalin 1.0 kg/ha PE + 1 HW 40 DAS	8.9 (79.5)	2.9 (8.0)	2.9 (9.0)	3.1 (9.0)	2.4 (5.0)
Pendimethalin 1.0 kg/ha PE	12.2 (148.5)	4.7 (22.0)	3.4 (11.0)	4.0 (16.0)	2.8 (7.0)
Oxyfluorfen 0.2 kg/ha PE + 1 HW 40 DAS	15.1 (228.5)	4.6 (23.0)	5.0 (25.0)	4.3 (18.0)	3.1 (9.0)
Oxyfluorfen 0.2 kg/ha PE	17.2 (299.5)	5.0 (24.0)	4.5 (20.0)	5.4 (29.0)	(14.0)
Imazethapyr 0.075 kg/ha PoE + 1 HW 40 DAS	11.4 (133.0)	4.3 (18.0)	2.9 (8.0)	3.7 (13.0)	(5.0)
Imazethapyr 0.075 kg/ha PoE	13.6 (188.0)	4.4 (20.0)	3.6 (12.0)	4.4 (19.0)	(8.0)
Quizalofop-*p*-ethyl 0.025 kg/ha PoE + 1 HW 40 DAS	14.4 (205.5)	2.7 (7.0)	3.7 (14.0)	3.7 (13.0)	(8.0)
Quizalofop-*p*-ethyl 0.025 kg/ha PoE	19.0 (360.0)	3.1 (9.0)	4.0 (15.0)	3.9 (14.0)	(14.0)
Weed-free	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	(0.0)
Weedy check	20.7 (428.0)	8.2 (68.0)	5.9 (34.0)	5.8 (33.0)	(20.0)
SEm±	0.60 (17.2)	0.49 (5.50)	0.30 (2.42)	0.33 (3.0)	0.20 (1.31)
CD (P=0.05)	1.75 (17.2)	1.41 (16.0)	0.87 (7.0)	0.95 (8.7)	0.59 (3.8)

PE, Pre-emergence; PoE, post-emergence; DAS, days after sowing; HW, hand-weeding

Original figures in parentheses were subjected to square-root transformation $\sqrt{x+1}$ before statistical analysis

DAS + 1 HW at 40 DAS. This might be owing to lower weed density and dry-matter production of weeds which resulted successful checking of weed growth under these treatments. Gupta *et al.* (2013) also reported higher weed-control efficiencies with pre-emergence application of pendimethalin and post-emergence application of imazethapyr. The higher herbicide-efficiency index and weed-management index resulted with pendamethalin 1.0 kg a.i./ha PE + 1 HW at 40 DAS followed by imazethapyr 0.75 kg a.i./ha PoE at 20 DAS + 1 HW at 40 DAS which may be owing to the better control of weeds resulting in higher weed-control efficiency under these treatments. The lowest herbicide-efficiency index and weed-management index obtained with oxyflurofen 0.2 kg a.i./ha PE were at par with quizalofop-*p*-ethyl 0.025 kg a.i./ha PoE at 20 DAS. The result confirms the findings of Gupta *et al.* (2013).

Different weed control treatments significantly affected the seed yield and yield attributes, viz. plant height, pods/plant, seeds/pod and 1,000-seed weight. Yield attributes, viz. plant height (cm), pods/plant, 1,000-seed weight and seed yield (kg/ha) increased significantly in absence of crop–weed competition created due to application of pre-emergence pendimethalin and post-emergence imazethpyr followed by HW 40 DAS (Table 3). The extent of increase in seed yield was 54.7% and 45.0% under pendimethalin

Table 2. Effect of pre- and post-emergence herbicides on weed parameters in seed crop of forage cowpea

