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Economics of post-emergence weed control in garden pea (*Pisum sativum* L.) under mid hill condition of Himachal Pradesh

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Abstract

A field experiment consisting of twelve treatments [*viz*. pendimethalin 1500 g/ha (pre-emergence, pre), pendimethalin 1000/ imazethapyr 100 g/ha (pre) followed by (fb) imazethapyr 100 g/ha post-emergence (post), imazethapyr + pendimethalin (Vellore) 1200 and 1500 g/ha (pre), imazethapyr + pendimethalin 1000 g/ha (pre) fb imazethapyr 100 g/ha (post), imazethapyr + imazamox (Odissy) 60 and 90 g/ha (post), pendimethalin 1000 g/ha fb imazethapyr + imazamox 60 g/ha (post), pendimethalin 1000 g/ha fb hand weeding (45 DAS), weed free and weedy check] was carried out during the winter season of 2012-13 and 2013-14 on a silty clay loam soil at Palampur to study the impact of post-emergence (post) weed control in pea. Weed free, pendimethalin fb hand weeding, pendimethalin fb imazethapyr + imazamox, imazethapyr + pendimethalin fb imazethapyr and imazethapyr + imazamox 60 g/ha gave more than 85% weed control efficiency upto 60 DAS. Weed free, pendimethalin 1000 g/ha *fb* HW **(**45 DAS) and pendimethalin 1000 g/ha *fb* imazethapyr + imazamox 60 g/ha (45 DAS) gave significantly higher green pod yield. Imazethapyr 100 g/ha *fb* imazethapyr 100 g/ha (45 DAS) had minimum weed persistence index (WPI). Crop resistance index (CRI) was highest under pendimethalin 1000 g/ha *fb* HW (45 DAS) followed by pendimethalin 1000 g/ha *fb* imazethapyr + imazamox 60 g/ha (45 DAS). Application of pendimethalin 1000 g/ha *fb* HW (45 DAS) followed by pendimethalin 1000 g/ha *fb* imazethapyr + imazamox 60 g/ha (45 DAS) resulted in higher net returns. Marginal benefit cost ratio (MBCR) was highest under imazethapyr + imazamox 60 g/ha (25.28).

Key words: Garden pea, imazethapyr, imazamox, pendimethalin, impact assessment

Himachal Pradesh has rich biodiversity and varied agro-climatic conditions which are highly suitable for growing peas round the year. In the recent past garden pea for its green pod has gained popularity among farming community. 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 – October), when it cannot be grown in the plains due to high temperature. As a sequel of the fact, the produce is sold at a higher premium bringing lucrative returns to the growers (Sangar 2003). Wider spacing in peas provides ample opportunities for weed infestation resulting in 18-76% yield losses (Singh *et al*., 1991; Kundra *et al.*, 1993; Banga *et al.*, 1998).

Hence effective weed management is pre-requisite to reduce losses caused by weeds and thereby improving productivity and profitability. Hand weeding is a commonly adopted method of weed control by farmers in field pea. This method is not only costly but also time consuming.

Chemical method of weed control is an effective and economical as compared to mechanical method. The pre-emergence application of herbicides is more common in pea. However, the major limitation with the use of pre-emergence application is the requirement of optimum moisture in the soil for its activity either through rainfall or irrigation water. High rainfall however can move a concentrated band of herbicide from the soil surface to the root zone and may result in crop injury. The post-emergence herbicides may be effective under these conditions. The post emergence herbicides have more flexible window of application and can be applied according to the types and density of weeds present. Mishra (2006) reported the effective control of wild oat with the post

-emergence herbicides in field pea. Imazethapyr and pendimethalin have been reported to be the effective chemical treatments for weed control in pea (Rana et al. 2013). New post-emergence herbicides *viz.*, imazethapyr alone and in combination with imazamox (odissey) have been introduced. The present investigation was carried out to study the impacts of post emergence weed control in pea under mid hill conditions of Himachal Pradesh.

