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Bio-efficacy of different herbicides in greengram under irrigated condition of middle Gujarat

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ABSTRACT

A systemic field study on bioefficacy of different herbicides in greengram (*Vigna radiata* L.) under irrigated condition of Gujarat and its residual effect on succeeding mustard crop was conducted during *Kharif* 2014 and 2015 at AAU, Anand. Among the tested options, hand hoeing at 20 and 40 days after sowing (DAS) and pre-emergence (PE) application of imazethapyr + pendimethalin ready mix (RM) at 1000 g/ha proved their supremacy in achieving highest seed yield (1.45 and 1.43 t/ha) with highest B:C of 2.91 & 2.88, respectively. These treatments provided season long control of weeds with the weed control efficiency (WCE) of 93% and 89%, respectively. Moreover, post-emergence (PoE) application of imazethapyr 70 and 80 g/ha or imazethapyr + imazamox ready mix (RM) 80 g/ha provided excellent WCE of more than 85%, but posed their negative impact on symbiotic parameters such as nodule number, plant dry weight and secured lower net return. Treatment receiving pre-emergence application of imazethapyr 80 g/ha was only found superior to achieve all profits with low input cost but did not control weeds effectively. Additionally, imazethapyr and its ready mix combination irrespective of dose did not show any residual effect to succeeding mustard crop.

Key words: Bio-efficacy, Dose-response, Herbicide combination, Integrated weed management

Greengram (*Vigna radiata* L.) is the most important and extensively cultivated legume crop grown during the *Kharif* season in India. It is cultivated on 3.44 million hectares with the production of 17.2 million tonnes in arid and semi-arid regions of India. Major constrains to the production of greengram are use of low genetic yield potential varieties, weed growth during the critical period, pre harvest sprouting and yellow vein mosaic virus incidence. Among these, weed infestation, particularly at early crop growth stages, poses a considerable threat to achieving the expected yields. Critical period of crop-weed competition in greengram is about 20-40 days after sowing (Saraswat and Mishra 1993). Life cycle of most of weeds coincide with that of crop they invade thus, ensuring mixing of their seed with those of the crops (Mahroof *et al*. 2009). Use of herbicide at critical stages plays a significant role in maintaining the productivity by decreasing weed interferences. Weeds in greengram have been reported to offer serious competition and cause yield reduction to the extent of 49% (Parkash *et al*. 1988) while Verma *et al*. (2015) reported that up to 96.5% yield reduction was observed depending on weed type and crop weed competition.

Greengram is a short duration crop requires initial control of weeds for crop establishment. The initial 70-80% of crop growth is generally achieved during initial 20-40 days of crop. Hence, pre-emergence herbicides presume great important during the initial growth period. The application of pre-emergence herbicide suppress the weed emergence hence, provide favorable environment to grow under weed free condition. The weed emerged during critical growth period also require indispensable attention to control weed flush, which can be controlled either by the use of post-emergence herbicides or hand weeding or inter culture operations. So that all growth stages can be covered to achieve higher yield outcome within time frame.

The most commonly and effective herbicides for controlling weeds in greengram are quizalofop-p-ethyl, pendimethalin, imazethapyr, imazamox, oxyfluorfen (Chhodavadia *et al*. 2013 and Kaur *et al*. 2016). The combination of pre- and post-emergence herbicide or some ready-mix formulations available in the market help to manage complex weed flora and reduced crop-weed competition. Hence, the present investigation was undertaken to determine the efficacy of different pre- and post-emergence herbicides applied as alone and ready mix in conjunction with mechanical method (hand hoeing) in greengram. The succeeding mustard crop was taken as test crop in the same set of treatment to assess residual effects of applied herbicides in greengram on growth and yield parameters of succeeding mustard crop.

