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Response of pea (*Pisum sativum* L.) to levels of phosphorus in relation to integrated weed management

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Abstract

Pea has higher requirement of P for symbiotic N fixation. However, weeds are the major threat in harnessing the full potential of native and applied P. Management of weeds through integrated means (INM) is imperative to enhance P use efficiency. Three P_2O_5 levels *viz.* 0, 30 and 60 kg/ha each with six weed management practices *viz.* weedy check, pendimethalin followed by (fb) hand weeding (HW), stale seedbed (SSB), SSB + pendimethalin fb HW, raised stale seedbed (RSSB), and RSSB + pendimethalin fb HW were evaluated during *rabi* 2006-07 and 2007-08 on a silty clay loam soil at Palampur. *Phalaris minor* was the most important weed constituting 60.9 and 64.4% of the total weed flora during 2006-7 and 2007-8, respectively. SSB and RSSB were equal to pendimethalin fb HW in reducing its count upto 120 DAS. Superimposition of pendimethalin fb HW further improved the effectiveness of SSB and RSSB in reducing the count of *P. minor.* Pendimethalin fb HW with or without SSB/RSSB significantly reduced the count of *Vicia* sp. and *Polygonum* sp. over other treatments. In the raised beds, the peas were early in emergence. In the weedy check peas were earlier in maturity. SSB and RSSB were as good as pendimethalin fb HW in influencing pea pod and straw yield. Yields were further increased under SSB/RSSB + pendimethalin fb HW. SSB, RSSB, pendimethalin fb HW, SSB + pendimethalin fb HW and pendimethalin fb HW increased green pea yield by 125, 63, 82, 154 and 173%, respectively over weedy check. All the weed control treatments except RSSB gave higher gross and net returns and B:C ratio. There was significant increase in plant height, plant dry weight, yield attributes, green pod and straw yield of pea and gross and net return, days to emergence, flowering, and maturity with increase in the level of P_2O_5. Under weedy check as well in SSB and RSSB, P_2O_5 application resulted in higher weed dry weight over no P_2O_5 application. But under SSB/RSSB fb pendimethalin fb HW, weed dry weight was more or less similar due to P_2O_5 levels. Crop fertilized with 60 kg P_2O_5/ha under RSSB fb pendimethalin fb HW resulted in highest green pod yield.

Key words: Peas, phosphorus, stale seedbed, raised bed, pendimethalin, handweeding.

Introduction

The continued decline in the availability of petroleum products, which form the basic material for chemical fertilizers, warrants greater dependence on legumes for N fixation and also in reducing the external applications of phosphatic fertilizers. Pea is a leguminous plant and therefore, has higher requirement of P for symbiotic N fixation. However, weeds continue to be a major threat in harnessing the full potential of the crop to absorb enough of native and applied plant nutrients. Due to full season weed competition, Rana *et al*. (2013) reported 56.8-60.1% reduction in peas green pod yield. Thus, the judicious management of weeds is imperative to enhance the nutrient use efficiency. Stale seedbed is useful in depleting the weed seed pool in the top few centimeters of soil (Rasmussen, 2004). Raised stale seedbed has an added advantage of better drainage, fewer diseases and easy irrigation which ultimately enhance nutrient use efficiency. The subsequent flushes of weeds after sowing of the crop may be controlled with herbicides or hand weeding. The present investigation was therefore, conducted to economize the dose of P in relation to integrated weed management.

Materials and Methods

The field experiment was conducted during *rabi* 2006-07 and 2007-08 at Bhadiarkhar farm (Palampur). The soil of the experimental field was silty clay loam, acidic (pH 5.2), medium is available N (313.6 kg N ha^{-1}) and K (202.1 kg ha^{-1}) and high in P (25.7 kg ha^{-1}). The experiment was conducted in split plot design with four replications. Six weed control treatments *viz*. weedy check, pendimethalin 1.50 kg/ha followed by (fb) hand weeding (HW), stale seedbed (SSB), SSB fb pendimethalin fb HW, raised stale seedbed (RSSB), and RSSB fb pendimethalin fb HW (Table 1) were accommodated in main plots while three P_2O_5 levels *viz.* 0, 30 and 60 kg/ha in the sub plots. Sowing of pea variety 'Palampriya' was done during the second fortnight of November using 75 kg/ha seed rate in a row to row spacing of 30 cm. Application of pendimethalin was made with power sprayer using 700 L water per hectare. Under the SSB/RSSB two flushes of weeds were destroyed with paraquat 0.60 kg/ha during 2006-7 while only one flush could be destroyed during 2007-8. Except weed control and phosphorus, the crop was raised in accordance with the recommended package of practices. In addition to phosphorus, the crop was fertilized with 20 kg N, and 40 kg K_2O/ha as basal dose. Weed count and dry weight were recorded at 60, 90, 120 DAS and at harvest from two randomly selected spots (0.25 m^2) in each plot and expressed as number m^{-2} and g m^{-2}, respectively. The data on count and dry weight of weeds was subjected to square root transformation ($\sqrt{x+1}$). Yields were harvested from net plot (4.0 m x 2.1 m). Economics of the treatments was computed based on the prevalent market prices of the inputs used and output produced.