Materials and Methods

The field experiment was conducted during *rabi* 2012 -13 and 2013-14 at Palampur. The soil of the experimental field was silty clay loam in texture, acidic in reaction (pH 6.0) and medium in available N (322.9 kg/ha) and K (276.4 kg/ha) and high in available P (25.8 kg/ha). Twelve treatments viz. pendimethalin 1500 g/ha (pre), pendimethalin 1000 g/ha (pre) *fb* imazethapyr 100 g/ha (45 DAS), imazethapyr 100 g/ha (pre) *fb* imazethapyr 100 g/ha (45 DAS), imazethapyr + pendimethalin 1200 & 1500 g/ha (pre), imazethapyr + pendimethalin 1000 g/ha (pre) *fb* imazethapyr 100 g/ha (45 DAS), imazethapyr + imazamox 60 & 90 g/ha (45DAS), pendimethalin 1000 g/ha (pre) *fb* imazethapyr + imazamox 60 g/ha (45 DAS), pendimethalin 1000 g/ha (pre) *fb* HW (45 DAS), weed free and weedy check were evaluated in randomized block design with three replications. Sowing of pea variety 'Palam Priya' was done during the last week of October on raised beds using 60 kg/ha seed rate in a row to row spacing of 45 cm. Application of herbicides was made with power sprayer using 750 L water per hectare. Except weed control treatments, the crop was raised in accordance with the recommended package of practices. The crop was fertilized with 45 kg N, 60 kg P_2O_5 and 60 kg K_2O/ha as basal dose.

Weed count was recorded at 60 DAS, 90 DAS, 120 DAS and at harvest from two randomly selected spots (0.5 m^2) in each plot and expressed as number/m^2. The data on count were subjected to square root transformation. Yields were harvested from net plot (3.1 m x 2.7 m). Impact assessment indices were worked out as per Walia (2003).

Weed persistence index (WPI)

$$WPI = \frac{\text{Weed weight in treated plot}}{\text{Weed weight in control plot}} \times \frac{\text{Weed count in control plot}}{\text{Weed count in treated plot}}$$

Crop resistance index (CRI)

$$CRI = \frac{\text{Crop weight in treated plot}}{\text{Crop weight in control plot}} \times \frac{\text{Weed weight in control plot}}{\text{Weed weight in treated plot}}$$

Pest (weed) management index (PMI or WMI)

$$PMI = \frac{\text{Percent yield over control}}{\text{Percent control of the pest}}$$

Agronomic management index (AMI)

$$AMI = \frac{\text{Percent yield over control} - \text{Percent control of the pest}}{\text{Percent control of the pest (weed)}}$$

Integrated Management index (IPMI)

$$IPMI = \frac{PMI + AMI}{2}$$

Treatment (Herbicide) efficiency index (TEI)

$$TEI = \frac{\frac{\text{Yield of treatment} - \text{Yield of control}}{\text{Yield of control}} \times 100}{\frac{\text{Weed weight in treatment}}{\text{Weed weight in control}} \times 100}$$

HEI indicates the weed killing potential of a herbicide treatment and its phytotoxicity on the crop.

Economics of the treatments was computed based on the prevalent market prices of the inputs used and output produced.

Results and Discussion

Weed count

The weed flora of the experimental field was mainly composed of *Phalaris minor*, *Alopecurus myosuroides*, *Avena ludoviciana*, *Lolium temulentum* and *Vicia sativa*. There was also a little infestation of *Stellaria media*, *Poa annua*, *Anagallis arvensis* and *Coronopus didymus.*

Weed control treatments brought about significant variation in total weed control at all the stages of observation (Table 1.). All weed control treatments were significantly superior to weedy check in reducing the density of weeds at all the stages of observation. Weed density was significantly lower under weed free, pendimethalin 1000 g/ha *fb* HW (45 DAS), pendimethalin 1000 g/ha *fb* imazethapyr + imazamox 60 g/ha (45 DAS) over other herbicide combinations. The activity of pendimethalin *fb* HW (Vaishya *et al.* 1999; Prakash *et al.* 2000; Rana 2002) and imazethapyr (Zabara and Yankovskaya 2007) against weeds in pea has been established. Due to synergetic, enhancement or additive effects, herbicidal combinations in general were better than sole application of herbicides in reducing the population of weeds.