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MATERIALS AND METHODS

The present studies were conducted at research farm of AICRP- Weed Management, B. A. College of Agriculture, Anand Agricultural University, Anand during the *Kharif* and *Rabi* seasons of 2014 and 2015 under irrigated condition. The soil of the experimental site had loamy sand in textured with the pH and electrical conductivity (EC) of 8.1 and 0.29 dS/m, respectively. The organic carbon, available nitrogen, phosphorus and potassium of the soil ranged from 0.42% (low), 233.8 (low), 13.8 (medium) and 270.5 (medium) kg/ha, respectively. The experiment was comprised of twelve treatments comprising alone and combinations of different pre-emergence (PE) and post-emergence (PoE) herbicides *viz.* imazethapyr 70 g/ha PE, imazethapyr 80 g/ha PE, imazethapyr 70 g/ ha PoE, imazethapyr 80 g/ha PoE, imazethapyr + imazamox ready mix (RM) 70 g/ha PE, imazethapyr + imazamox ready mix (RM) 80 g/ha PE, imazethapyr + imazamox ready mix (RM) 70 g/ha PoE, imazethapyr + imazamox ready mix (RM) 80 g/ha PoE, pendimethalin 1000 g/ha PE, imazethapyr + pendimethalin ready mix (RM) 1000 g/ha PE, hoeing 20 and 40 DAS and weedy check. The field experiment was laid out in randomized block design and replicated thrice.

Greengram cultivar '*Meha*' was sown at the rate of 20 kg/ha on August, 17 and July, 17 and harvested on November, 15 and October, 11 during the 2014 and 2015, respectively keeping 45 cm row spacing. The dose of nitrogen and phosphorous fertilizers was supplied through urea and di-ammonium phosphate (DAP) at 20 and 40 kg/ha, respectively. The PE herbicides were applied to soil on next day of sowing, while PoE herbicides spray was done at 15-20 days after sowing (DAS) (3-4 leaf stage of weeds) based on soil moisture condition by knapsack sprayer fitted with flat-fan nozzle using 500 litres/ha water. All the recommended package of practices was followed to grow greengram and mustard crop. Observations of weed density and weed dry biomass were recorded at 40 DAS by using one meter square size quadrate. The crop plant dry biomass was also recorded by uprooting five plants from each replication. Weed control efficiency (WCE) and weed index (WI) were calculated with the standard formula.

The weed index signifies loss of seed yield percent by the presence of weeds and its competition. This is used to assess the efficacy of herbicide. Lesser the weed index better is the efficiency of herbicides and vice versa. Weed control efficacy signifies herbicide use efficacy to control weeds effectively.

Phytotoxic effect of herbicides on crop in terms of yellowing, wilting, necrosis epinasty and hyponasty were recorded at 7 and 14 days after herbicide application (DAHA). Crop yield and yield parameters were recorded at maturity. Mustard crop cultivar '*GM 2*' was sown in second fortnight of November after harvest of greengram without disturbing soil in same layout of preceding greengram. Plant dry biomass and plant height of mustard were recorded at 60 DAS. Seed and stalk yield of mustard were recorded at harvest to quantify the residual effect of herbicides used in preceding greengram crop.

RESULTS AND DISCUSSION

Weed flora

The predominant weeds recorded in the experimental site among the monocot weeds were *Eleusine indica, Commelina benghalensis, Cyprus iria, Eragrostis major, Dactyloctenium aegyptium, Digitaria sanguinalis,* and among dicot weeds were *Digera arvensis, Phyllanthus niruri, Euphorbia hirta, Oldenlandia umbellate* and *Boerhavia diffusa.* The incidences of monocoat weeds were predominated (74.6%) followed by broad-leaved (25.4%) during the experimentation of greengram crop. *Eleusine indica* (30.7%) and *Digera arvensis* (6.79%) were found more dominant weed species among the grassy and broad-leaved weeds, respectively.

