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Research Paper

Bioefficacy of herbicides against weeds in greengram (*Vigna radiata*) and their residual effect on succeeding Indian mustard (*Brassica juncea*)

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ABSTRACT

An experiment was carried out during the rainy season of 2012 and 2013 at Hisar, Haryana, to study the efficacy of different herbicides against weeds in greengram [*Vigna radiata* (L.) R. Wilezek] and their carry over effect on succeeding Indian mustard [*Brassica juncea* (L.) Czernj & Cosson]. Post emergence (PoE) application of imazethapyr at 50 and 70 g/ha and imazethapyr + imazamox (RM) at 60, 70 and 80 g/ha significantly reduced the density and dry weight of weeds compared to weedy check, although, PoE application of both these herbicides caused phytotoxicity to greengram. At 30 days after sowing (DAS), dry weight of weeds was minimum (2.1 and 7.8 g/m^2) in pre-emergence (PRE) application of imazethapyr +pendimethalin (RM) at 1,000 g/ha in 2012 and 2013 respectively, but at 60 DAS, PoE use of imazethapyr and its ready-mix combinations with imazamox caused significant reduction in weed dry matter. Higher doses of imazethapyr (60 and 70 g/ha) and its ready-mix combination with imazamox applied at 3–4 leaf-stage caused 11.3–23.3% toxicity to greengram which mitigated within 15 days after application during both the years. Presence of weeds throughout the season caused 85.6 and 70.9% reduction in grain yield of greengram during 2012 and 2013 years respectively. Grain yield was the maximum in weed-free treatment during both the years, which was at par with post emergence application of imazethapyr at 50 and 70 g/ha and imazethapyr + imazamox (RM) at 60 g/ha in 2012; but during 2013, imazethapyr + imazamox (RM) at 80 g/ha applied at 3–4-leaf stage recorded the maximum seed yield (995 kg/ha). No residual effect of different herbicides applied to greengram at various rates was observed on Indian mustard due to enhanced microbial degradation of these herbicides, as heavy rainfall occurred between time of herbicide application and planting of Indian mustard.

Key words : Greengram, Herbicide efficacy, Indian mustard, Imazethapyr, Imazamox, Pendimethalin, Residual effect

Greengram contributes 14% for total pulses area and 7% in total pulse production of India. Due to limited irrigation facilities in south-western part of Haryana, it is the important rainy season crop of this region. The potential yield of most of the varieties ranges from 1,600 to 2,000 kg/ha, but the productivity of state as well as of the country is far less than the potential average. Weed infestation is one of the main constraints in decreasing the productivity of rainy season greengram. Kumar *et al*. (2005) reported that, on an average, crop-weed competition reduces the seed yield of greengram to a tune of 31.6%, maximum reduction in dry weight of weeds was recorded with HW at 20 and 40 DAS, which is a critical period of crop-weed competition. The magnitude of loss due to weeds can vary depending on the type of weeds, their densities and duration of competition with crops, soil type, crop type, type of irrigation, cropping pattern followed, weed-control measures adopted and environmental factors.

The most commonly and effective herbicides for controlling weeds in greengram are trifluralin, linuron and acetachlor (Malik *et al*., 2000) and pendimethalin, alachlor and fluchloralin (Mishra and Singh, 1993). Although pre-emergence (PRE) use of pendimethalin at 1.0 kg /ha has been found effective in controlling weeds in greengram but a residual herbicide is needed to control second flush of weeds emerging after rains. Imazethapyr is a new herbicide of imidazolinone group registered for use in soybean, groundnut and other legumes (Herbicide Handbook, USA, 2002). Imazethapyr and its ready-mix combination with imazamox, new herbicides of imidazolinone group

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have been found promising to control weeds in greengram. Singh *et al.* (2014) reported that, application of imazethapyr at 100 g/ha at 15 DAS in greengram gave the highest gross and net returns, followed by imazethapyr at 75 g/ha sprayed at 15 DAS. Punia *et al*. (2011) found that, the imazethapyr applied at 80 g/ha in clusterbean either PPI, PRE or 21 DAS did not cause any reduction in fresh weight/plant, number of leaves/plant and plant height and seed yield of Indian mustard, but residues of 100 g/ha application reduced the plant height, number of leaves/plant, fresh weight/plant and seed yield of Indian mustard. Chlorimuron and imazethapyr, irrespective of their dose and time of application, did not cause any injury to wheat, barley and chickpea planted as succeeding crop after harvesting of clusterbean, but both these herbicides caused severe injury to Indian mustard. Leon and Reinhardt (2001) reported, that leaching of imazethapyr takes place in coarse textured soils with low in clay and organic matter content. Imazethapyr being highly persistent in soil may cause residual toxicity in succeeding crops.