Results and discussion

Weed control methods

Phalaris minor was the most important weed constituting 60.9 and 64.4% of the total weed flora of the experimental field during 2006-07 and 2007-08, respectively. Weed control treatments brought about significant variation in its count during both the years (Table 1). Trends were almost similar during both the years.

Stale seedbed (SSB) and raised stale seedbed (RSSB) where one or two flushes of the weeds were destroyed before sowing of pea, were comparable to pendimethalin fb HW in reducing its count upto 120 DAS during both the years. Depleting the weed seed pool in the top few centimeters before seeding i.e. stale seedbed has been reported quite effective by a number of workers (Kumar *et al.*, 2005; Kumar *et al.,* 2003; Sheela *et al.,* 2006). Superimposition of pendimethalin fb HW over SSB or RSSB effectively reduced the count of *P. minor* than either of the alone during the second season. Superiority of pendimethalin 1.0 kg/ha in controlling weeds in pea + maize intercropping on raised bed has been reported (Singh *et al.,* 2012). *Vicia* sp. was the next dominant weed which constituted 20.4 and 19.8% of the total weed flora. Pendimethalin fb HW alone or alongwith SSB/RSSB significantly reduced the count of *Vicia* sp. over weedy check during both the years. *Polygonum alatum* was the third important weed constituting 15.2 and 13.6% of the total weed flora during the first and second year, respectively. All

Table 1. Effect of weed control methods and P levels on the count ($\sqrt{x+0.5}$, transformed) of weeds

Treatment	*Phalaris* (120 DAS)		*Vicia* 90 DAS)		*Polygonum* (90 DAS)		Total weed Count (120 DAS)	
	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08
Weed control method								
Weedy	13.3	14.1	7.4	8.0	7.0	7.0	16.9	18.2
	(182.7)	(199.3)	(55.0)	(64.0)	(49.2)	(50.3)	(291.0)	(334.5)
Pendimethalin + HW	9.1	10.3	5.6	6.3	3.3	3.5	11.0	11.9
	(83.3)	(107.0)	(31.3)	(40.0)	(11.3)	(12.3)	(120.7)	(143.2)
Stale seedbed (SSB)	10.9	9.7	6.9	7.8	5.5	5.9	14.5	13.7
	(135.0)	(97.8)	(48.3)	(61.0)	(30.3)	(35.3)	(222.3)	(191.0)
SSB + pendimethalin + HW	11.1	8.1	5.5	6.0	2.7	3.4	11.9	9.7
	(125.7)	(65.8)	(31.0)	(35.7)	(8.3)	(12.0)	(146.0)	(95.3)
Raised stale seedbed (RSSB)	11.0	10.1	6.9	7.8	5.5	5.8	14.5	13.9
	(125.0)	(105.5)	(48.7)	(62.0)	(31.3)	(34.3)	(213.7)	(195.3)
RSSB + pendimethalin + HW	10.4	8.4	5.8	6.4	3.1	3.4	11.7	10.4
	(112.3)	(73.5)	(34.3)	(42.0)	(9.7)	(11.7)	(140.7)	(110.7)
LSD (P=0.05)	1.9	1.5	1.3	1.2	1.0	0.9	1.9	1.5
P_2O_5 (kg/ha)								
0	10.3	9.7	6.4	7.0	4.6	4.9	13.0	12.5
	(111.3)	(98.3)	(41.3)	(50.3)	(23.9)	(26.0)	(173.6)	(162.8)
30	11.1	10.3	6.4	7.2	4.3	4.7	13.5	13.3
	(130.7)	(112.3)	(42.3)	(53.0)	(21.5)	(24.5)	(194.3)	(184.3)
60	11.5	10.3	6.3	6.9	4.6	4.9	13.7	13.2
	(140.1)	(113.9)	(40.7)	(49.0)	(24.7)	(27.5)	(199.3)	(187.9)
LSD (P=0.05)	NS	0.6	NS	NS	NS	NS	NS	0.6

