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Integrated weed management in garlic

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ABSTRACT

Four herbicides (oxyflurofen 0.25 kg/ha, pendimethalin 1.50 kg/ha, trifluralin 1.50 kg/ha and metachlor 1.50 kg/ha) at recommended rates alone and at half of the recommended rates integrated with one hand weeding were compared with hand weeding 30, 60, 90 days after planting (DAP) and untreated check in silty clay loam soil during *Rabi* 2008-09 and 2009-10 at Palampur. *Phalaris minor* followed by *Avena ludoviciana* were the predominant associated weeds. All treatments resulted in significantly lower density of *Phalais minor, Alopecurous myosuroides* and *Coronopus didymus*. Metolachlor 1.50 kg/ha effectively reduced the density of *Poa annua*. Metolachlor + hand weeding, pendimethalin and pendimethalin + hand weeding effectively reduced the density of *Stellaria media.* Integration of hand weeding with half dose of oxyflourfen, pendimethalin and metolachlor resulted in significantly higher yield of garlic than their respective higher dose alone. Weed index was lowest and weed management index (WMI), agronomic management index (AMI) and integrated weed management index (IWMI) were highest under pendimethalin + hand weeding. Herbicide efficiency index (HEI) was highest with oxyflourfen + hand weeding. Pendimethalin + hand weeding gave highest net return due to weed control (NRwc) and was followed by pendimethalin and metolachlor + hand weeding. Pendimethalin gave highest marginal benefit cost ratio (MBCR) of 40.7 followed by pendimethalin + hand weeding and metolachlor + hand weeding. Weeds reduced the garlic bulb yield by 72.5% over the best treatment pendimethalin 0.75 kg/ha + HW.

Key words: Garlic, Hand weeding, Herbicides, Integrated weed management, Pendimethalin

Garlic (*Allium sativum*) is grown for its pungent flavoured bulbs world-wide to season foods. It is cultivated commercially throughout tropical and subtropical belt of the world. It is an important cash crop of Himachal Pradesh. It is usually grown between the months of October-May, during which the weather is cool and dry that favours its growth and yield. Garlic crop is highly vulnerable to weed infestation due to its slow emergence and slow initial growth, non-branching habit, sparse foliage, shallow root system (Rahman *et al.* 2012, Lawande *et al*. 2009), frequent irrigation and high fertilizer application. It never forms a canopy with its short, vertical leaf arrangement.

Weed infestation in garlic is one of the major factors for loss in yield and bulb yield loss due to weed infestation to the tune of 30-60% (Lawande *et al.* 2009). In garlic, very close spacing and a shallow root system make mechanical method of weed control difficult and sometimes course damage to developing bulbs (Lawande *et al.* 2009). Besides non-availability and higher cost of labour, manual weeding make the method uneconomical. Moreover, being a long duration crop, single hand weeding is not sufficient to control weeds. Thus, all these situations make it necessary to rely on herbicides for an effective and timely control of weed in garlic. Pendimethalin (Mehmood *et al*. 2002), oxyfluorfen (Vora and Mehta 1999, Qasem 1996), metolachlor and trifluralin were found effective for managing weeds in garlic. Single application of any of herbicide is not sufficient to obtain yield equal to weed free treatment (Mehmood *et al.* 2002, Vora and Mehta 1998). However, use of herbicides at low doses in conjunction with manual weeding (Madan *et al.* 1994; Ankur *et al*. 2002, Singh and Nandal 2002) is more effective, environmentally safe, socially acceptable and economically viable. Information on integrated weed management methods in garlic in the agro-climatic conditions of mid-hills of Himachal Pradesh (India) is meager. Hence, the present investigation was undertaken to identify effective integrated weed management options in garlic.

MATERIALS AND METHODS

The field experiment was conducted during *Rabi* 2008-2009 and 2009-2010 at Palampur ($32^0$6' N Latitude, $76^0$3' E longitude, 1280 m above mean sea level). The soil of the experimental site was silty clay loam in texture, acidic in reaction (pH 6.1), medium in available N (333.4

