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Management of diverse weed flora of cumin by sole and combined herbicide application

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ABSTRACT

The field experiment was conducted during rabi 2014-15 to 2016-17 on clayey soil at Junagadh (Gujarat) to evaluate the efficacy of some pre- and post-emergence herbicides in combination with hand weeding (HW) for weed management in cumin. The major weed flora observed in the field were monocots viz., Brachiaria spp. (signal grass), Asphodelus tenuifolius (wild onion), Indigofera glandulosa (three leaf indigo), Echinochloa colona (Barnyard grass) and Dactyloctenium aegyptium (crow foot grass), dicots viz., Chenopodium album (common lambs quarters), Digera arvensis (false amaranth), Amaranthus viridis (pigweed), Portulaca oleracea (purslane), Physalis minima (ground cherry), Euphorbia hirta (common spurge) and Leucas aspera (thumba), and Cyperus rotundus (purple nutsedge) as sedge. The results revealed that the treatments viz., weed free, pendimethalin 900 g ha-1 as pre-emergence fb HW at 45 DAS and oxadiargyl 75 g ha-1 as early post-emergence at 7 DAS fb HW at 45 DAS significantly enhanced growth and yield attributes viz., plant height, number of branches per plant, number of umbels per plant, number of umbellates per umbel, number of seeds per umbel and 1000-seed weight, and ultimately increased seed (967, 934 and 919 kg ha-1) and stalk (2007, 1892 and 1849 kg ha-1) yields over unweeded check. These treatments also recorded the lower dry weight of weed at harvest (69, 188 and 277 kg ha-1) and weed index (0.00, 3.38 and 4.95%) as well as higher weed control efficiency (96.21, 89.62 and 88.06%) along with higher net returns (Rs. 64291, 66772 and 65328 ha-1) and B:C ratio (3.17, 3.80 and 3.74) over unweeded check.

Keywords **:** Cumin, herbicide, oxadiargyl, pendimethalin, weed

Cumin (*Cuminum cyminum* L.), one of the most important seed spice crops of arid region of Gujarat and Rajasthan, is used both as medicinal and flavouring agent. Cumin occupies first position in term of value and second in terms of production of seed spices in India. In India, it is cultivated on about 7.6 lakh hectares with a total production of 4.85 lakh tonnes with productivity of 639 kg ha^{-1} in 2016-17 (http://indianspices.com). In Gujarat it occupies an area of 2.79 lakh hectares with production of 2.84 lakh tonnes and productivity of 1019 kg ha^{-1} in 2016-17 (http://indianspices.com). The cumin crop is favoured by farmers due to higher profit with less input cost compared to other *rabi* crops. Cumin is a short stature crop with slow growth at initial stage, which makes it incapable to offer competition with weeds. This situation is aggravated by the broadcasting method of sowing. Investigations have revealed a loss of 80-90% in the seed yield of cumin due to weed infestation depending upon the intensity and type of weed flora (Yadav and Dahama, 2003). Hence, there is strong chance of crop failure if the weed problem is not managed properly. Manual removal of weeds, generally followed by cumin growers, is tedious, labour consuming and expensive. Moreover, there is shortage of manpower during early growth stage and therefore, complete weeding is not possible. This situation creates wide scope for use of pre- and post-emergence herbicides in combination with hand weeding for effective weed management practices. Earlier research documents revealed that herbicides *viz*., pendimethalin (Yadav *et al.*, 2012) and oxadiargyl (Patel *et al*., 2016) found to be very effective in controlling weeds. Since single method of weed control is not able to control weeds to the desired level, so integration of chemical and mechanical methods might be more effective to manage the weeds in this crop. Therefore, present experiment was conducted to evaluate efficacy of new herbicides for weed control in cumin.

MATERIALS AND METHODS

The field experiment was conducted on medium black calcareous clayey soil at Department of Agronomy, College of Agriculture, Junagadh Agricultural University, Junagadh (Gujarat) during *rabi* season of 2014-15 to 2016-17 to evaluate weed management in cumin. Geographically, Junagadh is situated at 21°29'48" N latitude and 70°26'29'' E longitude with an altitude of 60 m above the mean sea level. The experimental soil was clayey in texture (sand 25%, silt 16% and clay 59%) and slightly alkaline in reaction with pH 7.9 and EC 0.60 dS m^{-1}. It was medium in available nitrogen (234 kg ha^{-1}), low in available phosphorus (24 kg ha^{-1}) and high

