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Integrated weed management in cauliflower (*Brassica oleracea var. botrytis*) under dry temperate climate of western Himalayas

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ABSTRACT

Under dry temperate conditions of Western Himalayas limited information is available on control of weeds in cauliflower using herbicides. Field experiment was conducted during 2010 and 2011 to develop weed management practice for cauliflower (Brassica oleracea var. botrytis).The weed control strategy included pendimethalin, fluchloralin and isoproturon in different doses and combination constituting thirteen treatments. The application of pendimethalin 1.5 kg ha^{-1} and fluchloralin 1.0 kg ha^{-1} were the effective herbicides in reducing the weed density of both narrow and broadleaf weeds at all the stages of observation. However when these herbicides were applied at lower dose of 0.75 kg ha^{-1} and supplemented with one hand weeding at 30 days after transplanting then the weed biomass reduction was highest with weed control efficiency more than 90% compared to their higher rate application having weed control efficiency of 70-80%. Hand weeding twice at 30 and 60 days after transplanting was equally effective at later stages for reducing weed density and weed biomass in comparison with herbicides. Pendimethalin 1.5 kg ha^{-1} was observed to be best weed management treatment in terms of average curd weight, total curd yield and net returns. Although the next best yields are obtained when two hand weeding were practiced at 30 and 60 days after transplanting but in terms of net returns pendimethalin and fluchloralin each at 1.0 kg ha^{-1} as pre emergence were the second best option.

Keywords **:** *Brassica oleracea* var. *botrytis*, curd yield, economics, herbicides, weeds

North western Himalayas has a climate from dry to wet temperate to subtropical suitable for cultivation of vegetables. The Lahaul and Spiti valley in western Himalayas has dry temperate climate for six months of year with rainfall below 150 mm in season. Two crops of cauliflower can be taken in short period of 5-6 months. The major hindrance to its production is the non-availability of quality planting materials and competition from weeds. The demand for irrigation is 4-5 cm a week which supports weed growth. The magnitude of loss depends upon the weeds present, period of crop-weed competition and weed populations. Being a transplanted crop establishment may suffer from early weed competition (Zimdahl, 1980). The crop-weed competition in cauliflower can cause yield loss up to 77% (Porwal and Singh, 1993; Qasem, 2007). The availability of labour for field maintenance is very low indicating, weed control will likely be best through use of herbicide. The herbicides fluchloralin (Porwal and Singh, 1993; Leela, 1995) and pendimethalin (Mal *et al*., 1993; Whitewell, 1984; Leela, 1995) are recommended for weed control in cole crops. North western Himalayas with different weed flora than the dry, temperate conditions in other parts had limited literature on the weed control in cauliflower. The objective was to develop a cost effective weed management strategy using herbicides to control the weed.

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MATERIALS AND METHODS

Two independent field experiments were conducted at the research farm of Highland Agricultural Research and Extension Centre, Kukumseri 32º44'55''N latitude and 76 º 41'23'' E longitudes, at CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur, India, during 2009-2010 and 2010-2011 growing seasons. The soil site was a sandy loam, pH 6.8, with organic carbon 6.82 g kg^{-1}, N at 294.6 kg ha^{-1}, P at17.2 kg ha^{-1} and K at 142.1 kg ha^{-1}. The experiment was laid out in a Randomized Complete Block Design with 3 replications. The weed control treatments included pendimethalin (1.5 and 1.0 kg ha^{-1}), fluchloralin (1.0 and 0.75 kg ha^{-1}) and isoproturon (1.0 kg ha^{-1}) applied pre-emergence (PE) of weeds; isoproturon (1.0 kg ha^{-1}) applied post-emergence at 30 DAT; pendimethalin (0.75kg ha^{-1}) and fluchloralin (0.75 kg ha-1) applied pre-emergence followed by isoproturon (0.5 kg ha^{-1}) at 30 DAT; pendimethalin (0.75 kg ha^{-1}), fluchloralin (0.75 kg ha^{-1}) and isoproturon (0.75 kg ha^{-1}) each followed by one hand weeding at 30 DAT; and weed free and un-weeded checks (Table 2). Plot size was 3.60 × 3.15m. The 3-4 leaf seedlings of cv. Sweta, raised in a poly-house over fumigated nursery beds of FYM and soil mixture and irrigated periodically, were transplanted in field after hardening period outside polyhouse of 2 days. Transplanting was done on 24 May 2010 and 21 May 2011. Fertilization was with 125 kg ha^{-1} N, 75 kg ha^{-1} P_2O_5 and 70 kg ha^{-1} K_2O. Nitrogen was applied as urea (46%), P_2O_5 as single super phosphate (16%) and K_2O as muriate of potash (60%). Half of the nitrogen, and all of the P_2O_5 and K_2O were applied at transplanting. The remaining nitrogen was applied in two splits with 1/4 the rate at 30 DAT and 1/4 the rate at flowering. The number of irrigations was 2-3 a week. Herbicides were applied using a knapsack sprayer with a spray volume of 500 L ha^{-1}. Densities of monocot and broadleaf weeds were assessed within a 0.5m quadrat. Biomass of weeds were determined 30 DAT and at harvest. Weeds within the quadrat were cut close to soil, placed in paper bags and dried in oven for 72 h at 60ºC and weight taken. When 75% curds in plot were ready for harvest 10 randomly selected curds were harvested for average curd weight. The crop was harvested when 75% were ready (90 days) and when rest were ready (at 100 days) and summed for total yield. Economic analysis was based on prevailing market prices. Data were subjected to analysis of variance technique as suggested in by