Effects on weeds

All the herbicidal treatments convincingly suppressed weed growth of monocot, dicot and total weeds and found superior over weedy check (**Table 1**). Weed density and weed dry biomass recorded at 40 DAS were significantly influenced by weed management practices except for monocot weed dry biomass. Among the herbicides applied alone, application of pendimethalin 1000 g/ha as pre-emergence application resulted in the lowest density of monocot and total weeds, while the lowest density of dicot weeds was recorded with post-emergence application of imazethapyr 80 g/ha. The combination of imazethapyr + pendimethalin (RM 1000 g/ha PE) proved its supremacy over all other treatments to control monocot (4.74 weeds/m^2) and total weeds (5.62 weeds/m^2) and imazethapyr + imazamox (RM) 80 g/ha PoE (1.44 weeds/m^2) found superior to control dicot weeds over weedy check for each category. Singh *et al.* (2016) also reported the same trend of result in black gram. Kushwah and Vyas (2006) reported that imazethapyr applied at 75 g/ha was effective against both monocot and dicot weeds and was at par with one hand weeding carried out at

20 DAS, however, it was more effective against grassy weeds. The better performance of combination of herbicides might be due to synergistic effect between the two herbicides reducing the population as well as dry biomass accumulation of different weed species. All the premix herbicides were found to be superior over individual weed control treatments. This might be due to the combined effect of both herbicides in checking the weed growth successfully (Mansoori *et al.* 2015).

Further, it was noticed that the minimum weed dry biomass of monocot (3.74 g/m^2) and total weeds (4.30 g/m^2) was observed in imazethapyr + pendimethalin (RM) 1000 g/ha PE treatment, whereas, imazethapyr + imazamox (RM) 80 g/ha recorded the lowest dicot weed dry biomass (1.09 g/ m^2). Hand hoeing at 20 and 40 DAS was also found comparable with combination of imazethapyr + pendimethalin at 1000 g/ha in reducing the dry matter accumulation of weeds.

Weed index and weed control efficiency are generally driven based on abundance of weed species present in the field. Hand hoeing at 20 and 40 days after sowing recorded 93 per cent weed control and nullify yield lose of greengram due to crop weed competition. Among various herbicide application, the highest weed control efficiency (89%) and the lowest weed index (1%) was obtained under imazethapyr + pendimethalin (RM) applied at 1000 g/ha PE. Weedy check recorded with the highest weed index (44%) due to absolute crop-weed competition. The highest weed control efficiency in ready mix of imazethapyr + pendimethalin applied at 1000 g/ha PE was recorded due to synergistic impact of herbicides to control grassy weeds which led to less dry biomass accumulation by weeds.

Effect on yield attributes and yield

The result revealed that plant stand (no./m^2) at 15 DAS and dry biomass of *Rhizobium* root nodule (mg/plant) at 35 DAS was not influenced significantly but differed significantly in plant height (cm) at 60 DAS and plant dry biomass (g/plant) at 30 and 60 DAS (**Table 2**). The combination of imazethapyr + imazamox (RM) 70 g/ha PE recorded the highest number of plants /m^2 after 15 DAS. The highest biomass of *Rhizobium* root nodules were recorded under weedy check followed by hand hoeing at 20 and 40 DAS. The results of Brahmbhatt (2014) revealed that dry weight of *Rhizobium* nodules in blackgram plant recorded at 45 DAS was significantly higher under IC + HW carried out at 20 and 40 DAS than application of imazethapyr at 100 g/ ha as PoE but was found at par with post emergence application of imazethapyr at 75 g/ha. Gonzalez *et al.* (1996) also reported that the number of nodules/plant was affected by application of imazethapyr.

Plant height at 60 DAS and plant dry biomass (g/ plant) at 30 and 60 DAS differed significantly with different herbicide treatments. The highest plant dry biomass at 30 and 60 DAS was recorded under application of imazethapyr at 70 g/ha PE due to effective control of weeds and least effect on crop growth which reduced crop-weed competition at initial stage effectively.