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in available potash (381 kg ha^{-1}). The experiment comprised 10 treatments *viz*., T_1: Pendimethalin 900 g ha^{-1} as pre-emergence *fb* HW at 45 DAS, T_2: Oxadiargyl 75 g ha^{-1} as early post-emergence at 7 DAS *fb* HW at 45 DAS, T_3: Glyphosate 500 g ha^{-1} as early post-emergence at 7 DAS *fb* HW at 45 DAS, T_4: Glyphosate 1000 g ha^{-1} as early post-emergence at 7 DAS *fb* HW at 45 DAS, T_5: Pendimethalin 900 g ha^{-1} as pre-emergence *fb* Quizalofop-ethyl 40 g ha^{-1} as post-emergence at 45 DAS, T_6: Pendimethalin 900 g ha^{-1} as pre-emergence *fb* Fenoxaprop-ethyl 75 g ha^{-1} as post-emergence at 45 DAS, T_7: Pendimethalin 900 g ha^{-1} as pre-emergence *fb* Propaquizafop 75 g ha^{-1} as post-emergence at 45 DAS, T_8: Pendimethalin 900 g ha^{-1} as pre emergence *fb* Oxadiargyl 75 g ha^{-1} as post-emergence at 45 DAS, T_9: Weed free check and T_{10}: Unweeded control were replicated thrice in a randomized block design. The cumin variety 'Gujarat Cumin 4' was sown in November at a spacing of 30 cm x 10 cm using seed rate of 15 kg ha^{-1}. The gross and net plot size was 4.0 m x 2.4 m and 3.0 m x 1.8 m, respectively. The entire dose of fertilizer *i.e.* 30-15-0 kg N-P_2O_5-K_2O ha^{-1} was applied as basal in form of Urea and Diammonium Phosphate just before sowing in the furrows. The crop was raised as per the standard package of practices. All the herbicides were applied with manually operated knapsack sprayer fitted with flood jet nozzle at a spray volume of 500 litre ha^{-1}. Pre-emergence herbicides were applied on the very next day of sowing and the post-emergence spray was done at 7 (early post-emergence) or 45 DAS (post-emergence) as per treatments. In manual weed control treatments, weeds were uprooted and removed as per treatments. In weed free plots, the weeds were removed manually after every seven days for ensuring complete weed-free condition. Growth and yield attributing characters *viz*., plant height, number of branches per plant, number of umbels per plant, number of umbellates per umbel, number of seeds per umbel and 1000-seed weight were recorded at harvest. The crop was harvested in February from net plot at maturity. The seeds were separated from plants by thresher and seed and stalk yields were recorded for each plot. Dry weight of weeds was recorded at harvest. Weed index (WI) and weed control efficiency (WCE) were worked out using following formulae suggested by Gill and Kumar (1969) and Kondap and Upadhyay (1985).

$$WI(\%) = \frac{Y_{WF} - Y_T}{Y_{WF}} \times 100$$

Where; Y_{WF} and Y_T are the yield from weed-free plot and yield from treated plot, respectively.

$$WCE(\%) = \frac{DW_C - DW_T}{DW_C} \times 100$$

Where, DW_C = Dry matter accumulation of weeds in unweeded control, DW_T = Dry matter accumulation of weeds in treated plot.

The expenses incurred for all the cultivation operations from preparatory tillage to harvesting including the cost of inputs *viz*., seeds, fertilizers, pesticides, *etc*. applied to each treatments along with the treatment cost were calculated on the basis of prevailing local charges. The market price of herbicides used and cumin produce considered were: pendimethalin ₹ 400 L^{-1}, quizalofop ₹1350 L^{-1}, oxadiargyl ₹930 L^{-1}, fenoxaprop ₹1500 L^{-1}, glyphosate ₹270 L^{-1}, propaquizafop ₹1400 L^{-1}, cumin seed ₹ 95 kg^{-1} and cumin stalk ₹ 1 kg^{-1}. Net return against each treatment was calculated by deducting the total cost of cultivation from the gross returns. The Benefit : Cost (B:C) ratio was calculated with the help of the following formula.

$$B:C = \frac{\text{Gross returns}(₹\, ha^{-1})}{\text{Total cost of cultivation}(₹ ha^{-1})}$$

The data were subjected to statistical analysis by adopting appropriate analysis of variance (Gomez and Gomez, 1984). Wherever the F values found significant at 5 per cent level of probability, the least significant difference (LSD) values were computed for making comparison among the treatment means.