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kg/ha) and P (18.9 kg/ha) and high in K (226.4 kg/ha). The treatments consisted of four herbicides (oxyflurofen 0.25 kg/ha, pendimethalin 1.50 kg/ha, trifluralin 1.50 kg/ha and metachlor 1.50 kg/ha) at recommended rates alone and at half of the recommended rate with one hand weeding, three hand weedings (30, 60, 90 days after planting DAP) and unweeded check (Table 1). Well decomposed FYM 10 t/ha was applied uniformly at the time of field preparation. Garlic variety '*GCH-1*' was planted on 5 October 2008 and 17 October 2009. The crop was fertilized with 60 kg N, 50 kg P_2O_5 and 30 kg K_2O/ha. Required amount of N, P and K was supplied through urea, single super phosphate and muriate of potash, respectively. Except weed control treatments, the recommended cultural practices and plant protection measures were followed to raise the crop. Weeding was done manually with the help of hand tool '*Khuni*'. Herbicides were applied with the help of Maruyama power sprayer using flat fan nozzle delivering 700 litres of water per ha. Trifluralin was applied as pre-plant soil incorporation (PPI) (Just before planting), pendimethalin, oxyflurofen and metachlor as pre-emergence (just after planting). Weed density and biomass at 90 DAS and at harvest were recorded by placing 50 x 50 cm quadrates at two random places in each plot. After drying samples in hot air oven (70 ± 1^0C for 72 h), weed dry weight was recorded. Data were subjected to square root transformation ($\sqrt{x+1}$). The crop was harvested on 23 May 2009 and 26 May 2010, respectively. Yields were harvested from net plot. The different impact indices were worked out after Walia (2003)

RESULTS AND DISCUSSION

Effect on weeds

Garlic crop was infested with a large number of weeds owing to longer duration, slow initial growth, non-tillering/branching habit and sparce canopy development besides frequent irrigation and high fertilizer application. *Phalaris minor* was the most predominant weed constituting 30.9 and 40% of the total weed flora at 90 DAP and at harvest, respectively. The count of *Phalaris* during 2009-10 was twice of its count during 2008-09. Similarly, density of *Avena ludoviciana* was higher during 2009-10 as compared to 2008-09. Its density was greater at harvest than at 90 DAP during both the years. It constituted 12.8% of total weed flora at 90 DAP and 13.5% at harvest. Similar trend was observed with *Vicia sativa*. While density of *Poa annua* (11.8 and 3.5%, respectively at 90 DAP and at harvest), *Stellaria media* (14.5 and 6.2%), *Lolium temulentum* (3.6 and 0.0%) and other weeds (*Anagallis arvensis, Spergulla arvensis, Polygonum alatum* and *Gallinsoga parviflora*) (20.3 and 3.8%) decreased at harvest when compared to its density at 90 DAP. *Coronopus didymus* (14.1%), *Ranunculus arvensis* (1.8%) and *Alopecurous myosuroides* (8.5%) were present only at harvest.

All weed control treatments were more effective during 2008-09 than during 2009-10 (Table 1) and their efficacy was higher on grasses than broad-leaved weeds. *Vicia sativa* and the other weeds were not effectively controlled by oxyflurofen 0.25 kg/ha, pendimethalin 1.5 kg/ha, triflurolin 1.5 kg/ha and metolachlor 1.5 kg/ha especially during 2008-09. Mehmood *et al.* (2002) have reported similar results. However, when hand weeding was integrated with half dose of these herbicides, control of these weeds has improved.

At harvest, hand weeding thrice resulted in significantly lower density of *Phalaris minor* and *Avena ludoviciana* during 2008-09 (Table 2). All other treatments resulted in significantly lower density of *Phalais minor* but oxyflourfen 0.25 kg/ha could not significantly lower down the density of *Avena ludoviciana* over weedy check during 2008-09. Metolachlor 1.50 kg/ha effectively reduced the density of *Poa annua*. However, all the other treatments had statistically equal count of *Poa* as under weedy check. All weed control treatments were significantly superior to weedy check in reducing the count of *Vicia sativa* and *Ranunculus arvensis* at harvest during 2008-09. Pendimethalin, pendimethalin + hand weeding and metolachlor + hand weeding were as good as hand weeding thrice in reducing density of *Vicia sativa*. All the weed control treatments except trifluralin + hand weeding were comparable to hand weeding thrice in influencing the count of *Ranunculus*. Density of *Coronopus didymus* was significantly lower under all the treatments at harvest during 2008-09. However, during 2009-10, *Coronopus didymus* and *Steallaria media* were observed to be suppressed under weedy check and the population of the weed under the weed control treatments was either significantly higher or not different from that under weedy check. Metolachlor + hand weeding was at par with pendimethalin and pendimethalin + hand weeding in effectively reducing the density of *Stellaria media* than other treatments. Oxyflourfen and oxyflourfen + hand weeding were as good as hand weeding thrice in reducing the density of other weeds. But, all the other treatments were not effective against other weeds during 2008-09. There was build up of *Alopecurous myosuroides* under hand weeding thrice at harvest during 2009-10.