All the herbicide treatments produced significantly higher seed yield ranged from 0.98 to 1.43 t/ha in comparison to weedy check (0.81 t/ha) except under imazethapyr + imazamox (RM) 80 g/ha PoE (**Table 2**). Hand hoeing at 20 and 40 DAS achieved the highest seed yield (1.45 t/ha) followed by imazethapyr + pendimethalin (RM) at 1000 g/ha PE, imazethapyr 80 g/ha PE and least under weedy

Table 1. Observation of weed parameters under different weed management treatment and impact of herbicide on crop and weeds

Treatment	Weed density (No./ m^2) at 40 DAS			Weed dry biomass (g/m^2) at 40 DAS			WCE (%)	Weed Index (%)
	Monocot	Dicot	Total	Monocot	Dicot	Total		
Imazethapyr 70 g/ha PE	8.92^{ab} (158)	3.49^{bcd} (24.3)	9.59^{b} (91.2)	6.61 (45.2)	2.42^{b} (5.12)	7.04^{bc} (50.3)	71	10
Imazethapyr 80 g/ha PE	7.89^{abcd} (128)	3.52^{bcd} (27.0)	8.81^{bc} (77.4)	6.59 (46.2)	2.09^{b} (3.42)	6.87^{bc} (49.7)	71	3
Imazethapyr 70 g/ha PoE	7.77^{abcd} (121)	3.84^{ab} (32.8)	8.78^{bc} (76.8)	4.54 (21.1)	1.98^{b} (2.98)	4.86^{bc} (24.0)	86	9
Imazethapyr 80 g/ha PoE	7.54^{bcd} (113)	3.19^{bcd} (20.8)	8.21^{bcde} (66.7)	4.90 (23.4)	1.87^{b} (2.54)	5.22^{bc} (25.9)	85	12
Imazethapyr + imazamox 70 g/ha PE	8.16^{abc} (133)	2.59^{bcd} (12.1)	8.52^{bcd} (72.3)	8.20 (70.1)	2.31^{b} (5.13)	8.47^{b} (75.2)	57	7
Imazethapyr + imazamox 80 g/ha PE	7.53^{bcd} (114)	2.51^{bcd} (11.1)	7.90^{bcde} (62.4)	6.76 (50.7)	1.60^{b} (1.71)	6.88^{bc} (52.3)	70	6
Imazethapyr + imazamox 70 g/ha PoE	6.84^{bcd} (93.5)	1.46^{cd} (3.00)	6.96^{cdef} (48.0)	5.84 (33.4)	1.14^{b} (0.35)	5.86^{bc} (33.7)	81	19
Imazethapyr + imazamox 80 g/ha PoE	6.39^{cde} (81)	1.44^{d} (3.00)	6.52^{ef} (41.8)	4.52 (21.7)	1.09^{b} (0.20)	4.54^{bc} (21.9)	87	32
Pendimethalin 1000 g/ha PE	5.82^{de} (70.5)	3.56^{bcd} (23.6)	6.80^{def} (46.6)	6.23 (38.4)	3.94^{b} (17.3)	7.38^{bc} (55.6)	68	10
Imazethapyr + pendimethalin 1000 g/ha PE	4.74^{e} (47.3)	3.12^{bcd} (17.8)	5.62^{f} (32.5)	3.74 (14.6)	2.31^{b} (4.77)	4.30^{bc} (19.3)	89	1
Hoeing at 20 and 40 DAS	4.48^{e} (39.3)	3.19^{bcd} (16.8)	5.43^{f} (28.9)	2.89 (7.70)	2.11^{b} (3.65)	3.48^{c} (11.4)	93	0
Weedy check	9.9^{a} (209)	5.98^{a} (71.0)	11.7^{a} (140)	10.1 (105)	7.77^{a} (67.8)	13.2^{a} (173)	0	44
LSD (p=0.05)	1.93	1.88	1.78.	NS	2.99	3.81	-	-

Note: Data subjected to $(\sqrt{x+1})$ transformation. Figures in parentheses are means of original values. Treatment means with the letter/ letters in common are not significant by Duncan's New Multiple Range Test at 5% level of significance.