Weed control efficiency (WCE) ranged from 40.6% under imazethapyr 100 g/ha (pre) *fb* imazethapyr 100 g/ha (45 DAS) to 87.9% under pendimethalin 1000 g/ha (pre) *fb* 1HW at maximum weed count (90 DAS). Until 60 DAS, weed free, pendimethalin fb hand weeding, pendimethalin fb imazethapyr + imazethamox, imezethapyr + pendimethalin fb imazethapyr and imazethapyr + imazamox 60 g/ha were the effective treatments gave more than 85% weed control efficiency. The other treatments had lower weed control efficiency and thus were not satisfactory.

Impact assessment

Weed free, pendimethalin 1000 g/ha *fb* HW **(**45 DAS) and pendimethalin 1000 g/ha *fb* imazethapyr + imazamox 60 g/ha (45 DAS) gave significantly higher green pod yield (Table 2). Imazethapyr + imazamox 90 g/ha (45 DAS) and imazethapyr + pendimethalin 1000 g/ha *fb* imazethapyr 100 g/ha (45 DAS) being statistically similar were the other superior treatments in influencing green pod yield. Weeds in weedy check reduced the green pod yield of pea by 36.6% over pendimethalin 1000 g/ha *fb* imazethapyr + imazamox 60 g/ha (45 DAS). Imazethapyr 100 g/ha *fb* imazethapyr 100 g/ha (45 DAS) had minimum weed persistence index (WPI) probably owing to more persistence and broader activity spectrum of the chemical. It was followed by pendimethalin 1000 g/ha *fb* imazethapyr 100 g/ha (45 DAS), pendimethalin 1500 g/ha (pre) and imazethapyr + pendimethalin 1500 g/ha (pre). Crop resistance index (CRI) was highest under pendimethalin 1000 g/ha *fb* HW (45 DAS). It was followed by pendimethalin 1000 g/ha *fb* imazethapyr + imazamox 60 g/ha (45 DAS) and imazethapyr + imazamox 60 g/ha (45 DAS). Agronomic management index (AMI) and weed management index (WMI) were lowest under weed free followed by pendimethalin 1000 g/ha *fb* HW (45 DAS), imazethapyr + imazamox 60 g/ha (45 DAS), pendimethalin 1000 g/ha *fb* imazethapyr + imazamox 60 g/ha (45 DAS) and imazethapyr + pendimethalin 1200 g/ha (pre).

Economics

Owing to higher seed yield, weed free resulted in highest gross return and gross return due to weed control (Table 3.). It was followed by pendimethalin 1000 g/ha *fb* HW (45 DAS) and pendimethalin 1000 g/ha *fb* imazethapyr + imazamox 60 g/ha (45 DAS). Weed free was a costly practice while pendimethalin 1500 g/ha (pre) the costliest herbicide followed by imazethapyr + imazamox 60 g/ha (45 DAS).