Treatment	Total weed density (no/m^2)	Total weed dry weight (g/m^2)	WCE (%)	HEI	WMI	Weed index
Pendimethalin 1.0 kg/ha PE + 1 HW at 40 DAS	10.5 (110.5)	64.3	71.6	2.2	8.8	11.9
Pendimethalin 1.0 kg/ha PE	14.3 (209.5)	97.3	56.6	1.2	4.2	20.3
Oxyfluorfen 0.2 kg/ha PE + 1 HW at 40 DAS	17.4 (303.5)	121.6	47.6	0.9	2.8	20.0
Oxyfluorfen 0.2 kg/ha PE	19.6 (386.5)	162.7	29.2	0.1	1.7	39.7
Imazethapyr 0.075 kg/ha PoE + 1 HW at 40 DAS	13.2 (177.0)	80.0	64.3	1.6	5.1	17.5
Imazethapyr 0.075 kg/ha PoE	15.6 (247.0)	127.9	43.5	0.4	2.9	32.9
Quizalofop-*p*-ethyl 0.025 kg/ha PoE + 1 HW at 40 DAS	15.7 (247.5)	126.4	44.2	0.4	2.9	32.4
Quizalofop-*p*-ethyl 0.025 kg/ha PoE	20.3 (413.0)	175.5	22.9	0.2	1.6	37.4
Weed-free	1.0 (0.0)	0.0	100.0	0.0	0.0	0.0
Weedy check	24.1(583.0)	230.0	0.0	0.0	1.0	43.1
SEm±	0.6 (20.8)	10.9	4.5	0.2	0.5	4.0
CD (P=0.05)	1.8 (60.2)	31.6	12.9	0.7	1.3	11.6

PE, Pre-emergence; PoE, post-emergence; DAS, days after sowing; HW, hand-weeding
WCE, Weed-control efficiency; HEI, herbicide efficiency index; WMI, weed management index
Original figures in parentheses were subjected to square-root transformation $\sqrt{x + 1}$ before statistical analysis

Table 3. Influence of pre- and post-emergence herbicides on yield attributes and seed yield and economics of forage cowpea

Treatment	Plant height (cm)	Pods/ plant	1,000-seed weight (g)	Seed-yield (kg/ha)	Cost of cultivation (×10^3 ₹/ha)	Gross returns (×10^3 ₹/ha)	Net returns/ ha (×10^3 ₹/ha)	Benefit: cost ratio
Pendimethalin 1.0 kg/ha PE + 1 HW at 40 DAS	95.7	16.1	89.4	580	40.4	99.0	58.6	1.5
Pendimethalin 1.0 kg/ha PE	88.5	14.1	85.5	520	35.4	84.8	49.4	1.4
Oxyfluorfen 0.2 kg/ha PE + 1 HW at 40 DAS	82.1	14.3	83.9	520	42.2	85.7	43.4	1.1
Oxyfluorfen 0.2 kg/ha PE	81.6	14.8	81.6	390	37.2	71.0	33.7	0.9
Imazethapyr 0.075 kg/ha PoE + 1 HW at 40 DAS	86.5	14.8	87.7	540	40.4	90.4	50.0	1.2
Imazethapyr 0.075 kg/ha PoE	80.2	13.1	85.6	440	35.4	80.0	44.5	1.3
Quizalofop-*p*-ethyl 0.025 kg/ha PoE + 1 HW at 40 DAS	83.8	12.7	83.1	440	40.7	77.1	36.4	0.9
Quizalofop-*p*-ethyl 0.025 kg/ha PoE	78.0	12.6	87.4	410	35.7	70.9	35.1	1.0
Weed-free	100.8	16.8	90.9	660	48.6	110.5	61.8	1.3
Weedy check	68.1	10.6	71.8	370	33.6	64.2	30.5	0.9
SEm±	5.5	1.0	3.3	30				
CD (P=0.05)	16.0	2.9	9.6	80				

PE, Pre-emergence; PoE, post-emergence; DAS, days after sowing; HW, hand-weeding

and imazethapyr, respectively, over the weedy check. The increase in yield attributes and seed yield under these treatments may be because of better management of weeds during early crop growth which resulted in higher dry-matter accumulation, which resulted in greater translocation of photosynthtates to the reproductive parts and reflected in superiority of yield attributes and ultimately higher seed yield. Our results confirm those of Hanumanthappa *et al.* (2012).

Among the herbicidal treatments, the maximum net returns were recorded with pendimethalin 1.0 kg a.i./ha PE + 1 HW at 40 DAS followed by imazethapyr 0.075 kg a.i./ha PoE at 20 DAS + 1 HW at 40 DAS and the minimum with oxyflurofen 0.20 kg a.i./ha PE. The highest benefit: cost ratio was obtained with pendimethalin 1.0 kg a.i./ha PE + 1 HW at 40 DAS and the lowest with quizalofop-*p*-ethyl 0.025 kg a.i./ha PoE at 20 DAS + 1 HW at 40 DAS. Hanumanthappa *et al.* (2012) also obtained higher benefit: cost ratio with pendimethalin in cowpea.

Based on the study, it can be concluded that pendimethalin (PE) and imazethapyr (PoE) integrated with 1 HW at 40 DAS can be used for efficient and cost-effective weed-control in forage cowpea.

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