



Herbicide combinations for control of complex weed flora in garden pea

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ABSTRACT

A field experiment was carried out with twelve weed control treatments during the winter season of 2012-13 and 2013-14 on a silty clay loam soil to evolve an effective herbicide combination to control the complex weed flora in garden pea. *Phalaris minor* (28.8%), *Alopecurus myosuroides* (21.3%), *Avena ludoviciana* (15.8%), *Lolium temulentum* (12.1%) and *Vicia sativa* (16.7%) were found major weeds in experimental area. Pendimethalin 1000 g/ha supplemented with one HW at 45 DAS being statically at par to the application of pendimethalin 1000 g/ha (pre) fb imazethapyr + imazamox 60 g/ha (post) significantly reduced the density of major weeds. In general, the efficacy of the formulated mixtures whether as double knock or as a sole application was found better than the sole application of herbicides. Pendimethalin 1000 g/ha fb one HW and pendimethalin 1000 g/ha fb imazethapyr + imazamox 60 g/ha being statistically alike with weed free resulted in significantly higher number of nodules, green pod yield and straw yield.

Key words: Herbicide combination, Pea, weeds

Garden pea (*Pisum sativum* var. *hortense*) is one of the most important cool season frost hardy crops. In India, it shares 4.6% area with production 2.4% of the total vegetable crops. It is grown in 433.6 thousand ha with production of 3868.6 thousand tonnes and productivity 8.9 t/ha (NHB 2013-14). Pea has great potential for grain as well as vegetable purposes. As vegetable, it is grown in almost all agro-climatic zones of Himachal Pradesh. The green pods from hills are available at a time (April to October), when it cannot be successfully grown in the plains due to high temperature during this period. The fact, the produce is sold at a higher premium bringing lucrative returns to the growers (Sangar 2003). In Himachal Pradesh, it is grown in 23.9 thousand ha with production of 271.1 thousand tonnes and productivity 11.3 t/ha. Himachal Pradesh shares 7.0% of national production of pea.

Weeds are the major threat to the productivity of garden pea. They can be controlled by manual, mechanical and chemical methods. Manual method of weed control is labour intensive, cumbersome and time consuming. The mechanical methods cause injury to roots (Casarini *et al.* 1996). Various pre-plant incorporated and pre-emergence herbicides have been tested and recommended under different agro-climatic conditions of Himachal Pradesh (Singh *et al.* 1996). Post-emergence herbicides are also required when pre-emergence fail to give satisfactory

weed control. New post herbicides, *viz.* imazethapyr and imazamox either applied post as alone or in combination of both have been introduced. Therefore, the present investigation was carried out for having an effective management strategy for season long control of weeds in pea under mid hill conditions of Himachal Pradesh.

MATERIALS AND METHODS

Field investigation was carried out during winter season of 2012-13 and 2013-14 at Palampur (1290.8 m altitude, 32° 06' N latitude and 76° 34' 10" E longitude). The soil of the experimental site was silty clay loam in texture, acidic in reaction, medium in available N (322.9 kg/ha) and K (276.4 kg/ha) and high in available P (25.8 kg/ha). Garden pea 'Palam Priya' was treated with bavistin 2.5 g/kg and *Rhizobium* culture 200 g/10 kg seed. The pea seed was sown manually keeping the row to row distance of 45 cm at 60 kg/ha seed rate 17 October 2012 and 25 October 2013. N, P₂O₅ and K₂O (45, 60 and 60 kg/ha, respectively) were applied as basal through urea, SSP, and MOP. The crop was given five irrigations in first year and three irrigations in second year including the pre-sowing irrigation. The experiment was laid out in randomized block design (RBD) with three replications (Table 1). Manually operated knapsack sprayer fitted with a flat fan nozzle (WFN 40) was used for spraying the herbicides. The herbicides were sprayed using a spray volume of 700 litres of water/ha.

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Weed count and dry weight were recorded at 60, 90, 120 DAS and at harvest stage. The weed count was recorded species wise using 0.5 × 0.5 m quadrat from four randomly fixed places in each plot and the weeds falling within the frames of the quadrat were counted and the mean values were expressed in number/m². The crop was harvested on April 20 and 24 during the first and second year, respectively. Green pod yields were harvested from net plot area of 13.5 m² in four pickings.