weed control treatments were significantly superior to weedy check in reducing its count. Pendimethalin fb HW alone and alongwith SSB/RSSB was significantly superior to SSB/RSSB alone during both the years. Effective control of *P. alatum* with pendimethalin has been documented (Rana *et al.,* 1999). The other weeds (*Lathyrus aphaca*, *Spergula arvensis* and *Avena ludoviciana*) as a whole constituted 3.5 and 2.2% of the total weed flora during the first and second year, respectively. Owing to significant reduction in the population of *P. minor*, *V. sativa* and *P. alatum*, SSB and RSSB were significantly superior to weedy check in reducing the total weed count. Pendimethalin fb hand weeding along with SSB/RSSB resulted in further significant reduction in the total weed count over SSB or RSSB alone. Effective reduction in weed dry weight with pendimethalin fb HW has been documented (Vaishya *et al.,* 1999).

Controlling the one or two flushes of weeds before sowing peas under the SSB or RSSB resulted in significantly higher plant height and plant dry matter accumulation over the weedy check (Table 2). The subsequent suppression of other flushes with

Table 2. Effect of weed control methods and P levels on growth and development of peas

	Plant height (cm) 120 DAS		Plant DW (g/m^2) 120 DAS		Emergence (days)	Flowering (days)	Maturity (days)
	2006-07	2007-08	2006-07	2007-08	2006-07	2006-07	2005-06
Weed control methods							
Weedy	37.5	36.4	126.4	117.4	21.5	90.8	129.2
Pendimethalin + HW	44.4	39.6	200.0	179.6	21.8	89.3	131.2
Stale seedbed (SSB)	47.8	42.4	182.7	183.3	21.4	90.5	130.3
SS + pendimethalin + HW	51.8	44.3	261.5	246.1	21.3	91.2	131.1
Raised stale seedbed (RSSB)	40.5	38.2	185.4	177.1	20.7	90.8	130.8
RSSB + pendimethalin + HW	51.3	43.8	267.6	251.2	20.8	90.5	131.1
LSD (P=0.05)	3.9	2.0	45.4	47.0	0.5	NS	1.1
P_2O_5 (kg/ha)							
0	42.7	38.2	183.7	169.7	20.5	89.9	129.7
30	48.1	42.1	206.1	204.6	21.3	90.5	130.5
60	45.8	42.1	222.0	203.0	21.8	91.2	131.6
LSD (P=0.05)	3.8	1.7	26.9	16.3	0.4	0.8	0.7

pendimethalin fb HW gave further boost in plant height and plant dry matter accumulation.

The pea crop took 20.7-21.5 days for emergence which clearly indicating that it is slow in emergence and has slow initial growth. The data clearly indicated that in the raised beds, the peas were early in emergence. While high weed pressure in the weedy check forced the pea crop for early maturity.

The superior weed control and subsequently the better crop growth was reflected in yield attributes and pod and haulm yield of peas. Due to higher yield attributes all weed control treatments were significantly superior to weedy check in increasing green pod and haulm yield of peas (Table 3). SSB and RSSB were as good as pendimethalin fb HW in influencing pea pod and haulm yield. SSB and RSSB increased green pod yield by 124.7 and 63.2%, respectively, over weedy check. Yields were further higher with the integration of SSB/RSSB and pendimethalin fb HW over either of the alone. The green pod yield under SSB and RSSB was only 88.6 and 59.8% of that under SSB fb pendimethalin fb HW and RSSB fb pendimethalin fb HW, respectively. Increase in yield of pea owing to improved growth and yield attributes due to effective control of weeds has been documented (Rana, 2002; Rana *et al.,* 2007; Vaishya *et al.,* 1999).

Due to higher yield, all weed control treatments except RSSB during the second year gave higher net returns and B:C ratio over the weedy check (Table 4). RSSB fb pendimethalin fb HW, SSB fb pendimethalin fb HW, SSB, RSSB and pendimethalin fb HW gave net return 12, 8.8, 9.4, 3.7 and 6.9 times higher and B:C ratio 8.6, 6.6, 8.9, 3.1 and 5.6 times higher, respectively, over weedy check.