RESULTS AND DISCUSSION

Weed flora

Experimental field was infested with monocot weeds *viz*., *Brachiaria* spp. (signal grass), *Asphodelus tenuifolius* (wild onion), *Indigofera glandulosa* (three leaf indigo), *Echinochloa colona* (Barnyard grass) and *Dactyloctenium aegyptium* (crow foot grass), dicot weeds *viz*., *Chenopodium album* (common lambs quarters), *Digera arvensis* (false amaranth), *Amaranthus viridis* (pigweed), *Portulaca oleracea* (purslane), *Physalis minima* (ground cherry), *Euphorbia hirta* (common spurge) and *Leucas aspera* (thumba) and sedge weed *Cyperus rotundus* L. (purple nutsedge).

Effect of herbicides on growth and yield of cumin

An appraisal of data presented in Table-1 showed that growth and yield attributes of cumin were significantly influenced by different weed management practices. Significantly the highest plant height (29.6 cm) was recorded under the weed free check (T_9), however it remained at par with pendimethalin 900 g ha^{-1} as pre-emergence *fb* HW at 45 DAS (T_1) and oxadiargyl 75 g ha^{-1} as early post-emergence at 7 DAS *fb* HW at 45 DAS (T_2) having plant height of 28.7 and 27.7 cm, respectively. The weed free check (T_9) registered significantly the highest number of branches per plant (4.89), however it was statistically comparable to the

treatments *viz*., T_1 (pendimethalin 900 g ha^{-1} as pre-emergence *fb* HW at 45 DAS), T_2 (oxadiargyl 75 g ha^{-1} as early post-emergence at 7 DAS *fb* HW at 45 DAS), T_4 (glyphosate 1000 g ha^{-1} as early post-emergence at 7 DAS *fb* HW at 45 DAS), T_3 (glyphosate 500 g ha^{-1} as early post-emergence at 7 DAS *fb* HW at 45 DAS) and T_8 (pendimethalin 900 g ha^{-1} as pre emergence *fb* oxadiargyl 75 g ha^{-1} as post-emergence at 45 DAS) with 4.78, 4.65, 4.42, 4.30 and 4.28 branches per plant, respectively.

The treatment T_9 (weed free check) produced significantly the highest number of umbels per plant (12.45), which remained statistically at par with application of pendimethalin 900g ha^{-1} as pre-emergence *fb* HW at 45 DAS (T_1) and oxadiargyl 75 g ha^{-1} as early post-emergence at 7 DAS *fb* HW at 45 DAS (T_2) having 12.00 and 11.77 umbels per plant, respectively. The highest number of umbellates per umbel (5.92) was observed with the weed free check (T_9), but it was statistically equivalent to the treatments T_1 (pendimethalin 900g ha^{-1} as pre-emergence *fb* HW at 45 DAS) and T_2 (oxadiargyl 75 g ha^{-1} as early post-emergence at 7 DAS *fb* HW at 45 DAS) by recording 5.70 and 5.65 umbellates per umbel, respectively. The number of seeds per umbel was significantly the highest (16.09) under the weed free (T_9), however it maintained statistical equilibrium with application of pendimethalin 900 g ha^{-1} as pre-emergence *fb* HW at 45 DAS (T_1) and oxadiargyl 75 g ha^{-1} as early post-emergence at 7 DAS *fb* HW at 45 DAS (T_2) having 16.05 and 15.90 seeds per umbel, respectively. The highest 1000-seed weight of 4.25 g was recorded under the weed free check (T_9), however it remained at par with pendimethalin 900 g ha^{-1} as pre-emergence *fb* HW at 45 DAS (T_1), oxadiargyl 75 g ha^{-1} as early post-emergence at 7 DAS *fb* HW at 45 DAS (T_2) and glyphosate 1000 g ha^{-1} as early post-emergence at 7 DAS *fb* HW at 45 DAS (T_4) with test weight of 4.14, 4.10 and 3.95 g, respectively. Whereas, significantly the lowest values of these growth and yield attributes were registered under the weedy check (T_{10}). Different weed management treatments significantly influenced stalk yield of cumin (Table-1). Significantly higher mean stalk yield of 2007 kg ha^{-1} was recorded under the weed free check (T_9), which remained statistically at par with the treatments comprising pendimethalin 900 g ha^{-1} as pre-emergence *fb* HW at 45 DAS (T_1) and oxadiargyl 75 g ha^{-1} as early post-emergence at 7 DAS *fb* HW at 45 DAS (T_2). On the other hand, significantly the lowest stalk yield (578 kg ha^{-1}) was recorded under the unweeded control (T_{10}). The data furnished in Table-1 showed that different weed management treatments significantly influenced the seed yield of cumin during individual years and in pooled results. The weed free check (T_9) out yielded by producing significantly the highest seed yield of 814, 1067, 1020 and 967 kg ha^{-1} during 2014-15, 2015-16, 2016-17 and in pooled results, respectively, however it remained statistically at par with pendimethalin 900 g ha^{-1} as pre-emergence *fb* HW at 45 DAS (T_1) and oxadiargyl 75g ha^{-1} as early post-emergence at 7 DAS *fb* HW at 45 DAS (T_2) in 2014-15, 2015-16, 2016-17 and in pooled results. The yield increased with treatments T_9, T_1 and T_2 over T10 (unweeded control) was to the tune of 309, 296 and 289%, respectively. Significantly the lowest seed yield (332, 188, 188 and 236 kg ha^{-1}) was observed under the unweeded control (T_{10}) during all the three years and in pooled results. Effective control of weeds through manual weeding in treatment T_9 (Weed free) as well as integration of pre-emergence herbicide with manual weeding under treatments T_1 (pendimethalin 900 g/ha as pre-emergence *fb* HW at 45 DAS) and T_2 (oxadiargyl 75g ha^{-1} as early post-emergence at 7 DAS *fb* HW at 45 DAS) resulted into less weed-crop competition throughout the growth stage of crop and created favourable environment for plant growth. Thus, enhance availability of nutrients, water, light and space might have accelerated the photosynthetic rate, thereby increasing the supply of carbohydrates leading to increase in growth and yield. Enhanced growth and yield of cumin with application of pendimethalin and oxadiargyl were also reported by Dungarwal *et al.* (2003), Mehriya *et al.* (2007) and Singh *et al.* (2013).