Hence, herbicide imazethapyr alone or in combination with imazamox and pendimethalin as pre-mixture with imazethapyr was tested under pre- and post- emergence conditions to study herbicidal effect on growth and yield of greengram and succeeding Indian mustard crop.

MATERIALS AND METHODS

An experiment was carried out at Agronomy Research Area of Chaudhary Charan Singh Haryana Agricultural University (CCS HAU), Hisar. Experimental soil was sandy loam in texture, having *p*H 8.1, low in organic carbon (0.3%) and nitrogen (180 kg/ha), medium in available phosphorus (18 kg/ha) and high in potassium (370 kg/ha) content. Crop received 490 and 594 mm rainfall in the crop-growing season during the 2012 and 2013. Greengram variety 'Satya' was sown on 17 July 2012 and harvested on 5 October 2012 and variety 'MH 421' was sown on 22 June 2013 and harvested on 23 September 2013. Treatments consisted of PRE application of pendimethalin 1.0 kg/ha, ready-mix (RM) of pendimethalin + imazethapyr (Valor) 0.8, 0.9 and 1.0 kg/ha and post-emergence (PoE) application of imazethapyr 50 and 70 g/ha, imazethapyr + imazamox (Odyssey) 60, 70 and 70 g/ha along with weed free and weedy check. The experiment was laid out in randomized block design, replicated thrice. Pre-emergence herbicides were applied just after sowing of the crop by knapsack sprayer, fitted with flat-fan nozzle using 500 litres water, whereas PoE herbicides were applied at 23 DAS (2–3-leaf stage of weeds) by knapsack sprayer, fitted with flat-fan nozzle using 375 litres water/ha. Crop was raised as per the package of practices of the CCS HAU, Hisar. Observations on weeds were recorded at 30 and 60 days after sowing (DAS) using a quadrant of 0.5 m × 0.5 m and phytotoxic effect of herbicides on crop in terms of yellowing, stunting and necrosis were recorded at 30 and 45 DAS on a scale of 0–100. Plant material was dried at 65°C for 48 h before determining dry weight and this was used for calculating weed-control efficiency (WCE). Plant height, crop yield and yield parameters were recorded at maturity. To study the residual effect of herbicides applied in greengram on succeeding crop, Indian mustard var**. 'RH** 30' was sown during both the years after slight disking the field without disturbing the original layout and crop was raised as per package of practices recommended by CCS HAU, Hisar. To estimate the residual effect of herbicides applied to greengram on succeeding Indian mustard, data on number of plants/m row length (m.r.l) at 20 DAS and plant height at 30 DAS were recorded.

The experimental data recorded for various characters were subjected to statistical analysis. The significance of treatment effects was tested with the help of 'T' test. Appropriate standard errors along with critical differences (CD at 5%) were worked out for differentiating the treatment effects from those of change effects.

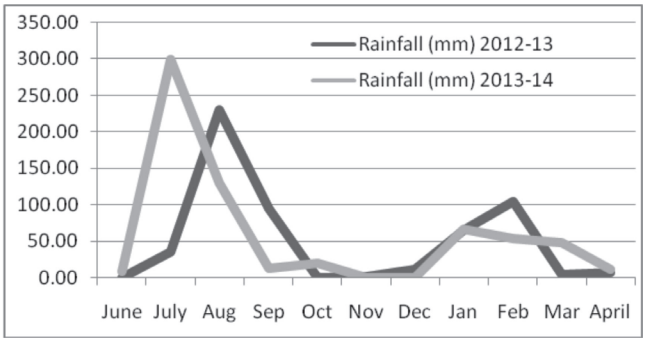

Fig. 1. Monthly rainfall data from June, 2012 to April, 2014 at Hisar, Haryana

RESULTS AND DISCUSSION

Dry weight of weeds

At 30 DAS, among all herbicidal treatments significantly lower weed dry weight (2.1 and 7.4 g/m^2) was recorded with PRE application of imazethapyr + pendimethalin (RM) at 1,000 g/ha followed by imazethapyr + pendimethalin (RM) at 900 g/ha, (3.0 and 9.1 g/m^2) during the 2012 and 2013 respectively (Table 1). But at 60 DAS, during 2012, PoE use of imazethapyr and its ready-mix combinations with imazamox resulted in significant reduction in weed dry-matter accumulation which was significantly less as compared to PRE use of pendimethalin and its ready-mix combination with imazethapyr at 800–1,000 g/ha, whereas during 2013, al-