RESULTS AND DISCUSSION

Effect on weeds

On an average of two years, the major weed flora of the experimental field was composed of *Phalaris minor* (28.8%), *Alopecurus myosuroides* (21.3%), *Avena ludoviciana* (15.8%), *Lolium temulentum* (12.1%) and *Vicia sativa* (16.7%). Other weeds like, *Stellaria media*, *Poa annua*, *Anagallis arvensis* and *Coronopus didymus* showed their infestation in very small number during both the year.

All treatments resulted in significantly lower density of weeds over the weedy check at 90 DAS (Table 1). Weed free treatment had lowest weed population during both the years. Among the herbicidal application, pendimethalin 1000 g/ha (pre-) supplemented with one HW at 45 DAS being statically at par- with application of pendimethalin 1000 g/ha as pre fb imazethapyr + imazamox at 60 g/ha as post-emergence at 45 DAS resulted in significantly superior control of *P. minor* over rest of the herbicidal treatments. The activity of pendimethalin fb HW (Kumar and Singh 1994; Vaishya *et al.* 1996; Prakash *et al.* 2000; Rana 2002) and imazethapyr (Zabara and Yankovskaya 2007) against *P. minor* has been established. Pendimethalin 1000 g/ha applied as pre fb one HW at 45 DAS and pendimethalin 1000 as pre-application fb imazethapyr + imazamox 60 g/ha applied as post-emergence being statistically similar, were superior to other herbicidal applications in reducing the population of *Alopecurus myosuroides*.

Table 1. Effect of treatments on weed count (no./m²) at 90 DAS in garden pea

Treatment	<i>Phalaris minor</i>		<i>Alopecurus myosuroides</i>		<i>Avena ludoviciana</i>		<i>Lolium temulentum</i>		<i>Vicia sativa</i>	
	2012-13	2013-14	2012-13	2013-14	2012-13	2013-14	2012-13	2013-14	2012-13	2013-14
Pendimethalin(1500 g/ha) PE	9.6 (90.7)	9.8 (96.0)	9.0 (80.0)	8.7 (74.7)	8.4 (69.3)	8.6 (73.6)	8.1 (64.0)	7.7 (58.7)	5.7 (32.0)	5.2 (26.7)
Pendimethalin PE fb imazethapyr POE (1000 fb 100 g/ha)	8.7 (74.7)	8.4 (69.3)	8.1 (64.0)	7.7 (58.7)	8.4 (69.3)	8.4 (69.3)	7.7 (58.7)	7.4 (53.3)	2.0 (5.3)	1.0 (0.0)
Imazethapyr PE fb imazethapyr POE (100 fb 100 g/ha)	9.8 (96.0)	10.1 (101.3)	8.1 (64.0)	8.4 (69.3)	8.7 (74.7)	8.7 (74.7)	9.0 (80.0)	8.4 (69.3)	6.6 (42.7)	5.1 (26.7)
Imazethapyr + pendimethalin PE (1200 g/ha)	7.7 (58.7)	7.4 (53.3)	7.4 (53.3)	7.0 (48.0)	7.4 (53.3)	7.4 (53.3)	6.2 (37.3)	6.2 (37.3)	4.7 (21.3)	4.7 (21.3)
Imazethapyr + pendimethalin PE (1500 g/ha)	6.6 (42.7)	6.6 (42.7)	7.0 (48.0)	6.6 (42.7)	5.2 (26.7)	4.7 (21.3)	7.0 (48.0)	6.6 (42.7)	5.7 (32.0)	6.2 (37.3)
Imazethapyr + pendimethalin PE fb imazethapyr POE 45 DAS(1000 fb 100 g/ha)	5.2 (26.7)	5.2 (26.7)	5.7 (32.0)	5.7 (32.0)	6.2 (37.3)	6.2 (37.3)	5.7 (32.0)	5.2 (26.7)	4.7 (21.3)	4.7 (21.3)
Imazethapyr + imazamox POE 45 DAS (60 g/ha)	5.7 (32.0)	5.7 (32.0)	6.2 (37.3)	6.2 (37.3)	6.2 (37.3)	6.2 (37.3)	5.7 (32.0)	5.7 (32.0)	4.7 (21.3)	4.7 (21.3)
Imazethapyr + imazamox POE 45 DAS (90 g/ha)	6.6 (42.7)	6.6 (42.7)	6.6 (42.7)	6.6 (42.7)	6.6 (42.7)	6.6 (42.7)	6.2 (37.3)	6.2 (37.3)	5.2 (26.7)	5.2 (26.7)
Pendimethalin fb imazethapyr + imazamox POE 45 DAS (1000 fb 60 g/ha)	4.1 (16.0)	4.1 (16.0)	4.7 (21.3)	4.7 (21.3)	5.7 (32.0)	5.7 (32.0)	4.7 (21.3)	4.7 (21.3)	3.1 (10.7)	3.1 (10.7)
Pendimethalin PE fb 1 HW 45 DAS (1000 g/ha)	3.1 (10.7)	3.1 (10.7)	4.7 (21.3)	4.7 (21.3)	4.1 (16.0)	4.1 (16.0)	4.1 (16.0)	4.1 (16.0)	2.0 (5.3)	2.0 (5.3)
Weed free	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)
Weedy check	13.1 (170.7)	12.9 (165.3)	11.6 (133.3)	11.1 (122.7)	10.1 (101.3)	9.6 (90.7)	9.0 (80.0)	8.4 (69.3)	9.6 (90.7)	9.8 (96.0)
LSD (P=0.05)	1.2	1.2	0.9	1.0	1.0	1.0	0.7	1.1	1.7	1.5