All the weed control treatments resulted in significantly lower total weed density and total weed biomass (Table 3). Owing to species-wise reduction in the density of weeds, oxyfluorfen 0.15 kg/ha + HW,

Table 1. Effect of different weed management treatments on weed density (no./m^2) at 90 days after planting of garlic

Treatment	*Phalaris*		*Avena*		*Lolium*		*Poa*		*Vicia*		*Stellaria*		*Others*	
	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10
T_1- Oxyflurofen 0.25 kg/ha	1.0 (0.0)	3.4 (10.7)	1.0 (0.0)	1.8 (2.7)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.7 (2.7)	4.0 (14.7)	1.4 (1.3)	3.2 (9.3)	1.7 (2.7)	1.0 (0.0)	1.0 (0.0)
T_2- Oxyflurofen + HW 0.25 kg/ha	1.0 (0.0)	2.1 (4.0)	1.0 (0.0)	3.5 (12.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.4 (1.3)	1.0 (0.0)	1.4 (1.3)	1.0 (0.0)	1.4 (1.3)
T_3- Pendimethalin 1.50 kg/ha	1.0 (0.0)	2.9 (8.0)	1.0 (0.0)	2.6 (8.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	2.3 (5.3)	3.2 (9.3)	2.2 (4.0)	1.0 (0.0)	1.4 (1.3)	2.9 (8.0)	1.7 (2.7)
T_4- Pendimethalin + HW 1.50 kg/ha	1.0 (0.0)	2.5 (5.3)	1.0 (0.0)	2.1 (4.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	2.1 (4.0)	1.0 (0.0)	2.1 (4.0)	1.0 (0.0)	1.4 (1.3)	1.0 (0.0)	1.4 (1.3)
T_5- Trifluralin 1.50 kg/ha	3.0 (8.0)	3.3 (10.7)	1.0 (0.0)	1.8 (2.7)	1.0 (0.0)	1.0 (0.0)	1.4 (1.3)	1.4 (1.3)	3.8 (13.3)	2.1 (4.0)	1.4 (1.3)	1.8 (2.7)	5.4 (28.0)	1.0 (0.0)
T_6- Trifluralin + HW 1.50 kg/ha	1.0 (0.0)	3.0 (8.0)	1.0 (0.0)	2.1 (4.0)	1.0 (0.0)	1.4 (1.3)	2.1 (4.0)	1.4 (1.3)	1.0 (0.0)	2.1 (2.0)	1.0 (0.0)	1.4 (1.3)	1.0 (0.0)	1.4 (1.3)
T_7- Metolachlor 1.50 kg/ha	1.0 (0.0)	3.6 (12.0)	1.0 (0.0)	2.9 (9.3)	1.0 (0.0)	1.0 (0.0)	1.7 (2.7)	2.1 (4.0)	3.4 (10.7)	2.5 (5.3)	1.8 (2.7)	1.8 (2.7)	4.9 (22.7)	1.0 (0.0)
T_8- Metolachlor + HW 1.50 kg/ha	1.0 (0.0)	2.5 (5.3)	1.0 (0.0)	3.4 (10.7)	1.0 (0.0)	1.0 (0.0)	2.3 (5.3)	1.0 (0.0)	1.0 (0.0)	1.4 (1.3)	1.0 (0.0)	1.8 (2.7)	1.0 (0.0)	1.9 (4.0)
T_9- Hand weeding (HW)	1.0 (0.0)	2.3 (5.3)	1.0 (0.0)	1.4 (1.3)	1.0 (0.0)	1.4 (1.3)	1.0 (0.0)	2.5 (6.7)	1.0 (0.0)	2.5 (5.3)	1.0 (0.0)	1.4 (1.3)	1.0 (0.0)	1.0 (0.0)
T_{10}- Unweeded	7.9 (61.3)	11.3 (128.0)	4.2 (17.3)	7.9 (61.3)	3.2 (9.)	3.8 (13.3)	5.8 (33.3)	6.3 (38.7)	4.6 (20.)	4.3 (17.3)	4.4 (18.)	8.5 (70.7)	10.4 (108.)	4.1 (16.0)
LSD (P=0.05)	0.1	1.3	0.6	1.7	0.2	0.3	1.2	1.4	0.4	1.2	0.6	1.1	0.5	1.1

Values given in the parentheses are the original means

Table 2. Effect of different weed management treatments on different weed species density (no./m^2) at the harvest of garlic