though all herbicide treatments caused significant reduction in dry-weight but ready mix formulation of imazethapyr + imazamox applied at 3–4-leaf stage at 80 g/ha was more effective than other treatments as dry weight of weeds in this treatment was 78 g/m^2 which was significantly less than the other herbicides used (Table 1).

Weed-control efficiency

During 2012, at 30 DAS, weed-control efficiency (WCE) was more than 90% in all herbicide treatments except pendimethalin at 1,000 g/ha, but at 60 DAS, it decreased in all PRE treatments due to second flush of weeds appeared due to frequent rains and the maximium WCE (82.2%) was recorded with PoE use of imazethapyr at 70 g/ha (Table 1). During 2013, at 30 DAS, the maximum weed-control efficiency (81.9%) was recorded with ready-mix formulation of imazethapyr + pendimethalin at 1,000 g/ha applied as PRE followed by imazethapyr + pendimethalin (76.6%) at 900 g/ha applied as PRE. At 60 DAS, among the herbicide treatments maximum weed-control efficiency (78.2%) was recorded with PoE application of imazethapyr + imazamox (RM) at 80 g/ha applied at 3–4-leaf stage, followed by imazethapyr + imazamox (RM) at 70 g/ha applied at 3–4-leaf stage (72.5%). Although PRE use of pendimethalin at 1,000 g/ha provided effective control of weeds up to 30 DAS, but efficacy decreased from 70–71% to 31–44% at 60 DAS, as it could not control second flush of weeds appeared due to its short-residue nature and high rains (Table 1).

Visual phytotovicity-toxicity on crop

Higher doses of imazethapyr and its ready-mix combination with imazamox applied at 3–4-leaf stage caused 8.3–35.2% toxicity to greengram in terms of chlorosis, yellowing, epinasty and stunting at 45 DAS which mitigated within 15 days after application in all the treatments during both the years, except imazethapyr + imazamox (RM) at 70 and 80 g/ha with only 5–7% crop suppression causing reduction in plant height and seed yield during 2012 only. At 30 DAS, higher visual phytotoxicity (35.2 and 23.3%) on crop was recorded with imazethapyr + imazamox (RM) at 80 g/ha applied at 3–4-leaf stage during 2012 and 2013, respectively, which was at par with imazethapyr + imazamox (RM) at 60 and 70 g/ha only in 2013.

Table 1. Effect of weed-control treatments on dry weight (g/m^2) of weeds and (weed control efficiency WCE, %) at 30 and 60 days after sowing in greengram

Treatment	Dose (g/ha)	Application time	Dry weight (g/m^2)				WCE (%)			
			30 DAS		60 DAS		30 DAS		60 DAS	
			2012	2013	2012	2013	2012	2013	2012	2013
Pendimethalin	1000	PRE	6.8 (45.5)	3.5 (11.3)	15.3 (233.3)	14.3 (203.0)	69.9	71.1	31.6	44.3
Imazethapyr	50	3–4-leaf stage	3.0 (8.3)	4.6 (20.2)	8.6 (72.7)	11.5 (131.7)	94.5	47.3	78.6	63.7
Imazethapyr	70	3–4-leaf stage	2.2 (4.2)	4.2 (16.7)	7.8 (60.7)	10.2 (103.3)	97.2	56.6	82.2	71.5
Imazethapyr + pendimethalin (RM)	800	PRE	1.9 (9.1)	3.3 (9.8)	14.5 (212.7)	14.2 (200.3)	93.9	74.7	37.6	44.7
Imazethapyr + pendimethalin (RM)	900	PRE	1.9 (3.0)	3.2 (9.1)	13.0 (171.3)	13.6 (185.0)	98.0	76.6	49.8	49.1
Imazethapyr + pendimethalin (RM)	1000	PRE	1.8 (2.1)	2.9 (7.4)	12.6 (158.7)	13.1 (170.2)	98.6	81.9	53.5	53.2
Imazethapyr + imazamox (RM)	60	3–4-leaf stage	2.5 (6.1)	4.0 (15.1)	8.6 (73.3)	10.5 (108.8)	95.9	61.2	78.5	70.1
Imazethapyr + imazamox (RM)	70	3–4-leaf stage	3.5 (11.9)	4.0 (14.9)	8.6 (65.7)	10.0 (99.8)	92.1	61.3	78.3	72.5
Imazethapyr + imazamox (RM)	80	3–4-leaf stage	2.3 (5.9)	3.5 (11.0)	9.6 (90.7)	8.9 (78.0)	96.1	71.5	80.8	78.2
Weedy check	–	3–4-leaf stage	12.3 (151)	6.3 (38.3)	18.5 (341.3)	19.0 (360.0)	0	0	0	0
Weed free	–	–	1 (0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	100	100	100	100
SEm±	–	–	0.54	0.1	0.7	0.2	–	–	–	–
CD (P=0.05)	–	–	1.61	0.3	2.0	0.5	–	–	–	–