check. Alone adoptability of two hand hoeing (20 and 40 DAS) found comparable with imazethapyr + pendimethalin (RM) applied at 1000 g/ha PE. Among the different pre-mix herbicides, maximum seed yield was recorded with the application of imazethapyr + pendimethalin (RM) at 1000 g/ha PE which was at par with all other RM combinations except with imazethapyr + imazamox (RM) 80 g/ha PoE. Seed yield under this treatment was negatively associated with total weed density and weed dry biomass and positively associated with plants (no./m^2), pods/plant and seeds/pod. Rao *et al.* (2010) also reported that application of pendimethalin alone or combinations of imazethapyr + pendimethalin found better in reduction of dry matter accumulation of weeds with maximum seed yield. Among alone application of herbicide, higher seed yield (1.40 t/ha) was recorded with the application of imazethapyr at 80 g/ha PE, which showed 72.8% increment in yield over weedy check. Out of chemical treatments imazethapyr + imazamox (RM) 80 g/ha PoE accounted 32% yield reduction in seed yield in comparison with hand hoeing at 20 and 40 DAS. The reduction in yield in the seed yield in treatment was accounted due to phytotoxic effect of herbicide on greengram. Haulm yield followed the similar on trend of green yield.

Phytotoxic effects on greengram

The phytotoxicity score of the applied herbicides on greengram crop indicated that application of imazethapyr 80 g/ha PoE and imazethapyr + imazamox (RM) 70 and 80 g/ha PoE caused phytotoxicity in crop up to two weeks but after that crop fully recovered from the ill effect of herbicides. However, this slight impact of phytotoxicity in initial growth period of greengram resulted in yield reduction to the tune of 11.7, 18.6 and 32.4% in these three treatments, respectively.

Economics

Hand hoeing at 20 and 40 DAS achieved the highest seed yield, gross income, net return, and reduced weed dry biomass and weed density followed by imazethapyr + pendimethalin (RM) applied at 1000 g/ha PE (**Table 2**). Treatment imazethapyr 80 g/ha as pre-emergence was only comparable to achieve all profits with low input cost. Ali *et al.* (2011) recorded that among the other weed control treatments application of imazethapyr 100 g/ ha as post-emergence recorded maximum net return of ` 50,472/ha. The B:C ratio also reported highest under hand hoeing at 20 and 40 DAS treatment followed by imazethapyr at 80 g/ha PE, imazethapyr + pendimethalin (RM) applied at 1000 g/ha PE and lowest under imazethapyr + imazamox (RM) 80 g/ha PoE. Tamang *et al.* (2015) also observed maximum net returns and benefit: cost ratio obtained from pendimethalin + imazethapyr 1000 g/ha.

From the results of field experiments, it is concluded that hand hoeing at 20 and 40 DAS achieved best results but in paucity of labour, pre-emergence application of imazethapyr + pendi-methalin (RM) at 1000 g/ha or imazethapyr 80 g/ha PE was found suitable alternate for managing complex weed flora and obtaining higher seed yield, net return and return per rupee invested for *Kharif* greengram in alluvial soil of middle Gujarat.

Table 2. Influence of different weed management practices on growth parameters of greengram

