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Integrated weed management in okra [*Abelmoschus esculentus* (L.) Moench] under mid-hill conditions of Himachal Pradesh

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Abstract

The effects of trifluralin at 1.5 kg/ha and pendimethalin 1.0 kg/ha alone and their half doses with one hand weeding and quizalofop- ethyl 30 and 20 g/ha on okra and associated weeds were compared to HW (twice as well as thrice) and weedy check in 2007 and 2008 at Palampur. All the weed control treatments caused significant reduction in total weed density and weed biomass, in turn brought significant improvement in fruit yield as compared to weedy check. Integration of one hand weeding at 45 days after sowing with trifluralin 0.75 kg/ha (Pre), pendimethalin 0.5 kg/ha and post emergence application of quizalofop methyl 30 g/ha proved distinctly superior to respective herbicides applied alone and were comparable with repeated weeding. Weeds in weedy check reduced okra fruit yield by 69% over hand weeding thrice. Trifluralin 0.75 kg/ha + HW gave highest net returns due to weed management. Quizalofop- butyl 30 g/ha gave highest net return/ rupee invested.

Key words: Okra, quizalofop, integrated, trifluralin and pendimethalin.

Introduction

Kharif season okra is a widely grown vegetable in the mid hills of Himachal Pradesh. One of the major problems encountered in its cultivation during rainy season is heavy infestation of weeds owing to wider spacing and initial slow growth, frequent rains, liberal use of manures and fertilizers coupled with congenial weather conditions. Uncontrolled weeds have been reported to reduce okra fruit yield by 80% (Singh *et al* 1991, Ved Prakash *et al* 2001) and seed yield by 55-67.3% (Sandhu *et al*, 1991). Manual weeding is time consuming and expensive due to high labour cost. Unavailability of labour at the desired time and sometimes unfavorable field conditions do not permit manual weeding. Under such situations, use of herbicides becomes imperative. However, use of herbicides at low doses in conjunction with manual weeding is environmentally safe, socially acceptable and economically viable. Information on integrated weed management methods in okra in Himachal Pradesh in general and agro-climatic conditions of mid- hills in particular is meager. Hence, the present investigation was undertaken to find out effective integrated weed control practices in okra.

Materials and Methods

A field experiment was conducted during *kharif* 2007 and 2008 at Research farm of Department of Agronomy, CSK Himachal Pradesh Krishi Vishvavidyalaya, 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, acidic in reaction (pH 6.1), medium in available N (326.4 kg ha^{-1}) & P (19.8 kg ha^{-1}) and high in K (216.4 kg ha^{-1}). A set of nine treatments (Table 1) was laid out in randomized block design with three replications. Okra variety '*Arka Anamika*' was planted in rows 45 cm apart on June 2 each

during 2007 and 2008, using 20 kg seed/ha. Well decomposed FYM @ 10 t/ha was applied uniformly at the time of field preparation. 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. The recommended cultural practices and plant protection measures were followed to raise the healthy crop. Weeding was done manually with the help of hand tool '*Khunti*'. 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), pendimethalin as pre-emergence (PRE), whereas quizalofop as post-emergence. Weed count and their dry weight were recorded by placing 25 cm x 25 cm quadrates at two random places in each plot and after drying them in hot air oven (70 ± 1^0 C for 72 h), weed dry weight was recorded. Yields were harvested from net plot. Economics of the treatments was computed based on the prevalent market prices of the inputs used and output produced.

Results and Discussion

The predominant weed species infesting the crop at 60 DAS were: *Ageratum conyzoides* (23.6%), *Echinochloa colona* (21.6%), *Commelina benghalensis* (21.6%), *Cyperus* spp. (12.1%) and *Panicum dichotomiflorum* (11.2%). The other weeds with minor infestation were *Digitaria sanguinalis* (3.2%) and *Eleusine indica* (2.0%). By the harvest *Ageratum conyzoides* assumed alarming proportions and constituted 75.4% of total weed population thereby decreasing the percentage of other weeds viz. *Echinochloa colona* (9.6%), *Polygonum alatum* (6.2%), *Cyperus* sp.(5.7%), *P.dichotomiflourum* (1.9%) and *Digitaria sanguinalis* (1.3%).