PRE, Pre-emergence; Original data given in parentheses were subjected to square root $\sqrt{(x+1)}$ transformation before analysis

Plant height (cm)

At 60 DAS, the maximum plant height was recorded in weedy check (86.9 and 81.2 cm) during 2012 and 2013 respectively, but among all the herbicidal treatments higher plant height (87.5 and 74 cm) was recorded with pendimethalin at 1,000 g/ha which was at par with the imazethapyr + pendimethalin (RM) at 900 and 1,000 g/ha applied as PRE in 2012 and 2013 respectively (Table 2). At 30 DAS, lower plant height was recorded with PoE application of imazethapyr and its ready mix combination with imazamox at all the doses and reduction in plant height due to these herbicides remained consistent up to 60 DAS.

Yield and yield attributes

The maximum number of pods/plant (36.8 and 37.1) was recorded in weed-free treatment during 2012 and 2013 respectively (Table 2). In 2012, among all herbicidal treatments, maximum pods/plant (36.1) were recorded with imazethapyr + imazamox (RM) at 60 g/ha, but during 2013 the maximum number of pods/plant (34.6) was recorded with imazethapyr + imazamox (RM) at 80 g/ha which were significantly higher than all PRE herbicides during 2013. Weedy check recorded significantly minimum number of pods/plant which was significantly less than all the other weed-control treatments during 2012 and 2013 respectively. Weed-free treatment by virtue of providing a favourable environment registered the maximum seed yield during 2012 and 2013 respectively, which was significantly higher over all the other treatments (Table 2). In 2012, seed yield in weed-free treatment was at par with PoE application of imazethapyr at 50 and 70 g/ha and imazethapyr + imazamox (RM) at 60 g/ha. In 2013, among all the herbicidal treatments imazethapyr + imazamox (RM) at 80 g/ha applied at 3–4-leaf stage resulted the maximum seed yield (1.0 t/ha) which was significantly higher than all herbicide treatments and 51% higher yield than PRE application of pendimethalin at 1,000 g/ha (Table 2). Post-emergence application of imazethapyr at 70 g/ha at 3–4-leaf stage also increased the seed yield (0.92 t/ha) significantly which was at par with the imazethapyr + imazamox (RM) at 70 g/ha.

All herbicidal treatments except imazethapyr at 70 g/ha and its ready-mix combinations with imazamox did not cause any phytotoxic effect on succeeding India mustard. Indian mustard in these treatments showed only 5% toxicity up to 15 DAS due to residues of these herbicides applied to greengram which mitigated within 1 month after planting, as shown by plants/m row length and seed yield of Indian mustard during 2012. Similarly, Sangawan *et al.* (2016) reported that, only higher dose of imazethapyr and its ready-mix combinations with imazamox herbicides applied in clusterbean caused some residual effects on Indian mustard crop by showing some visual crop injury symptoms (<10%) up to 15 DAS at location Kheri Batter (loamy sand texture), but the effect was transient and not visible 4 weeks after sowing or later stages. Plant height, plants/m row length and seed yield of Indian mustard did not differ significantly by residual carry-over effect of different herbicides applied to greengram due to enhanced microbial degradation of these herbicides, as the heavy rainfall (594.3 mm) occurred between time of herbicide application and planting of Indian mustard during 2013 (Table 3). In 2012, grain yield of Indian mustard varied from 1.80 to 1.95 t/ha, but in 2013 it varied from 2.45 to 2.52 t/ha (Table 3).