*Value in parentheses are the means of original values. Data transformed to square root transformation ($\sqrt{x+1}$); PE = Pre-emergence, POE= Post-emergence

All weed control treatments except imazethapyr 100 g/ha (pre) *fb* imazethapyr 100 g/ha (post 45 DAS) had significantly reduced the population of *A. ludoviciana* over the weedy check (Table 2). In general, efficacy of the formulated mixtures was better than the sole application of herbicide whether as double knock or as a sole treatment. Nelson and Giles (1989) and Haar *et al.* (2010) have reported poor control of *A. ludoviciana* with application of pendimethalin. Population of *L. temulentum* was significantly lower under weed free situation followed by pendimethalin 1000 g/ha *fb* one HW (45 DAS), pendimethalin 1000 g/ha applied as pre *fb* imazethapyr + imazamox 60 g/ha applied as post-emergence (45 DAS) as well as other herbicidal combinations over the weedy check. These results were in accordance with the findings of Lemerle *et al.* (2006) who have reported the lower count of *L. temulentum* in weed free treatment. Pendimethalin 1000 g/ha *fb* imazethapyr 100 g/ha (45 DAS), pendimethalin 1000 g/ha *fb* one HW (45 DAS) and pendimethalin 1000 g/ha (pre) *fb* imazethapyr + imazamox 60 g/ha (45 DAS) were as effective as weed free situation in reducing the population of *V. sativa*. Similar findings were also reported by Sandhu *et al.* (1978).

All weed control treatments significantly decreased total weed dry matter accumulation over

weedy check (Table 2). Pendimethalin 1000 g/ha *fb* one HW (45 DAS) being at par with application of pendimethalin 1000 g/ha (pre) *fb* combination of imazethapyr + imazamox 60 g/ha applied as post emergence (45 DAS) resulted in significantly lower total dry matter accumulation of weeds over other herbicidal treatments. The superiority of pendimethalin *fb* HW in controlling weeds has been reported by Kumar and Singh (1994). Imazethapyr + imazamox 60 g/ha (45 DAS), imazethapyr + pendimethalin 1000 g/ha *fb* imazethapyr 100 g/ha (45 DAS), imazethapyr + pendimethalin 1200 g/ha, imazethapyr + imazamox 90 g/ha (45 DAS) and pendimethalin 1000 g/ha *fb* imazethapyr 100 g/ha (45 DAS) behaving statistically alike were the next better treatments.