Effect on weeds

All treatments were significantly superior to weedy check in reducing the density of *Echinochloa colona* upto harvest during 2007 and until 60 DAS during 2008. However, its population under trifluralin 1.5 kg/ha (PPI, trifluralin 0.75 kg/ha (PRE) + HW, quizalofop 30 g/ha and pendimethalin 1.0 kg/ha was not significantly different from weedy check at harvest during 2008. Hand weeding thrice resulted in significantly lowest count of *Echinochloa colona* during 2007. However, hand weeding twice did equally well during 2008. All herbicide treatments were as good as hand weeding twice at 60 DAS during 2007. All treatments significantly reduced the count of *Panicum dichotomiflorum* at 60 DAS during both the years (Table 1). Hand weeding thrice remaining at par with HW twice, quizalofop 20 g/ha and trifluralin + HW resulted in significantly lower count of *Panicum dichotomiflorum at* 60 DAS over other treatments during 2007. However, all treatments were equally good as hand weeding thrice in reducing the count of *Panicum* at 60 DAS during 2008. Probably owing to competitive stress from other weeds by the harvest of okra crop, *Panicum* was completely eliminated from the weedy check as was evident, its count under all herbicide treatments was significantly higher over weedy check at harvest during 2008. *Digitaria* and *Eleusine* had shown their little infestation and effectively controlled by all weed control treatments until 60 DAS during 2008. Their population during 2008 was however, not significantly affected under different treatments. None of the herbicide treatment was able to control *Cyperus* spp. as its population under trifluralin 1.5 kg/ha, pendimethalin 1.0 kg/ha and quizalofop 30

Table 1. Effect of different treatments on density (No/ m^2) of grassy weeds in okra

Treatment	*Echinochloa colona*				*Panicum dichotomiflorum*				*Digitaria sanguinalis*				*Eleusine indica*	
	60 DAS		At harvest		60 DAS		At harvest		60 DAS		At harvest		60 DAS	
	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008
Trifluralin 1.5 kg/ha	3.9	5.4	3.6	5.6	3.7	2.1	2.9	3.2	1.0	1.0	2.3	1.0	1.0	1.7
	(14.7)	(28)	(12.0)	(30.7)	(14.7)	(4.0)	(8.0)	(12.0)	(0.0)	(0.0)	(5.3)	(0.0)	(0.0)	(2.7)
Trifluralin 0.75 kg/ha+ 1 HW	4.0	4.6	3.8	5.2	2.1	2.3	2.9	3.9	1.0	1.0	2.3	2.7	1.0	1.0
	(16.0)	(20)	(13.3)	(26.7)	(4.0)	(5.3)	(8.0)	(14.7)	(0.0)	(0.0)	(5.3)	(8.0)	(0.0)	(0.0)
Pendimethalin 1.0 kg/ha	3.7	5.5	3.8	4.9	3.2	1.8	3.4	2.9	1.0	1.4	2.3	1.0	1.0	1.0
	(13.3)	(29.3)	(13.3)	(22.7)	(9.3)	(2.7)	(10.7)	(8.0)	(0.0)	(1.3)	(5.3)	(0.0)	(0.0)	(0.0)
Pendimethalin 0.5 kg/ha + HW	4.3	4.3	4.9	4.4	3.4	1.4	3.6	3.6	1.0	1.0	2.9	1.0	1.0	1.0
	(17.3)	(18.0	(22.7)	(18.7)	(10.7)	(1.3)	(12.0)	(12.0)	(0.0)	(0.0)	(9.3)	(0.0)	(0.0)	(0.0)
Quizalofop 30 g/ha	4.2	5.4	3.9	5.3	4.0	2.1	3.6	2.9	1.0	1.0	1.7	2.8	1.0	1.0
	(17.3)	(28.0)	(14.7)	(26.7)	(16.0)	(4.0)	(12.0)	(14.7)	(0.0)	(0.0)	(2.7)	(13.3)	(0.0)	(0.0)
Quizalofop 20 g/ha	3.4	5.0	4.3	4.6	2.5	2.1	3.1	4.6	1.0	1.0	1.7	1.7	1.0	1.4
	(10.7)	(24.0)	(17.3)	(20.0)	(6.7)	(4.0)	(9.3)	(20.0)	(0.0)	(0.0)	(2.7)	(2.7)	(0.0)	(1.3)
Handweeding (20 & 40 DAS)	3.9	1.0	4.1	4.3	2.3	1.0	4.0	1.0	1.0	1.0	1.9	2.3	1.0	1.0
	(14.7)	(0.0)	(16.0)	(17.3)	(5.3)	(0.0)	(14.7)	(0.0)	(0.0)	(0.0)	(4.0)	(5.3)	(0.0)	(0.0)
Handweeding(20. 40 & 60 DAS)	1.0	1.0	2.7	3.1	1.0	1.0	2.7	1.0	1.0	1.0	1.7	2.3	1.0	1.0
	(0.0)	(0.0)	(6.7)	(10.7)	(0.0)	(0.0)	(6.7)	(0.0)	(0.0)	(0.0)	(2.7)	(5.3)	(0.0)	(0.0)
Unweeded	6.8	7.5	7.4	6.1	5.9	4.3	4.3	1.0	3.6	1.8	3.6	1.0	3.0	1.4
	(45.3)	(54.7)	(53.3)	(36.0)	(34.7)	(17.3)	(17.3)	(0.0)	(12.0)	(2.7)	(12.0)	(0.0)	(8.0)	(1.3)
CD (P=0.05)	1.1	1.2	0.9	1.2	1.7	1.3	NS	2.4	1.1	NS	NS	NS	0.7	NS