Thus, it may be concluded that effective control of weeds and improved productivity of greengram can be

Table 2. Effect of weed-control treatments on plant height, pods/plant and grain yield of green gram

Treatment	Dose (g/ha)	Application time	Plant height (cm)		Pods/plant		Grain yield (t/ha)	
			2012	2013	2012	2013	2012	2013
Pendimethalin	1,000	PRE	87.5	74.0	28.3	25.3	0.91	0.49
Imazethapyr	50	3–4-leaf stage	85.6	59.8	34.5	31.4	1.44	0.72
Imazethapyr	70	3–4 leaf stage	85.8	61.1	34.9	32.8	1.48	0.92
Imazethapyr + pendimethalin (RM)	800	PRE	85.7	69.7	34.1	25.2	1.41	0.57
Imazethapyr + pendimethalin (RM)	900	PRE	86.2	70.6	33.5	27.5	1.41	0.58
Imazethapyr + pendimethalin (RM)	1,000	PRE	86.4	71.6	35.0	30.3	1.43	0.78
Imazethapyr + imazamox (RM)	60	3–4 leaf stage	85.6	66.1	36.1	32.4	1.48	0.85
Imazethapyr + imazamox (RM)	70	3–4 leaf stage	84.2	67.4	33.3	33.3	1.37	0.88
Imazethapyr + imazamox (RM)	80	3–4 leaf stage	83.7	69.8	33.2	34.6	1.36	1.0
Weedy-check	–	–	87.9	81.2	19.7	19.6	0.22	0.29
Weed-free	–	–	85.8	73.7	36.8	37.1	1.50	1.14
SEm±								
CD (P=0.05)	–	–	1.3	7.1	5.2	6.2	0.07	0.04

PRE, Pre-emergence Residual effect of herbicides applied to greengram on succeeding Indian mustard

Table 3. Residual effect of various weed control treatments applied in green gram on no. of plant/m. r. l. at 20 days after sowing (DAS), plant height (cm) at 30 days after sowing (DAS) and seed yield (kg/ha) of Indian mustard

Treatment	Dose (g/ha)	Application time	Plants/m row length		Plant height (cm)		Seed yield (t/ha)	
			2012	2013	2012	2013	2012	2013
Pendimethalin	1,000	PRE	8.9	11.0	22.4	19.6	1.84	2.48
Imazethapyr	50	3–4 leaf stage	9.3	11.7	20.1	17.5	1.92	2.47
Imazethapyr	70	3–4 leaf stage	8.7	9.0	20.8	17.8	1.89	2.52
Imazethapyr + pendimethalin (RM)	800	PRE	8.3	9.3	22.0	18.6	1.82	2.47
Imazethapyr + pendimethalin (RM)	900	PRE	9.7	10.7	23.4	20.6	1.84	2.50
Imazethapyr +pendimethalin (RM)	1,000	PRE	9.3	12.0	21.9	17.9	1.95	2.50
Imazethapyr + imazamox (RM)	60	3–4 leaf stage	8.7	10.3	21.3	18.7	1.88	2.49
Imazethapyr + imazamox (RM)	70	3–4 leaf stage	8.7	10.0	21.5	20.2	1.88	2.47
Imazethapyr + imazamox (RM)	80	3–4 leaf stage	8.3	10.7	21.5	19.2	1.80	2.45
Weedy check	–	–	8.0	7.3	20.1	17.5	1.88	2.52
Weed-free	–	–	8.7	10.0	22.4	17.6	1.88	2.47
SEm±	–	–	0.8	1.4	0.8	0.9	0.42	0.22
CD (P=0.05)	–	–	NS	NS	NS	NS	NS	NS

PRE, Pre-emergence

attained with the application of imazethapyr at 50 and 70 g/ha and imazethapyr + imazamox (RM) at 60 and 80 g/ha applied at 3–4-leaf stage. Residual effect was not recorded even at highest rate of herbicides used which could be due to high rainfall and temperature during the crop season.

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