Effect of herbicides on weed dry weight

The data (Table-2) indicated that different weed management treatments exerted significant effect on dry weight of weeds during 2014-15, 2015-16, 2016-17 and in pooled results. The weed management treatments including the weed free treatment significantly reduced dry weight of weeds over the unweeded control (T_{-10}). During all the individual years and in pooled results, the weed free treatment (T_9) recorded significantly the lowest weed dry weight (67, 77, 62 and 69 kg ha^{-1}), which was statistically at par with pendimethalin 900 g ha^{-1} as pre-emergence *fb* HW at 45 DAS (T_1) and oxadiargyl 75 g ha^{-1} as early post-emergence at 7 DAS *fb* HW at 45 DAS (T_2) in 2014-15 and pooled results, and with pendimethalin 900 g ha^{-1} as pre-emergence *fb* HW at 45 DAS (T_1), oxadiargyl 75 g ha^{-1} as early post-emergence at 7 DAS *fb* HW at 45 DAS (T_2) and glyphosate 1000 g ha^{-1} as early post-emergence at 7 DAS *fb* HW at 45 DAS (T_4) in 2015-16 and 2016-17. Whereas, the unweeded control (T_{10}) recorded the highest dry weight of weeds (1712, 1850, 1883 and 1815 kg ha^{-1}).

Weed control and herbicidal efficiency in cumin

Mean data of weed index (WI) and weed control efficiency (WCE) were given in Table-2. The results

Table 1: Growth and yield of cumin under different weed management practices

Treatments	Plant height (cm)	Branches plant^{-1}	Umbels plant^{-1}	Umbellates umbel^{-1}	Seeds umbel^{-1}	1000-seed wt. (g)	Stalk yield (kg ha^{-1})	Seed yield (kg ha^{-1})			
								2014-15	2015-16	2016-17	Pooled
T_1:Pendimethalin *fb* HW @ 900 g ha^{-1}	28.7	4.78	12.00	5.70	16.05	4.14	1892	780	1036	988	934
T_2:Oxadiargyl @ 75 g ha^{-1}*fb* HW	27.7	4.65	11.77	5.65	15.90	4.10	1849	775	1016	967	919
T_3:Glyphosate @ 500 g ha^{-1}*fb* HW	26.5	4.30	10.55	5.15	13.75	3.80	1475	610	609	599	606
T_4:Glyphosate @ 1000 g ha^{-1}*fb* HW	26.6	4.42	10.58	5.28	13.89	3.95	1546	631	710	679	673
T_5:Pendimethalin @ 900 g ha^{-1} *fb* Quizalofop @ 40 g ha^{-1}	24.5	3.75	9.69	4.79	12.63	3.30	1006	501	471	478	484
T_6:Pendimethalin @ 900 g ha^{-1}*fb* Fenoxaprop @ 75 g ha^{-1}	25.5	3.77	9.83	4.87	12.74	3.52	954	512	472	469	485
T_7:Pendimethalin @ 900 g ha^{-1}*fb* propaquizafop @ 75 g ha^{-1}	23.7	2.82	8.76	4.75	11.98	3.25	914	457	326	318	367
T_8:Pendimethalin @ 900 g ha^{-1}*fb* oxadiargyl @ 75 g ha^{-1}	26.2	4.28	11.52	5.08	13.72	3.67	1449	627	556	509	564
T_9:Weed free	29.6	4.89	12.45	5.92	16.09	4.25	2007	814	1067	1020	967
T_{10}:Unweeded check	18.1	1.15	5.80	3.90	8.92	2.37	578	332	188	188	236
SEm(±)	**0.81**	**0.26**	**0.59**	**0.20**	**0.56**	**0.15**	**68**	**53**	**41**	**43**	**26**
LSD (0.05)	**2.3**	**0.74**	**1.67**	**0.57**	**1.58**	**0.42**	**192**	**156**	**122**	**127**	**75**