Treatment	*Phalaris*		*Avena*		*Poa annua*		*Vicia*		*Ranunculus*		*Stellaria*		*Alopecurous*		*Others*	
	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10
T_1	3.6 (12.0)	3.0 (8.0)	5.3 (26.7)	2.9 (8.0)	3.5 (12.0)	1.9 (4.0)	4.1 (16.0)	2.7 (6.7)	1.4 (1.3)	1.0 (0.0)	2.9 (8.0)	3.8 (13.3)	1.0 (0.0)	1.9 (4.0)	1.0 (0.0)	1.0 (0.0)
T_2	4.0 (14.7)	4.1 (16.0)	3.4 (10.7)	1.0 (0.0)	4.1 (16.0)	2.7 (6.7)	3.8 (13.3)	2.3 (5.3)	1.4 (1.3)	1.4 (1.3)	4.1 (16.0)	3.2 (9.3)	1.0 (0.0)	1.0 (0.0)	1.9 (4.0)	1.7 (2.7)
T_3	4.7 (21.3)	2.7 (6.7)	3.4 (10.0)	2.7 (6.7)	3.6 (12.0)	1.7 (2.7)	3.4 (10.7)	3.6 (12.0)	1.0 (0.0)	1.8 (2.7)	2.2 (4.0)	1.4 (1.3)	1.0 (0.0)	2.7 (8.0)	4.4 (18.7)	3.2 (12.0)
T_4	3.4 (10.7)	3.6 (12.0)	2.5 (5.3)	4.1 (16.0)	4.1 (16.0)	1.9 (4.0)	3.2 (9.3)	1.7 (2.7)	1.4 (1.3)	1.0 (0.0)	2.2 (4.0)	1.8 (2.7)	1.0 (0.0)	1.7 (2.7)	3.6 (12.0)	3.8 (13.3)
T_5	3.6 (12.0)	2.0 (5.3)	3.8 (13.3)	3.1 (10.7)	4.4 (18.7)	1.9 (4.0)	4.0 (14.7)	3.6 (12.0)	1.0 (0.0)	1.4 (1.3)	3.6 (12.0)	1.9 (4.0)	1.0 (0.0)	1.4 (1.3)	7.1 (49.3)	2.7 (8.0)
T_6	4.1 (16.0)	3.6 (12.0)	3.6 (12.0)	3.8 (13.3)	3.7 (13.3)	3.3 (10.7)	4.4 (18.7)	3.6 (12.0)	2.1 (4.0)	1.8 (2.7)	3.6 (12.0)	2.3 (5.3)	1.0 (0.0)	2.3 (5.3)	4.1 (16.0)	2.9 (8.0)
T_7	3.1 (9.3)	5.0 (24.0)	3.1 (9.3)	4.5 (20.0)	1.0 (0.0)	1.0 (0.0)	4.0 (14.7)	3.0 (8.0)	1.0 (0.0)	1.4 (1.3)	3.4 (10.7)	6.6 (52.0)	1.0 (0.0)	1.7 (2.7)	7.8 (60.0)	4.9 (30.7)
T_8	4.4 (18.)7	4.6 (20.0)	3.6 (12.0)	4.4 (18.7)	2.5 (5.3)	2.3 (5.3)	3.2 (9.3)	3.4 (10.7)	1.0 (0.0)	1.0 (0.0)	1.8 (2.7)	1.7 (2.7)	1.0 (0.0)	1.0 (0.0)	8.3 (68.0)	4.5 (25.3)
T_9	1.8 (2.7)	6.3 (38.7)	1.0 (0.0)	3.9 (14.7)	4.3 (17.3)	3.6 (12.0)	3.0 (8.0)	2.5 (6.7)	1.0 (0.0)	1.0 (0.0)	3.2 (9.3)	3.2 (9.3)	1.0 (0.0)	3.4 (10.7)	2.2 (6.7)	7.2 (50.7)
T_{10}	7.6 (57.3)	11.2 (124.0)	5.0 (24.0)	6.2 (37.3)	3.8 (13.3)	1.7 (2.7)	5.2 (26.7)	3.6 (12.0)	3.0 (8.0)	1.0 (0.0)	5.1 (25.3)	1.7 (2.7)	5.0 (24.0)	4.0 (14.7)	4.3 (17.3)	1.0 (0.0)
LSD (P=0.05)	0.9	1.2	0.8	1.2	0.9	1.2	0.6	NS	0.9	NS	0.9	2.4	0.4	1.5	1.5	2.7