Table1: Effect of weed control treatments on the weed density, biomass and weed control efficiency

Treatment	Weed count (m^{-2})								Weed dry matter (g m^{-2})				WCE (%)
	30DAT				At harvest				30DAT		At harvest		
	Narrow		Broad		Narrow		Broad		2010	2011	2010	2011	
	2010	2011	2010	2011	2010	2011	2010	2011					
T_1:Pendimethalin@ 1.5 kg ha^{-1}(PE)PE	0.00 (1.00)	2.66 (1.66)	2.66 (1.82)	14.66 (3.95)	3.33 (1.98)	2.66 (1.67)	6.33 (2.69)	10.66 (3.32)	2.66 (1.71)	6.13 (2.59)	94.53 (9.50)	46.80 (6.91)	80.3
T_2:Pendimethalin@ 1.0 kg ha^{-1}(PE)	0.33 (1.14)	1.33 (1.41)	1.00 (1.33)	14.66 (3.95)	8.33 (3.05)	0.00 (1.00)	31.66 (5.67)	17.33 (3.88)	6.67 (2.19)	6.26 (2.67)	216.30 (13.52)	26.00 (4.71)	66.2
T_3:Fluchloralin@ 1.0 kg ha^{-1}(PE)	0.00 (1.00)	0.00 (1.00)	0.00 (1.000)	4.00 (2.07)	3.00 (1.99)	4.00 (2.23)	11.67 (3.55)	1.33 (1.41)	0.00 (1.00)	1.60 (1.56)	174.80 (13.19)	7.60 (2.29)	74.6
T_4:Fluchloralin@ 0.75 kg ha^{-1}(PE)	0.00 (1.00)	1.33 (1.41)	0.00 (1.00)	5.33 (2.33)	4.33 (2.29)	22.67 (4.23)	14.33 (3.84)	9.33 (2.90)	0.00 (1.00)	2.66 (1.90)	317.20 (17.75)	66.00 (7.62)	46.6
T_5:Isoproturon@ 1.0 kg ha^{-1}(PE)	0.00 (1.00)	13.33 (3.75)	5.66 (2.33)	22.67 (4.83)	8.00 (2.94)	17.67 (4.20)	22.67 (4.83)	12.00 (3.47)	10.93 (2.89)	37.60 (6.20)	455.60 (21.27)	59.60 (7.63)	28.2
T_6:Isoproturon 1.0 kg ha^{-1}(POE)	3.00 (1.99)	54.67 (6.95)	10.33 (3.36)	84.67 (8.36)	6.66 (2.65)	89.33 (9.33)	39.33 (6.33)	93.33 (9.49)	19.47 (4.46)	91.06 (9.82)	468.40 (21.63)	283.20 (13.47)	4.7
T_7:Pendimethalin@ 0.75 kg ha^{-1} (PE)+ Isoproturon@ 0.5 kg ha^{-1} at 30DAT	0.00 (1.00)	10.66 (3.37)	0.00 (1.00)	58.67 (7.69)	2.66 (1.90)	4.00 (2.07)	18.66 (4.41)	56.00 (6.71)	0.00 (1.00)	63.46 (7.99)	212.53 (14.47)	90.80 (9.52)	57.7
T_8:Fluchloralin@ 0.75 kg ha^{-1} PE + Isoproturon @ 0.5 kg ha^{-1} at 30DAT	0.00 (1.00)	10.67 (3.08)	0.00 (1.00)	26.67 (5.25)	9.33 (3.06)	20.00 (4.25)	25.33 (4.99)	5.33 (2.33)	0.00 (1.00)	41.46 (6.49)	460.27 (21.45)	100.80 (9.31)	21.8
T_9:Pendimethalin@ 0.75 kg ha^{-1} (PE)+ HW at30 DAT	1.00 (1.38)	2.67 (1.67)	3.00 (1.88)	13.33 (3.77)	2.33 (1.80)	5.33 (2.49)	4.33 (2.29)	2.67 (1.82)	7.33 (2.66)	9.73 (3.25)	20.80 (4.54)	15.30 (4.00)	94.9
T_{10}:Fluchloralin@ 0.75 kg ha^{-1} (PE) + HW at 30 DAT	0.00 (1.00)	4.00 (2.07)	0.00 (1.00)	22.67 (4.82)	1.33 (1.52)	2.67 (1.82)	4.00 (2.19)	4.00 (2.07)	0.00 (1.00)	15.60 (3.90)	14.93 (3.69)	8.80 (2.97)	96.7
T_{11}:Isoproturon @ 0.75 kg ha^{-1} (PE) + HW at 30 DAT	0.00 (1.00)	10.67 (3.37)	1.33 (1.41)	34.67 (5.96)	2.00 (1.73)	5.33 (2.49)	6.00 (2.65)	2.66 (1.67)	0.66 (1.24)	23.86 (4.94)	35.47 (5.91)	7.93 (2.81)	93.9
T_{12}:Hand weeding twice at 30, 60 DAT	2.33 (1.79)	18.67 (4.29)	11.00 (3.35)	20.00 (4.49)	2.00 (1.72)	6.67 (2.53)	7.33 (2.88)	6.67 (2.74)	21.33 (4.20)	24.93 (4.98)	16.80 (4.15)	12.10 (3.60)	95.9
T_{13}:Weedy check	2.00 (1.65)	56.00 (7.51)	11.33 (3.16)	93.33 (9.67)	8.33 (2.91)	106.67 (10.31)	26.33 (4.96)	110.67 (10.56)	19.33 (3.81)	102.00 (10.09)	492.93 (22.16)	224.80 (14.92)	
SEm (±)	**0.17**	**0.53**	**0.48**	**0.51**	**0.32**	**0.84**	**0.49**	**0.97**	**0.87**	**0.49**	**1.59**	**1.32**	
LSD (0.05)	**0.50**	**1.55**	**1.39**	**1.48**	**0.92**	**2.46**	**1.44**	**2.83**	**2.53**	**1.43**	**4.65**	**3.85**	