Table 1. Effect of treatments on total weed count (No./m^2) and weed control efficiency

Treatment	Dose (g/ha)	Time of application	Weed count (DAS)				Weed control efficiency (DAS)			
			60	90	120	At harvest	60	90	120	At harvest
Pendimethalin	1500	Pre emergence	13.7 (186.7)	18.2 (329.6)	15.5 (240.0)	10.6 (112.0)	65.3	42.7	52.8	71.0
Pendimethalin *fb* imazethapyr	1000 *fb* 100	Pre *fb* post (45 DAS)	12.9 (165.3)	15.8 (250.7)	14.3 (202.7)	9.5 (90.7)	69.3	56.4	60.2	76.5
Imazethapyr *fb* imazethapyr	100 *fb* 100	Pre *fb* post (45 DAS)	13.1 (170.7)	18.5 (341.3)	16.5 (272.0)	13.7 (186.7)	68.3	40.6	46.5	51.6
Imazethapyr + pendimethalin	1200	Pre emergence	10.4 (106.3)	14.6 (213.3)	14.0 (196.3)	10.4 (106.7)	80.2	62.9	61.4	72.3
Imazethapyr + pendimethalin	1500	Pre emergence	10.1 (101.3)	13.7 (186.7)	13.1 (170.7)	10.8 (117.3)	81.2	67.5	66.5	69.6
Imazethapyr + pendimethalin *fb* imazethapyr	1000 *fb* 100	Pre *fb* post (45 DAS)	7.0 (48.0)	12.0 (144.0)	11.3 (127.5)	7.4 (53.3)	91.1	75.0	74.9	86.2
Imazethapyr + imazamox	60	Post (45 DAS)	8.0 (64.0)	12.7 (160.0)	11.8 (137.6)	8.3 (69.3)	88.1	72.2	73.0	82.0
Imazethapyr + imazamox	90	Post (45 DAS)	9.8 (96.0)	13.9 (192.0)	12.5 (154.7)	9.5 (90.1)	82.2	66.6	69.6	76.6
Pendimethalin *fb* imazethapyr + imazamox	1000 *fb* 60	Pre *fb* post (45 DAS)	3.6 (16.0)	10.1 (101.3)	8.3 (69.3)	6.2 (37.3)	97.0	82.4	86.4	90.3
Pendimethalin *fb* HW	1000	Pre *fb* HW (45 DAS)	2.0 (5.3)	8.4 (69.3)	7.7 (58.7)	5.2 (26.7)	99.0	87.9	88.5	93.1
Weed free	-	-	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	100.0	100.0	100.0	100.0
Weedy check	-	-	23.2 (538.7)	24.0 (574.9)	22.6 (508.8)	19.7 (385.6)	0.0	0.0	0.0	0.0
SE(m±)			0.89	0.58	0.57	0.62				
CD (P=0.05)			1.9	1.2	1.2	1.3				

The data on weed count have been transformed to square root transformation. Value given in parentheses are the means of original values.

Table 2. Effect of weed control treatments on yield and impact indices in pea

Treatment	Dose (g/ha)	Time of application	Pod yield (t/ha)		WPI	CRI	WMI	AMI	IWMI	HEI
Pendimethalin	1500	Pre	6.57	6.57	0.90	2.62	2.96	1.96	2.46	0.87
Pendimethalin *fb* imazethapyr	1000 *fb* 100	Pre *fb* post	6.29	6.49	0.88	3.39	2.31	1.31	1.81	1.05
Imazethapyr *fb* imazethapyr	100 *fb* 100	Pre *fb* post	6.21	6.37	0.87	2.47	2.89	1.89	2.39	0.74
Imazethapyr + pendimethalin	1200	Pre	5.97	6.25	0.96	3.59	2.09	1.09	1.59	0.98
Imazethapyr + pendimethalin	1500	Pre	6.13	6.41	1.41	2.83	2.55	1.55	2.05	0.83
Imazethapyr + pendimethalin *fb* imazethapyr	1000 *fb* 100	Pre *fb* post	6.09	6.81	1.41	3.81	2.19	1.19	1.69	1.20
Imazethapyr + imazamox	60	Post	6.01	6.69	1.20	4.06	2.07	1.07	1.57	1.23
Imazethapyr + imazamox	90	Post	6.53	6.81	1.13	3.76	2.32	1.32	1.82	1.28
Pendimethalin *fb* imazethapyr + imazamox	1000 *fb* 60	Pre *fb* post	7.01	7.25	1.43	5.98	2.08	1.08	1.58	2.33
Pendimethalin *fb* HW	1000	Pre *fb* HW	7.17	7.33	1.93	6.60	2.06	1.06	1.56	2.64
Weed free	-	-	7.21	7.37	-	-	1.61	0.61	1.11	-
Weedy check	-	-	4.34	4.74	1.00	-	-	-	-	0.00
SE(m±)			0.26	0.43	-	-	-	-	-	-
LSD (P=0.05)			0.56	0.90	-	-	-	-	-	-