Effect on crop

Herbicides at the dose tried were selective as is evident from the emergence count which was not significantly affected (Table 2). The plant height increased with sigmoidal pattern with a grand growth stage between 60 and 120 DAS (Fig. 1). Weed control methods significantly affected plant height. Application of pendimethalin 1000 g/ha as pre *fb* one HW (45 DAS), pendimethalin 1000 g/ha (pre) *fb* imazethapyr + imazamox 60 g/ha (45 DAS), imazethapyr + imazamox 90 g/ha (45 DAS),

Table 2. Effect of treatments on total weed dry weight (g/m²), emergence count, plant height (120 DAS) and count (no./plant) and weight (mg/plant) of root nodules of pea

Treatment	Total weed dry weight (120 DAS)	Emergence count (no/m ²)	Plant height (cm)	Root nodules			
				Count		Weight	
				Pre-flowering	Post-flowering	Pre-flowering	Post-flowering
Pendimethalin (1500 g/ha) PE	12.1 (145.6)	17.0	60.73	44.7	27.0	40.4	28.2
Pendimethalin PE <i>fb</i> Imazethapyr POE (1000 <i>fb</i> 100 g/ha)	10.7 (114.1)	17.0	65.49	45.3	31.3	40.2	27.1
Imazethapyr PE <i>fb</i> imazethapyr POE (100 <i>fb</i> 100 g/ha)	12.3 (149.3)	18.5	64.67	44.3	28.0	40.0	26.8
Imazethapyr + pendimethalin PE (1200 g/ha)	10.2 (104.0)	18.5	59.00	45.0	28.3	41.3	26.6
Imazethapyr + pendimethalin PE (1500 g/ha)	11.2 (124.8)	17.0	65.87	45.3	29.7	40.0	28.0
Imazethapyr + pendimethalin PE <i>fb</i> imazethapyr POE 45 DAS (1000 <i>fb</i> 100 g/ha)	10.2 (102.4)	18.5	66.17	46.0	32.3	43.1	29.9
Imazethapyr + imazamox POE 45 DAS (60 g/ha)	9.8 (94.4)	18.5	65.74	45.7	31.7	42.0	28.4
Imazethapyr + imazamox POE 45 DAS (90 g/ha)	10.5 (109.3)	18.5	67.23	45.3	31.3	41.3	28.0
Pendimethalin <i>fb</i> imazethapyr + imazamox POE 45 DAS (1000 <i>fb</i> 60 g/ha)	8.8 (76.3)	17.0	67.78	46.3	33.3	44.1	32.3
Pendimethalin PE <i>fb</i> 1 HW 45 DAS (1000 g/ha)	8.1 (65.1)	18.5	70.39	46.7	34.7	44.7	32.6
Weed free	1.0 (0.0)	18.5	70.93	47.3	35.3	45.4	33.0
Weedy check	17.1 (292.8)	17.0	60.00	33.3	24.3	33.3	19.2
LSD (P=0.05)	0.9	NS	3.98	2.7	1.7	0.9	0.7

Table 3. Effect of treatments on yield attributes and yield of pea

Treatment	Pod/ plant	Pod length (cm)	Seed/ pod	Shelling (%)	Pod yield (t/ha)	
					2012-13	2013-14
Pendimethalin (1500 g/ha) PE	20.7	6.3	5.0	40.3	6.57	6.57
Pendimethalin PE <i>fb</i> Imazethapyr POE (1000 <i>fb</i> 100 g/ha)	21.0	6.7	5.3	42.0	6.29	6.49
Imazethapyr PE <i>fb</i> imazethapyr POE (100 <i>fb</i> 100 g/ha)	20.7	6.7	5.3	41.7	6.21	6.37
Imazethapyr + pendimethalin PE (1200 g/ha)	21.7	6.7	5.0	40.0	5.97	6.25
Imazethapyr + pendimethalin PE (1500 g/ha)	21.3	6.3	5.7	42.7	6.13	6.41
Imazethapyr + pendimethalin PE <i>fb</i> imazethapyr POE 45 DAS(1000 <i>fb</i> 100 g/ha)	21.7	6.7	6.0	43.0	6.09	6.81
Imazethapyr + imazamox POE 45 DAS (60 g/ha)	22.0	7.3	5.7	45.7	6.01	6.69
Imazethapyr + imazamox POE 45 DAS (90 g/ha)	22.3	7.0	6.3	42.0	6.53	6.81
Pendimethalin <i>fb</i> imazethapyr + imazamox POE 45 DAS (1000 <i>fb</i> 60 g/ha)	21.3	7.0	6.3	45.3	7.01	7.25
Pendimethalin PE <i>fb</i> 1 HW 45 DAS (1000 g/ha)	22.3	7.7	6.7	46.7	7.17	7.33
Weed free	22.7	7.7	6.7	47.3	7.21	7.37
Weedy check	20.7	6.0	4.7	39.7	4.34	4.74
LSD (P=0.05)	1.16	0.8	0.9	2.7	0.56	0.90