Note: Figures in the parenthesis indicates transformed values

Gomez and Gomez (1984). Normality, homogeneity of variance and interaction were tested, and data was presented separately for years. Weed population and biomass data was arc sign transformed.

RESULTS AND DISCUSSION

The dominant broadleaf weeds were: *Amaranthus spinosus* L., *Gallinsoga parviflora* Cav., *Coronopus didymus* L.and monocots weeds were: *Digitaria sangunalis* L., *Poa annua* L., *Avena fatua* L. Other weeds were *Polygonum alatum* L., *Malva parviflora* L., *Chenopodium botrys* L., *Setaria galuca* L., *Panicum dicotomi florum* L. and *Medicago denticulate* Willd.

Weed density

All weed management treatments except Isoproturon (post-emergence) reduced weed populations of monocot and broadleaf weeds compared to the weedy check (Table 1).

At 30 DAT the pre-emergence application of pendimethalin and fluchloralin reduced weed populations. At harvest hand weeding twice was comparable with the pendimethalin 1.5 kg ha^{-1} and fluchloralin 1.0 kg ha^{-1}. The likely reason was that the first hand weeding was at 30 DAT where weed population were higher than due to herbicides. At later stages hand weeding could suppress weeds effectively. This is supported by the first experiment where the

Table 2: Effect of weed management treatments on the yield attribute, yield and economics