Values given in the parentheses are the original means which were subjected to $\sqrt{x+1}$ transformation for analysis.

g/ha was either at par or significantly higher over years (Table 2). Superimposition of hand weeding with lower dose of trifluralin and pendimethalin significantly reduced the count of *Cyperus* spp over their respective higher dose alone. Hand weeding thrice remaining at par with hand weeding twice during 2008 was most effective treatment in eliminating competition offered by *Cyperus* spp. in okra until 60 DAS. Thereafter, there was a buildup of *Cyperus* sp. in these treatments as well, as its population at harvest was not significantly different from weedy check.

The population of *Commelina benghalensis* under trifluralin 1.5, pendimethalin 1.0 and quizalofop 30 g/ha was equal or higher over weedy check at 60 DAS during 2007. Lower dose of each herbicide along with HW was significantly superior to respective higher dose of each herbicide in reducing the count of *Commelina benghalensis*. Hand weeding thrice resulted in significantly lowest count of this weed during 2007.

Ageratum appeared late in the season. The superior control of other weeds owing to herbicidal treatments might have resulted in the buildup of this weed. This was evident as the count of *Ageratum* under herbicidal treatment was significantly higher over weedy check plots at 60 DAS. *Ageratum* also appeared to be suppressed in the weedy check at 60 DAS, owing to competition from other weeds. This can be seen from its count at harvest which increased over trifluralin, pendimethalin and quizalafop treatments. It is also to mention that herbicides at higher dose alone were superior to their respective lower dose treatment coupled with HW in reducing its count both at 60 DAS and at harvest. HW thrice remaining at par with HW twice during weedy check at 60 DAS during both the 2007 resulted in complete elimination of this weed by 60 DAS during both the years, but thereafter there was tremendous appearance of *Ageratum* in hand weeded plots which even did not significantly different from weedy check during 2007. However, it was at 2-3 leaf stage at harvest. All treatments except quizalofop 30 g/ha 60 DAS during 2007 had significantly lower count of *Polygonum* over weedy check. Hand weeding thrice being at par with hand weeding twice was superior to all the herbicidal/integrated weed management treatments at harvest during 2008. All the weed control treatments were significantly superior to weedy check in reducing total weed count at both the stages of observation during both the years of study (Table 3). Significantly lower total count and total dry weight of weeds was recorded in hand weeding thrice treatment at both the stages of observation. At 60 DAS all the treatments behaving statistically similar were the next superior in reducing total weed count whereas at harvest pendimethalin 0.5 kg ha^{-1} + HW behaved statistically similar with trifluralin 0.75 kg ha^{-1} + HW treatment in this regard.

Effect on yield

Okra fruit yield was comparatively better in 2007 than 2008 probably owing to better establishment. All the treatments were significantly superior to weedy check in increasing okra fruit yield during 2007 (Table 3). However, trifluralin 1.5 kg/ha, pendimethalin 1.0 kg/ha and quizalofop 20 g/ha could not significantly increase okra fruit yield over weedy check during 2008. HW thrice remaining at par with HW twice, trifluralin + HW, pendimethalin + HW and quizalofop 30 g/ha during both the years and pendimethalin 1.0 kg/ha during

Table 2. Density (No/m^2) of *Cyperus* and broadleaved weeds as affected by weed control treatments in okra