Values given in the parentheses are the original means

Table 3. Effect of different weed management treatments on yield of garlic, density and weed biomass

Treatment	Total weed density (no./m^2)				Total weed biomass (g/m^2)				Garlic yield (t/ha)		
	2008-09		2009-10		2008-09		2009-10		2008-09	2009-10	Mean
	90 DAP	At harvest	90 DAP	At harvest	90 DAP	At harvest	90 DAP	At harvest			
T_1	5.0 (24.0)	9.2 (84.0)	4.5 (20.00	6.8 (45.3)	1.4 (1.1	3.2 (9.2)	1.4 (0.9)	3.4 (11.2)	2.87	1.85	2.36
T_2	1.0 (0.0)	9.4 (88.0)	4..5 (20.0)	6.7 (44.0)	1.0 (0.0)	1.9 (2.9)	1.9 (3.0)	3.2 (9.5)	3.88	3.38	3.64
T_3	5.0 (24.0)	9.6 (92.0)	5.5 (29.3)	7.4 (53.3)	1.4 (1.0)	1.9 (3.1)	2.2 (3.9)	3.8 (13.9)	4.22	3.23	3.73
T_4	1.0 (0.0)	9.1 (82.7)	4.6 (20.0)	9.0 (81.3)	1.0 (0.0)	1.7 (2.1)	1.1 (0.3)	6.4 (40.9)	4.11	4.77	4.44
T_5	8.5 (70.7)	12.4 (153.3)	4.8 (22.7)	7.7 (61.3)	1.8 (2.2)	4.0 (15.3)	1.5 (1.6)	4.5 (23.5)	2.72	2.15	2.44
T_6	2.1 (4.0)	10.2 (102.7)	4.9 (24.0)	9.1 (82.7)	1.0 (0.0)	2.1 (3.8)	1.2 (0.3)	5.3 (28.1)	2.98	1.69	2.34
T_7	7.4 (53.3)	11.6 (134.7)	5.8 (33.3)	7.2 (50.7)	1.7 (1.8)	4.2 (17.0)	1.8 (2.4)	3.7 (13.2)	2.81	1.38	2.10
T_8	2.3 (5.3)	11.3 (126.7)	4.9 (24.0)	7.6 (57.3)	1.0 (0.0)	4.4 (19.2)	1.4 (1.1)	4.9 (23.4)	3.78	3.38	3.58
T_9	1.0 (0.0)	7.3 (53.3)	4.8 (22.7)	8.8 (77.3)	1.0 (0.0)	1.6 (1.8)	1.3 (0.7)	4.9 (23.4)	4.11	1.88	2.99
T_{10}	20.8 (432.0)	17.0 (289.3)	18.9 (356.0)	11.8 (137.3)	5.6 (30.3)	7.4 (54.3)	11.2 (123.6)	8.0 (63.9)	1.39	1.05	1.22
LSD (P=0.05)	1.0	1.2	1.4	1.7	0.2	1.1	0.8	1.7	0.60	0.31	0.46

Values given in the parentheses are the original means

pendimethalin 0.75 kg/ha + HW and hand weeding thrice were statistically on par with each other in reducing weed density at 90 DAS. At harvest, oxyflurofen 0.25 kg/ha, pendimethalin 1.5 kg/ha and trifluralin 0.75 kg/ha + HW were on par with above treatments. Oxyflurofen 0.15 kg/ha + HW, pendimethalin 1.5 kg/ha, pendimethalin 0.75 kg/ha + HW, trifluoralin 0.75 kg/ha + HW and metolachlor 0.75 kg/ha + HW were statistically equally effective in significantly lowering total weed biomassas compared to other weed control treatments.

Effect on crop

Weeds in unweeded check reduced the garlic bulb yield by 72.5% over the best treatment pendimethalin 0.75 kg/ha + HW (Table 3). Among the herbicides, pendimethalin resulted in highest bulb yield. The other herbicides, *viz.* oxyflourfen, metolachlor and trifluralin were comparable to each other. Integration of hand weeding with half dose of oxyflourfen, pendimethalin and metolachlor resulted in significantly higher yield of garlic than their respective higher dose alone. This indicated that hand weeding could economies the dose of the herbicides by 50%. Pendimethalin and pendimethalin/metolachlor/oxyflourfen + hand weeding were superior to hand weeding thrice in increasing bulb yield of garlic. Sandhu *et al.* (1997), Ankur *et al.* (2002), Singh and Nandal (2002) have reported similar results with the integration of hand weeding with pendimethalin. The bulb yield of garlic was negatively associated with weed density (r= -0.320 to -0.852) and weed biomass (r= - 0.13 to -0.832); with significantly higher association during 2008-09 than during 2009-10. Irrespective of species, with every one weed/m^2 increase in density of weeds, garlic bulb yield would be expected to fall by 5.3 kg/ha (Y= 3199.4 – 5.328 x, R^2= 0.298). Similarly, every g/m^2 increase in biomass of weeds would result in 35 kg/ha loss in bulb yield of garlic (Y= 3547.5 – 34.963 x, R^2= 0.430).