Treatments	Weight/ curd(g)			Curd yield (kg ha^{-1})			Net return (×10^{3}Rs ha^{-1})		B:C	
	2010	2011	Pooled	2010	2011	Pooled	2010	2011	2010	2011
T_1:Pendimethalin@ 1.5 kg ha^{-1}(PE)	803.3	986.3	894.8	29827	30439	30133	253.3	260.0	3.39	3.48
T_2:Pendimethalin@ 1.0 kg ha^{-1}(PE)	640.0	770.0	705.0	23753	23777	23765	167.3	167.5	2.26	2.26
T_3:Fluchloralin@ 1.0 kg ha^{-1}(PE)	596.7	815.0	705.8	22024	25424	23724	168.0	205.4	2.26	2.77
T_4:Fluchloralin@ 0.75 kg ha^{-1}(PE)	481.7	595.0	538.3	18000	18775	13387	64.2	132.7	0.87	1.80
T_5:Isoproturon @ 1.0 kg ha^{-1}(PE)	376.7	536.7	456.7	14247	16846	15546	63.9	52.5	0.88	0.72
T_6:Isoproturon 1.0 kg ha^{-1}(POE)	300.0	356.7	328.3	11309	11123	11216	51.6	49.5	0.71	0.68
T_7:Pendimethalin@0.75 kg ha^{-1} (PE)+ Isoproturon@ 0.5 kg ha^{-1} at 30DAT	521.7	595.0	558.3	19704	18685	19194	142.9	131.7	1.94	1.78
T_8:Fluchloralin @0.75 kg ha^{-1} PE + Isoproturon @ 0.5 kg ha^{-1} at 30DAT	465.0	605.0	535.0	17235	18749	17992	55.6	132.3	0.75	1.79
T_9:Pendimethalin@ 0.75 kg ha^{-1} (PE)+ HW at 30 DAT	708.3	816.7	762.5	26173	25706	25939	169.3	164.1	2.15	2.09
T_{10}:Fluchloralin@ 0.75 kg ha^{-1} (PE) + HW at 30 DAT	588.3	883.3	735.8	21728	27417	24573	160.2	222.8	2.03	2.83
T_{11}:Isoproturon @ 0.75 kg ha^{-1} (PE) + HW at 30 DAT	400.0	590.0	495.0	14815	18260	16537	65.2	123.1	0.84	1.58
T_{12}:Hand weeding twice at 30, 60DAT	700.0	603.3	651.7	26025	18801	22413	163.8	124.3	1.99	1.51
T_{13}:Weedy check	271.7	250.0	260.8	10000	8101	9050	37.5	-3.3	0.52	-0.05
SEm(±)	**21.5**	**49.8**	**27.1**	**769**	**1469**	**638**				
LSD (0.05)	**62.6**	**145.5**	**77.1**	**2246**	**4349**	**2383**				

critical period for weed crop competition was between 20 to 30 DAT and a weed free period up to 60 DAT could increase weed control efficiency >90%. Pendimethalin and fluchloralin applied at dose 0.75 kg ha^{-1} supplemented with 1 hand weeding was equally effective in reducing weeds populations as higher doses of the herbicides.

Weed biomass

Weed biomass was correlated with weed density and affected by weed management practices reductions in biomass. At 30 DAT, herbicide application of pendimethalin 1.5 and 1.0 kg ha^{-1}, fluchloralin 1.0 and 0.75 kg ha^{-1} were equal and reduced weed biomass compared to other weed management practices (Table 1). At later stages when pendimethalin and fluchloralin was applied at 0.75 kg ha^{-1} each and supplemented with 1 hand weeding the weed biomass reduction was higher than their application at higher doses. Hand weeding alone was better than herbicide application in curbing weeds at later stages. The critical crop weed competition period is when weeding is at 30 DAT; at later stages herbicide efficiency declines. Weed control efficiency is >90% when pendimethalin or fluchloralin applied at 0.75 kg ha^{-1} but supplemented with 1 hand weeding at 30 DAT or 2 hand weeding at 30 and 60 DAT. An effective WCE can be achieved with only herbicide application of pendimethalin 1.5 kg ha^{-1} and fluchloralin 1.0 kg ha^{-1}. Under subtropical and semi-arid conditions a single hand weeding with herbicide (Pormal and Singh, 1993) and pendimethalin 1.5 kg ha^{-1} (Mal *et al*., 2005) have been reported to control weeds in cauliflower. Higher weed control efficiency with hand weeding was supported due to the critical period being between 20 to 30 DAT.

Yield and yield attributes

All weed management treatments except isoproturon (post-emergence) resulted in improving average curd yield and consequently profits over the untreated check. Higher dose application of pendimethalin 1.5 kg ha^{-1}resulted in maximum curd weight, curd yield and higher net returns with high benefit:cost ratio in 2010 and 2011(Table 2).

The results are in agreement with workers on the effective control of weeds and increase in curd yield using pendimethalin (Qasem, 2007; Mal *et al*., 2005; Porwal and Singh, 1993). Hand weeding twice at 30 and 60 DAT was the next best weed management practice in terms of yields. Application of lower doses of pendimethalin and fluchloralin supplemented with 1 hand weeding at 30 DAT produced yields comparable with 2 hand weedings. If the dose of pendimethalin and fluchloralin were increased, without hand weeding, yields obtained were similar to the combination of pendimethalin or fluchloralin with 1 hand weeding at 30 DAT. In semi -arid conditions the fluchloralin alone (Singh *et al*., 1996) or with 1 hand weeding (Porwal and Singh, 1993) increased the yield of cauliflower. The best weed management option for higher yields and higher returns in cauliflower under dry temperate conditions is application of pendimethalin at1.5 kg ha^{-1}. The next best option in terms of yield is hand weeding at 30 and 60 DAT; pendimethalin or fluchloralin 0.75 kg ha^{-1} with 1 hand weeding at 30 DAT. If economics is taken into consideration hand weeding reduces return in favour of pendimethalin and fluchloralin 1.0 kg ha^{-1} each as next best weed management option.

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