Treatment	*Cyperus spp.*				*Commelina*		*Ageratum conyzoides*				*Polygonum alatum*			
	60 DAS		At harvest		60 DAS		60 DAS		At harvest		60 DAS		At harvest	
	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008
Trifluralin 1.5 kg/ha	6.0	6.7	5.6	5.1	7.2	4.6	6.9	9.0	9.5	12.5	2.5	1.0	2.1	5.4
	(34.7)	(44.0)	(30.7)	(25.3)	(52.0)	(20.0)	(46.7)	(80.0)	(89.3)	(156.0)	(6.7)	(0.0)	(4.0)	(28.0)
Trifluralin 0.75 kg/ha+	3.8	6.0	5.6	5.4	3.6	3.2	11.5	11.2	23.9	16.8	1.9	2.1	2.1	4.6
1 HW	(13.3)	(34.7)	(30.7)	(28.0)	(12.0)	(9.3)	(130.7)	(124.0)	(572.0)	(280.0)	(4.0)	(4.0)	(4.0)	(20.0)
Pendimethalin 1.0	6.1	4.9	5.5	3.1	6.2	7.9	7.7	9.0	6.1	13.7	1.7	2.8	1.0	6.3
kg/ha	(36.0)	(22.7)	(29.3)	(10.7)	(37.3)	(61.3)	(58.7)	(80.0)	(36.0)	(186.7)	(2.7)	(13.3)	(0.0)	(40.0)
Pendimethalin 0.5	4.3	4.7	5.4	4.6	4.0	5.5	11.4	12.8	21.3	16.1	1.4	1.0	1.7	5.5
kg/ha + HW	(17.3)	(21.3)	(28.0)	(20.0)	(14.7)	(29.3)	(129.3)	(164.0)	(454.7)	(257.3)	(1.3)	(0.0)	(2.7)	(29.3)
Quizalofop 30 g/ha	6.4	5.9	7.5	6.1	6.3	4.1	7.5	8.4	7.3	9.2	3.4	1.0	1.4	5.4
	(40.0)	(34.7)	(54.7)	(36.0)	(38.7)	(16.0)	(56.0)	(70.0)	(52.0)	(84.0)	(10.7)	(0.0)	(1.3)	(28.0)
Quizalofop 20 g/ha	4.0	4.6	5.0	3.3	3.2	4.1	11.5	11.2	20.2	17.3	1.8	1.0	2.1	5.0
	(14.7)	(20.0)	(24.0)	(10.7)	(12.0)	(16.0)	(132.0)	(125.3)	(405.3)	(300.0)	(2.7)	(0.0)	(4.0)	(24.0)
Handweeding (20 & 40	4.3	1.7	4.4	4.1	3.6	1.0	11.9	1.0	23.1	11.5	2.1	1.0	1.4	1.0
DAS)	(18.7)	(2.7)	(18.7)	(16.0)	(12.0)	(0.0)	(140.0)	(0.0)	(534.7)	(132.0)	(4.0)	(0.0)	(1.3)	(0.0)
Handweeding(20, 40	1.0	1.7	4.6	5.1	1.0	1.0	1.0	1.0	20.4	11.1	1.0	1.0	1.0	1.0
& 60 DAS)	(0.0)	(2.7)	(20.0)	(26.7)	(0.0)	(0.0)	(0.0)	(0.0)	(416.0)	(122.7)	(0.0)	(0.0)	(0.0)	(0.0)
Unweeded	6.6	3.7	4.1	6.0	5.0	8.8	6.6	8.2	21.9	14.9	3.6	2.5	1.8	7.5
	(42.7)	(13.3)	(16.0)	(36.7)	(24.0)	(76.0)	(42.7)	(66.7)	(480.0)	(220.0)	(12.0)	(9.3)	(2.7)	(54.7)
CD (P=0.05)	0.9	1.3	0.8	1.6	1.5	0.6	1.2	0.5	1.7	1.3	1.5	NS	NS	1.2

Values given in the parentheses are the original means which were subjected to $\sqrt{x+1}$ transformation for analysis.