imazethapyr + pendimethalin 1000 g/ha *fb* imazethapyr 100 g/ha (45 DAS), pendimethalin 1500 g/ha (pre), imazethapyr + imazamox 60 g/ha (45 DAS), pendimethalin 1000 g/ha *fb* imazethapyr 100 g/ha (45 DAS) and weed free had an edge over other herbicidal treatments in influencing plant height of pea at 120 DAS. This may be ascribed to least competition from weeds due to their effective suppression.

Close examinations of the data inferred that pendimethalin 1000 g/ha *fb* one HW (45 DAS) and pendimethalin 1000 g/ha *fb* imazethapyr + imazamox 60 g/ha (45 DAS) being statistically at par with weed free treatment resulted in significantly higher number of nodules over rest of the treatments at pre-flowering stage. However, application of pendimethalin 1000 g/ha *fb* one HW (45 DAS) being at par with weed free, gave significantly higher number of nodules over rest of the treatments at post-flowering stage. Weed free resulted in highest nodules dry weight both at pre and post-flowering stage. However, it was statistically at par with application of pendimethalin 1000 g/ha *fb* one HW (45 DAS) at pre-flowering stage (Table 2).

All weed control treatments were significantly superior to weedy check in influencing yield attributes and yield of peas (Table 3). Among the treatments, weed free, pendimethalin 1000 g/ha *fb* one HW (45 DAS), imazethapyr + imazamox 90 g/ha (45 DAS) and imazethapyr + imazamox 60 g/ha (45 DAS) being statistically at par with application of imazethapyr + pendimethalin 1200 g/ha applied as pre-emergence and imazethapyr + pendimethalin 1000 g/ha *fb* imazethapyr 100 g/ha as post-

emergence (45 DAS) resulted in significantly higher pods/plant. Weed free and pendimethalin 1000 g/ha supplemented with one HW (45 DAS) had produced longer pods. However, these were statically similar with application of imazethapyr + imazamox 60 g/ha (45 DAS), imazethapyr + imazamox 90 g/ha (45 DAS) and pendimethalin 1000 g/ha *fb* imazethapyr + imazamox 60 g/ha (45 DAS). Significantly higher seeds/pod were obtained with weed free and application of pendimethalin 1000 g/ha *fb* one HW (45 DAS). Weed free, pendimethalin 1000 g/ha *fb* one HW (45 DAS), pendimethalin 1000 g/ha *fb* imazethapyr + imazamox 60 g/ha (45 DAS) and imazethapyr + imazamox 60 g/ha (45 DAS) resulted in significantly higher shelling percentage over weedy check.

Significantly higher green pod yield was obtained in weed free situation followed by application of pendimethalin 1000 g/ha *fb* one HW (45 DAS) and sequential application of pendimethalin 1000 g/ha *fb* imazethapyr + imazamox 60 g/ha (45 DAS) treatments. Imazethapyr + imazamox 90 g/ha (45 DAS) and imazethapyr + pendimethalin 1000 g/ha *fb* imazethapyr 100 g/ha (45 DAS) being statically similar with each other, were superior to other herbicidal treatments in influencing green pod yield.

The present investigation conclusively inferred that application of pendimethalin 1000 g/ha (pre) *fb* combination of imazethapyr + imazamox 60 g/ha applied as post-emergence (45 DAS) can be an effective alternative to pendimethalin 1000 g/ha *fb* one HW (45 DAS) as it provided good control of mixed weed flora and increased the pod and straw yield as good as weed free situation.

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