Phosphorus

The data on count of weeds as affected by phosphorus levels have been given in Table 1. Phosphorus application could not bring about significant variation in the count of weeds during the

Table 3. Effect of weed control methods and P levels on yield attributes and yield

	Pods/plant		Pod weight (g)		Pod yield		Haulm yield	
	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08
Weed control methods								
Weedy	11.5	5.9	2.5	2.2	1609	1788	653	606
Pendimethalin + HW	12.7	6.5	2.8	2.9	3341	3167	1754	1783
Stale seedbed (SSB)	12.1	6.1	2.7	2.6	3501	4132	1841	2278
SS + pendimethalin + HW	18.8	9.7	2.9	3.1	4033	4578	2107	2001
Raised stale bed (RSSB)	17.6	9.1	2.4	2.6	2816	2729	1652	1077
RSSB + pendimethalin + HW	19.3	9.8	2.7	3.0	4687	4592	2280	2508
LSD (P=0.05)	3.8	1.8	0.3	0.4	1150	692	614	894
P_2O_5 (kg/ha)								
0	13.4	6.8	2.5	2.6	2892	2854	1564	1316
30	15.7	8.0	2.7	2.7	3408	3726	1650	1748
60	16.9	8.7	2.8	2.8	3694	3912	1929	2062
LSD (P=0.05)	1.8	0.9	0.2	NS	246	257	271	310

Table 4. Economics of treatments

	Gross return		COC		Net return		B:C ratio	
	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08
Weed control methods								
Weedy	16872	9488	11905	10357	4967	-869	0.41	-0.09
Pendimethalin + HW	35362	22948	16104	14011	19258	8937	1.16	0.64
Stale seedbed (SSB)	37221	27809	14139	12301	23082	15507	1.59	1.26
SS + pendimethalin + HW	42962	26476	17745	15438	25217	11037	1.41	0.71
Raised stale bed (RSSB)	30142	12181	14543	12652	15599	-471	1.05	-0.05
RSSB + pendimethalin + HW	49661	34688	18811	16365	30850	18322	1.63	1.12
LSD (P=0.05)	12078	9610	569	495	11510	9793	0.68	0.71
P_2O_5 (kg/ha)								
0	30628	17801	14532	12642	16097	5158	1.04	0.37
30	36199	22528	15579	13554	20620	8974	1.27	0.62
60	39282	26466	16513	14366	22769	12100	1.31	0.80
LSD (P=0.05)	2529	3811	122	106	2408	3811	0.14	0.29

first year. However, the count of *P. minor* and thereby total weed count was significantly higher under P application over its no application during the second year. P is an indispensable nutrient for legumes because of its key role in N fixation. Therefore, increasing plant height and dry matter accumulation due to P application was quite obvious over its no application (Table 2). However, 30 and 60 kg P_2O_5/ha levels were statistically at par with each other in influencing plant height and dry matter accumulation by pea crop. The increase in growth and yield attributes of pea owing to P application over no P application has been amply documented (Dass *et al.,* 2005; Dubey *et al.,* 1999). It is interesting to note that days to emergence, flowering, and maturity were increased with increase in the level of P_2O_5. The accumulated amount of growth and development due to P was reflected in yield attributes and yield of pea. Number of pods/plant, per pod weight and thereby green pod and haulm yield of peas was significantly higher due the application of P over no application of P (Table 3). Grain and straw yield of peas in general increased with increase in the level of P_2O_5. Increase in green pod yield of pea owing to improved growth and yield contributing traits was also observed by several workers (Dass *et al*., 2005; Aga *et al*., 2004). 30 and 60 kg P_2O_5/ha increased green pod yield by 24.2 and 32.4%, respectively, over no P. The corresponding increase in haulm yield was 18.0 and 38.6%, respectively. Owing to higher green pod and straw yield, gross and net returns were significantly higher with increase in the dose of P_2O_5 (Table 5). However, 30 and 60 kg P_2O_5/ha were statistically at par with each other in influencing B:C ratio. P_2O_5 at 30 and 60 kg/ha increased net returns by 39.2 and 64.1%, respectively, over no P_2O_5 application.

Interaction

Weed control methods interacted significantly with P_2O_5 levels for weed dry weight accumulation at 90 DAS and green pod yield of peas (Table 5). When weeds were left uninterrupted after sowing as under weedy check, SSB and RSSB, P_2O_5 application resulted in higher weed dry weight over no P_2O_5 application. But under SSB fb pendimethalin + HW or RSSB fb pendimethalin fb HW, where weeds were also removed by hands, weed dry weight was more or less similar under P_2O_5 application and no P_2O_5 application. It is clearly evident that under the weedy check P_2O_5 application favoured weed growth at the expense of green pod yield as P_2O_5 application could not significantly increase yield over no P_2O_5 application. However, under other treatments where weed competition was reduced at the critical period of competition, P_2O_5 application gave significantly higher yield over no P_2O_5 application. The response of P application under weedy check, pendimethalin fb HW and SSB was quadratic. The green pod yield – phosphorus relationship for these weed management techniques has been shown by quadratic ($Y=a+bP+cP^2$, a is intercept; b slope and c the curvature, Y is yield in kg/ha and P is P_2O_5 in kg/ha) functions as below:

Weed control method	Quadratic response function				
	a	b	c	Optimum dose	RSQ
Weedy check	1520	15.4	-0.189	38.53	0.604
Pendimethalin fb HW	2644	46.68	-0.527	43.50	0.731
Stale seedbed (SSB)	3153	53.82	-0.634	41.79	0.674

The yield -P_2O_5 relationship under SSB fb pendimethalin fb HW and RSSB alone or along with pendimethalin fb HW was linear because P was applied not beyond the recommended dose (60 kg P_2O_5/ha). The green pod yield– phosphorus relationship for these weed management techniques has been shown by

Weed control method	Linear function		
	a	b	RSQ
SSB fb pendimethalin fb HW	3698	20.24	0.938
Raised stale seedbed (RSSB)	2108	22.13	0.983
RSSB fb pendimethalin fb HW	4168	15.72	0.998

Table 5. Integrated effect of weed control methods and phosphorus levels on weed dry weight (90 DAS, $\sqrt{x+0.5}$, transformed) and green pod yield

	2006-07			2007-08			Mean		
	P_0	P_{30}	P_{60}	P_0	P_{30}	P_{60}	P_0	P_{30}	P_{60}
				Weed dry weight					
Weedy	14.6	16.5	18.1	16.2	18.0	18.9	15.4	17.3	18.5
	(214.2)	(273.9)	(327.6)	(262.6)	(328.0)	(362.2)	(238.4)	(301.0)	(344.9)
Pendimethalin + HW	9.4	10.0	12.3	9.1	9.2	10.5	9.3	9.6	11.4
	(91.8)	(102.4)	(163.5)	(86.9)	(86.9)	(124.6)	(89.3)	(94.7)	(144.0)
Stale seedbed (SSB)	13.2	14.7	16.0	11.6	14.5	15.8	12.4	14.6	15.9
	(174.7)	(217.8)	(262.4)	(136.3)	(210.2)	(255.3)	(155.5)	(214.0)	(258.9)
SSB + pendimethalin + HW	7.9	7.2	8.1	8.6	6.9	8.5	8.2	7.0	8.3
	(62.8)	(51.8)	(66.4)	(73.9)	(47.6)	(74.6)	(68.3)	(49.7)	(70.5)
Raised stale bed (RSSB)	10.3	16.0	16.6	10.2	15.2	15.4	10.2	15.6	16.0
	(106.4)	(255.9)	(276.3)	(105.3)	(232.6)	(236.4)	(105.8)	(244.3)	(256.3)
RSS + pendimethalin + HW	6.7	7.9	7.3	7.6	7.3	6.9	7.2	7.7	7.1
	(45.2)	(63.0)	(53.2)	(58.3)	(55.3)	(47.6)	(51.7)	(59.2)	(50.4)
LSD (P=0.05) (1)	1.8			2.2			1.80		
(2)	2.2			2.4			2.20		
				Green pod yield					
Weedy	1487	1783	1556	1553	1842	1971	1520	1812	1764
Pendimethalin + HW	2762	3628	3632	2526	3512	3462	2644	3570	3547
Stale seedbed (SSB)	3081	3690	3732	3225	4703	4468	3153	4197	4100
SS + pendimethalin + HW	3804	4070	4227	3413	4902	5419	3608	4486	4823
Raised stale bed (RSSB)	2052	2729	3667	2266	2612	3308	2159	2671	3487
RSSB + pendimethalin + HW	4167	4545	5351	4144	4784	4846	4155	4664	5099
LSD (P=0.05) (1)	603			630			474		
(2)	1083			743			505		

Data given in parentheses are the means of original values; LSD - (1), P level at the same weed control method; LSD - (2), Weed control method at the same or different P level linear (Y=a+bP, a is intercept and b slope) functions as below:

The equations explain that when weeds were effectively controlled following weed management techniques especially at initial stage of crop growth, the yield level without fertilizers was considerably higher than the weedy check. The weed management techniques had the higher phosphorus optimum dose which showed that better weed management resulted in increased fertilizer use efficiency. The findings of the present investigation conclusively inferred that for satisfactory weed management and higher green pod yield of peas, crop must be fertilized with 60 kg P_2O_5/ha along with raised stale seed bed sowing followed by application of pendimethalin fb hand weeding.

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