Table 3. Effect of treatments on total weed count, total weed dry weight and marketable yield of okra

Treatment	Total weed count (No/ m^2)				Total weed dry weight (g/m^2)				Yield (kg/ha)	
	2007		2008		2007		2008		2007	2008
	60 DAS	At Harvest	60 DAS	At Harvest	60 DAS	At Harvest	60 DAS	At Harvest		
Trifluralin 1.5 kg/ha	13.4(178.7)	12.6(160.0)	14.1 (197.3)	16.6 (276.0)	7.0(47.8)	8.3(95.0)	7.9 (61.1)	7.6 (56.1)	6904	2262
Trifluralin 0.75 kg/ha+ 1 HW	13.2(174.7)	11.5(132.0)	13.4 (178.7)	19.8 (389.3)	6.4(39.9)	6.2(51.0)	7.4 (54.2)	7.0 (48.3)	10633	4387
Pendimethalin 1.0 kg/ha	13.8(190.7)	24.3(590.7)	14.9 (221.3)	17.9 (321.3)	7.1(49.5)	12.6(157.9)	7.4 (54.3)	8.5 (70.5)	8429	2323
Pendimethalin 0.5 kg/ha + HW	12.5(157.3)	10.3(105.3)	15.7 (245.3)	18.8 (353.3)	6.4(40.0)	7.8(59.6)	6.9 (47.1)	6.9 (46.0)	10068	3504
Quizalofop 30 g/ha	13.4(180.0)	12.1(146.7)	12.4 (152.7)	14.8 (218.7)	7.0(47.7)	8.9(78.6)	6.9 (46.1)	7.3 (52.9)	8565	3497
Quizalofop 20 g/ha	13.4(178.7)	22.0(482.7)	13.8 (190.7)	19.9 (394.7)	7.2(50.7)	11.8(138.3)	7.6 (56.6)	7.5 (56.1)	6394	2812
Handweeding (20 & 40 DAS)	8.9(78.6)	24.6(602.7)	1.7 (2.7)	13.2 (173.3)	7.0(47.7)	13.5(182.3)	1.0 (0.0)	6.6 (42.0)	10710	3047
Handweeding (20. 40 & 60 DAS)	6.8(45.3)	22.4(501.3)	1.7 (2.7)	13.3 (177.3)	7.3(51.9)	8.1(64.5)	1.0 (0.0)	6.1 (36.9)	10904	4168
Unweeded	15.2(229.3)	25.5(650.7)	15.6 (241.3)	20.5 (419.3)	7.8(60.3)	14.7(215.3)	8.8 (77.1)	9.3 (84.8)	3150	1534
CD (P=0.05)	1.5	0.9	1.2	1.1	0.4	4.4	0.5	0.8	2658	1304

Values given in the parentheses are the original means which were subjected to $\sqrt{x+1}$ transformation for analysis.

2007, resulted in significantly higher okra fruit yield over remaining treatments. Weeds in unweeded check reduced okra fruit yield by 68.9% over hand weeding thrice. Lower dose of pendimethalin with HW was statistically equal to its respective higher dose alone indicating that hand weeding could economize its dose by 50%.

Economics

The weed control treatments under study registered 2-3 times higher gross returns than weedy check (Table 4). Total gross and additional gross returns over weedy check were highest under hand weeding thrice treatment (20, 40 and 60 DAS) followed by trifluralin 0.75 kg/ ha *fb* HW at 45 DAS and hand weeding twice treatments (Table 4). Trifluralin 0.75 kg/ ha *fb* HW at 45 DAS was found to be the best in terms of net returns due to weed management. This was followed by HW twice, HW thrice and pendimethalin + HW in that order. However, quizalofop butyl 30 g/ha gave the highest net profit/rupee invested. It was followed by quizalofop butyl 20 g/ha + HW. It was mainly due to low herbicide cost ultimately leading to lower application cost. Superiority of herbicides over age old traditional manual weeding with respect to B: C ratio has also been reported by Ved Prakash *et al.* (2001).

Table 4. Economics of treatments

Treatment	Gross returns (Rs/ha)	Additional returns due to WM (Rs/ha)	Cost of WM (Rs/ha)	Net return due to WM (Rs /ha)	Net profit/ rupee invested on WM
Trifluralin 1.5 kg/ha	45834	22416	2098	20318	9.7
Trifluralin 0.75 kg/ha+ 1 HW	75101	51683	5769	45914	8.0
Pendimethalin 1.0 kg/ha	53761	30343	2480	27863	11.2
Pendimethalin 0.5 kg/ha + HW	67859	44441	5960	38481	6.5
Quizalofop 30 g/ha	58061	34643	1504	33139	22.0
Quizalofop 20 g/ha	46028	22610	1216	21394	17.6
Handweeding (20 & 40 DAS)	71036	47618	8800	38818	4.4
Handweeding(20, 40 & 60 DAS)	75363	51945	13200	38745	2.9
Unweeded	23418	----	----	----	-----

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