WPI- Weed persistence index, CRI- Crop resistance index, WMI- Weed management index, AMI- Agronomic management index, IWMI- Integrated Weed management index, HEI- Herbicide efficiency index

Table 3. Economics of weed control treatments

Treatment	Dose (g/ha)	Time of application	GR	GRwc	CWC	NRwc	MBCR
Pendimethalin	1500	Pre emergence	134926	36718	1425	35293	24.77
Pendimethalin *fb* imazethapyr	1000 *fb* 100	Pre *fb* post (45 DAS)	133572	35364	2050	33314	16.25
Imazethapyr *fb* imazethapyr	100 *fb* 100	Pre *fb* post (45 DAS)	130864	32656	1720	30936	17.99
Imazethapyr + pendimethalin	1200	Pre emergence	128714	30506	1560	28946	18.55
Imazethapyr + pendimethalin	1500	Pre emergence	131820	33612	1770	31842	17.99
Imazethapyr + pendimethalin *fb* imazethapyr	1000 *fb* 100	Pre *fb* post (45 DAS)	140183	41975	2280	39695	17.41
Imazethapyr + imazamox	60	Post (45 DAS)	137634	39427	1500	37927	25.28
Imazethapyr + imazamox	90	Post (45 DAS)	140104	41896	1890	40006	21.17
Pendimethalin *fb* imazethapyr + imazamox	1000 *fb* 60	Pre *fb* post (45 DAS)	149104	50896	2690	48206	17.92
Pendimethalin *fb* HW	1000	Pre *fb* HW (45 DAS)	150777	52569	5950	46619	7.84
Weed free	-	-	151573	53365	11900	41465	3.48
Weedy check	-	-	98208	0	0	0	

GR, gross return (INR/ha); GR_{WC}, gross return due to weed control (INR/ha); CWC, cost of weed control (INR/ha); NR_{WC}, net return due to weed control (INR/ha); MBCR, Marginal benefit cost ratio

Maximum cost of weed control was under weed free treatment because of use of more workers. The cost variation has changed the trends in net return. Net returns accrued under different treatments followed almost the same trend as gross returns. Net returns from weed free treatment was lower as compared to other weed control treatments due to higher cost. Application of pendimethalin 1000 g/ha *fb* HW (45 DAS) resulted in higher net returns. This was followed by pendimethalin 1000 g/ha *fb* imazethapyr + imazamox 60 g/ha (45 DAS). Weed control treatments were superior to weedy check in influencing net returns due to weed control. Similar results were reported by Rana (2002). He also obtained higher net returns with better control of weeds. Due to lower cost of treatment, imazethapyr + imazamox 60 g/ha (25.28) resulted in the highest marginal benefit cost ratio (MBCR) closely followed by pendimethalin 1500 g/ha (24.77) and imazethapyr + imazamox 90 g/ha (21.17). Due to higher cost in manual weeding, weed free gave lowest MBCR (3.48). In the weed free, MBCR was 86.2% of the imazethapyr + imazamox 60 g/ha.

The findings of present investigation conclusively inferred that pendimethalin 1000 g/ha (pre) fb hand weeding and pendimethalin 1000 g/ha (pre) fb imazethapyr + imazamox 60 g/ha (post) were the better alternatives to get higher net returns.

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