Treatment	Plant stand at 15 DAS (no./m)	Plant height at 60 DAS (cm)	Root nodule Dry biomass 35 DAS (mg/plant)	Plant dry biomass at (g/plant)		Seed yield (t/ha)	Haulm yield (t/ha)	B: C ratio
				30 DAS	60 DAS			
Imazethapyr 70 g/ha PE	9.85	72.6^{bc}	55.9	4.29^{a}	29.2^{a}	1.30^{a}	2.11^{abc}	2.72
Imazethapyr 80 g/ha PE	10.4	72.5^{bc}	52.1	4.12^{abc}	26.7^{abcd}	1.40^{a}	2.19^{ab}	2.90
Imazethapyr 70 g/ha PoE	10.4	66.7^{cd}	56.6	3.47^{bcd}	25.1^{abcd}	1.33^{a}	2.07^{abc}	2.77
Imazethapyr 80 g/ha PoE	10.4	65.2^{d}	56.2	3.37^{cde}	23.8^{bcd}	1.28^{a}	2.01^{bc}	2.66
Imazethapyr + imazamox 70 g/ha PE	10.3	73.7^{abc}	60.3	4.18^{ab}	27.2^{abc}	1.35^{a}	2.18^{ab}	2.79
Imazethapyr + imazamox 80 g/ha PE	10.3	74.7^{ab}	58.3	3.98^{abc}	28.1^{ab}	1.36^{a}	2.21^{ab}	2.78
Imazethapyr + imazamox 70 g/ha PoE	10.6	64.8^{d}	51.7	2.76^{de}	23.4^{cd}	1.18^{a}	2.02^{abc}	2.43
Imazethapyr + imazamox 80 g/ha PoE	10.5	62.9^{d}	50.9	2.72^{e}	22.7^{de}	0.98^{bc}	1.81^{c}	2.02
Pendimethalin 1000 g/ha PE	10.2	72.5^{bc}	56.7	3.94^{abc}	26.6^{abcd}	1.31^{a}	2.04^{abc}	2.71
Imazethapyr + pendimethalin 1000 g/ha PE	10.2	74.3^{ab}	57.0	3.55^{abc}	27.5^{abc}	1.43^{a}	2.38^{a}	2.88
Hoeing at 20 and 40 DAS	10.3	72.3^{bc}	62.0	4.12^{abc}	26.9^{abcd}	1.45^{a}	2.29^{ab}	2.91
Weedy check	9.8	80.3^{a}	66.4	3.71^{abc}	19.3^{e}	0.81^{c}	1.22^{d}	1.84
LSD (p=0.05)	NS	6.55	NS	0.70	3.82	0.27	0.34	-

Note: Data subjected to $(\sqrt{x+1})$ transformation. Figures in parentheses are means of original values. Treatment means with the letter/ letters in common are not significant by Duncan's New Multiple Range Test at 5% level of significance.

Table 3. Influence of different weed management practices of preceding greengram crop on growth of succeeding mustard crop

Treatment	Plant population at 15 DAS (no./m)	Plant height at 60 DAS (cm)	Plant dry biomass at 60 DAS (g/plant)	Seed yield (t/ha)	Stalk yield (t/ha)
Imazethapyr 70 g/ha PE	9.00	165	41.4	1.55	5.68
Imazethapyr 80 g/ha PE	9.05	167	40.7	1.61	5.88
Imazethapyr 70 g/ha PoE	8.82	168	41.8	1.68	6.08
Imazethapyr 80 g/ha PoE	8.72	167	43.4	1.72	6.09
Imazethapyr + imazamox 70 g/ha PE	8.90	165	41.6	1.60	5.84
Imazethapyr + imazamox 80 g/ha PE	8.65	164	41.3	1.58	5.85
Imazethapyr + imazamox 70 g/ha PoE	9.05	164	43.1	1.61	6.10
Imazethapyr + imazamox 80 g/ha PoE	8.95	165	41.2	1.55	5.79
Pendimethalin 1000 g/ha PE	8.92	167	42.9	1.61	5.66
Imazethapyr + pendimethalin 1000 g/ha PE	9.00	167	42.8	1.66	6.20
Hoeing at 20 and 40 DAS	9.25	162	42.5	1.55	6.09
Weedy check	9.27	167	39.9	1.57	6.00

Residual effect of herbicides on mustard

No any residual effect of applied herbicides in greengram was visible on succeeding mustard crop in plant stand, plant height, plant dry biomass, seed and stalk yield and exhibited no significant differences in these parameters (**Table 3**).

The present investigation observed that weeds in greengram caused 44% reduction in seed yield. As per the findings of this study, it was inferred that hand hoeing at 20 and 40 days after sowing or pre-emergence application of imazethapyr + pendimethalin (RM) at 1000 g/ha proved their supremacy in achieving higher seed yield, net monetary, gross monetary returns with no phytotoxic effect on greengram. No residual effect of any herbicide applied in greengram was observed on succeeding mustard crop.

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