Table 2: Weed dry weight, weed control effic]y and economics under different management practices

Treatments	Weed dry weight (kg ha^{-1})				WI (%)	WCE (%)	Cost of cultivation (₹ ha^{-1})	Gross returns (₹ ha^{-1})	Net returns (₹ ha^{-1})	B : C ratio
	2014-15	2015-16	2016-17	Pooled						
T_1:Pendimethalin *fb* HW @ 900 g ha^{-1}	191	177	198	188	3.38	89.62	23880	90652	66772	3.80
T_2:Oxadiargyl @ 75 g ha^{-1}*fb* HW	211	217	222	217	4.95	88.06	23843	89171	65328	3.74
T_3:Glyphosate @ 500 g ha^{-1}*fb* HW	507	520	556	528	37.34	70.93	23009	59042	36033	2.57
T_4:Glyphosate @ 1000 g ha^{-1}*fb* HW	334	235	259	276	30.36	84.79	23339	65524	42185	2.81
T_5:Pendimethalin @ 900 g ha^{-1} *fb* Quizalofop @ 40 g ha^{-1}	1199	1025	1111	1112	50.00	38.75	23460	46942	23482	2.00
T_6:Pendimethalin @ 900 g ha^{-1}*fb* Fenoxaprop @ 75 g ha^{-1}	1089	849	926	955	49.89	47.40	23505	46988	23483	2.00
T_7:Pendimethalin @ 900 g ha^{-1}*fb* propaquizafop @ 75 g ha^{-1}	1360	1215	1296	1291	62.06	28.90	24030	35767	11737	1.49
T_8:Pendimethalin @ 900 g ha^{-1}*fb* oxadiargyl @ 75 g ha^{-1}	737	745	864	782	41.68	56.91	23543	55028	31485	2.34
T_9:Weed free	67	77	62	69	0.00	96.21	29580	93871	64291	3.17
T_{10}:Unweeded check	1712	1850	1883	1815	75.57	0.00	20580	23018	2438	1.12
SEm(±)	**58**	**73**	**73**	**40**	-	-	-	-	-	-
LSD (0.05)	**174**	**218**	**217**	**112**	-	-	-	-	-	-

Note: HW, Hand weeding; WI, weed index; WCE, weed control efficiency; B:C, Benefit : cost

showed that treatments *viz*., pendimethalin 900 g ha^{-1} as pre-emergence *fb* HW at 45 DAS (T_1) and oxadiargyl 75g ha^{-1} as early post-emergence at 7 DAS *fb* HW at 45 DAS (T_2) recorded lower WI of 3.38 and 4.95%, respectively. Similarly, the weed free check (T_9) recorded the highest WCE of 96.21%, followed by the treatments *viz*., pendimethalin 900g ha^{-1} as pre-emergence *fb* HW at 45 DAS (T_1) and oxadiargyl 75 g ha^{-1} as early post-emergence at 7 DAS *fb* HW at 45 DAS (T_2) by recording WCE of 89.62 and 88.06%, respectively. This might be attributed to the effective control of weeds under these treatments, which reflected in less number of weeds and ultimately lower weed biomass. In addition to this, dense crop canopy might have suppressed weed growth and ultimately less biomass. This might be due to elimination of weeds by manual weeding and herbicides. The combined effect on dry weight of weeds and seed yield under these treatments might have been responsible for excellent weed indices. The weedy check (T_{10}) recorded significantly the highest dry weight of weeds owing to uncontrolled condition favoured luxurious weed growth leading to increased weed dry matter. These findings are in close conformity with those reported by Yadav *et al*. (2004), Patel *et al.* (2008), Yadav *et al.* (2011), Gohil *et al.* (2015) and Bhutia *et al.* (2017). They found that pendimethalin and oxadiargyl are effective for weed control in spice crops.

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