Impact assessment

Weed control efficiency under treatments ranged from 77.7 (in trifluralin) to 93.5% (oxyflourfen + hand weeding) (Table 4). Weed management index (WMI), agronomic management index (AMI) and integrated weed management index (IWMI) were highest under pendimethalin + hand weeding. It was followed by metolachlor + hand weeding, pendimethalin, oxyflourfen + hand weeding and hand weeding thrice. Herbicide efficiency index (HEI) which indicates weed killing potential and phytotoxicity

Table 4. Impact assessment indices and economics of weed management treatments

Treatment	WCE (%)	WMI	AMI	IWMI	HEI	WI	GR (x10^3 ₹ /ha)	GRwc (x10^3 ₹ /ha)	CWC (x10^3 ₹ /ha)	NRwc (x10^3 ₹ /ha)	MBCR
Oxyflurofen	88.6	2.33	1.33	1.83	5.39	21.3	109.29	52.38	2.16	50.22	23.2
Oxyflurofen + HW	93.5	3.33	2.33	2.83	18.85	-21.3	170.18	113.27	3.85	109.41	28.4
Pendimethalin	89.4	3.56	2.56	3.06	14.26	-24.3	173.65	116.75	2.80	113.95	40.7
Pendimethalin + HW	80.5	5.71	4.71	5.21	7.24	-48.1	209.66	152.75	3.80	148.95	39.2
Trifluralin	77.7	2.97	1.97	2.47	3.03	18.7	113.70	56.80	1.86	54.94	29.5
Trifluralin + HW	84.7	2.62	1.62	2.12	3.38	22.0	107.90	50.99	3.70	47.29	12.8
Metolachlor	81.7	2.31	1.31	1.81	2.81	30.0	96.55	39.64	1.50	38.14	25.4
Metolachlor + HW	80.1	4.58	3.58	4.08	5.36	-19.5	167.74	110.83	3.30	107.53	32.6
Hand weeding (HW)	87.9	3.12	2.12	2.62	6.82	0.0	137.56	80.65	9.82	70.83	7.2
Unweeded	0.0	-	-	-	0.00	59.3	56.90	0	0	0	0.0

WCE - weed control efficiency; WMI - weed management index; AMI - agronomic management index; IWMI - integrated weed management index; HEI - Herbicide efficiency index; WI - weed index; GR - gross returns; GRwc - gross returns due to weed control; CWC - cost of weed control; NRwc - net returns due to weed control; MBCR - marginal benefit: cost ratio

on the crop (Walia 2003), was highest under oxyflourfen + hand weeding. This was followed by pendimethalin, pendimethalin + hand weeding, hand weeding thrice and oxyflourfen. Pendimethalin + hand weeding had lowest weed index (WI) and was followed by pendimethalin, oxyflourfen + hand weeding and metolachlor + hand weeding. Rest of the treatments had higher weed index indicating lower yield than hand weeding thrice.

Gross returns (GR) and gross returns due to weed control (GRwc) followed the trend of yield and were highest under pendimethalin + hand weeding, pendimethalin, oxyflourfen + hand weeding and metolachlor + hand weeding. Cost of weed control was lower with herbicides/integrated weed control treatments than with hand weeding thrice. Net return due to weed control (NRwc) followed the trend of GRwc and was higher under pandimethalin + hand weeding, pendimethalin, oxyflourfen + hand weeding and metolachlor + hand weeding. All treatments resulted in higher MBCR over hand weeding thrice. Pendimethalin gave highest MBCR of 40.7 followed by pendimethalin + hand weeding, metolachlor + hand weeding, trifluralin + hand weeding, oxyflourfen + hand weeding and metolachlor.

Pendimethalin 0.75 kg/ha + hand weeding, oxyflourfen 0.125 kg/ha + hand weeding and metolachlor + hand weeding may be recommended for economically viable weed management in garlic, under mid-hills conditions of Himachal Pradesh.

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