

Bio-efficacy of herbicides applied in cumin (*Cuminum cyminum*) and their carry-over effects on succeeding pearl millet (*Pennisetum glaucum*)

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ABSTRACT

A field experiment was conducted during the winter seasons of 2010–11 and 2011–12 to study bio-efficacy of pendimethalin available in capsule suspension form (CS) and other recommended herbicides on the productivity of cumin (*Cuminum cyminum* L.) and their carry-over effects on the succeeding pearl millet [*Pennisetum glaucum* (L) R. Br. Emend. Stuntz.]. Pre-emergence application of pendimethalin CS @ 484 g/ha + 1 hand-weeding controlled the weeds effectively in cumin and resulted in seed yield of 684 kg/ha, which was at par with weed-free check (701 kg/ha). Increase in the dose of pendimethalin CS from 484 to 580 and 580 to 677 g/ha did not influence seed yield of cumin but significantly suppressed plant count and biomass of succeeding pearl millet. Application of pendimethalin liquid formulation @ 750 g/ha exhibited similar trend. Oxadiargyl and oxyfluorfen applied @ 50 g/ha + 1 hand-weeding at 30 days decreases the weed stand and weed dry matter, where the extent of control was at par with weed-free plots without any residual effect on succeeding pearl millet. Post-emergence application of oxadiargyl @ 50 g/ha + 1 hand-weeding at 30 days recorded maximum seed yield (715 kg/ha), net return (₹58,400/ha) and benefit: cost ratio (4.08), with weed control efficiency of 99%, closely followed by oxyfluorfen 50 g/ha + 1 hand-weeding.

Key words : Bio efficacy, Crop protection, Carry-over effects, Cumin, Oxadiargyl, Oxyfluorfen, Pearl millet, Pendimethalin, Seed yield, Weed-control

Cumin is an important seed spice having immense export potential covering 4.68 lakh ha area in Rajasthan with average productivity of 380 kg/ha. Rajasthan is a leading producer of cumin accounting 70% of all India's output. The climatic conditions prevailing in Rajasthan, i.e. dry and moderately cool winter, light and well-drained soil with low fertility status are well suited to cumin. But, the crop is highly susceptible to pest, diseases and weeds causing losses of different magnitudes, and complete crop failure is not an uncommon phenomenon. The common practice of dry sowing followed by 2 light irrigations and low initial plant growth results in severe weed infestation in this crop. The weeds with their ability to germinate earlier and having fast growth suppress the growth and development of the crop. *Chenopodium album*, a common weed of cumin, enhances humidity and create environment most congenial for the spread of blight disease responsible for severe yield loss in cumin. Contamination of

cumin seed with the weed *Plantago pumela*, locally called as *zirri*, seeds makes it unfit for export (Yadav and Dhahama, 2003).

Pendimethalin, trifluralin, oxadiargyl and oxyfluorfen are some herbicides, which are commonly used to manage weeds in cumin. Pendimethalin and fluchloralin may persist for longer period under low soil moisture and poor organic matter conditions (Yadav *et al.*, 2004a). The capsule suspension (greasy) form of pendimethalin has not been tested in the cumin and its persistency on succeeding pearl millet. Hence experiment was planned to study efficacy of capsule suspension form of pendimethalin with already recommended herbicides on the productivity of cumin and their persistency/phyto-toxicity on the succeeding pearl millet.

MATERIALS AND METHODS

The field experiment was conducted at Agricultural Research Station, during the winter (*Rabi*) seasons of 2010–11 and 2011–12. The soil was loamy sand in texture, low in available nitrogen (160 kg/ha), medium in available P₂O₅ (34 kg/ha) and available K₂O (298 kg/ha). Sixteen

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treatments comprising pre-emergence (PE) application of pendimethalin @ 484, 580, 677 g/ha through capsule suspension form (CS) with and without hand-weeding at 30 days after sowing (DAS), pendimethalin @ 750 g/ha through liquid formulation (as PE) with and without weeding at 30 days after sowing, early post-emergence (20 DAS) application of oxadiargyl and oxyfluorfen @ 50 g/ha with and without hand-weeding 30 days after sowing, pre-plant incorporation (PPI) of trifluralin @ 1.0 kg/ha with and without hand-weeding at 30 days after sowing, weed-free and weedy check were evaluated in randomized block design with 3 replications.

Cumin variety 'GC 4' was sown in the first fortnight of November during both the years at 30 cm row-to-row and 7 cm plant-to-plant spacing using hand plough. After sowing, irrigation was given through check basin system. A light irrigation was given 8 days after sowing to facilitate germination. Pre-plant incorporation of herbicide was done by spraying the required quantity of solution before sowing and mixing it in the soil with spade and rack, whereas pre-emergence application was done on the second day of sowing. Post-emergence application of herbicide was done at 20 days after sowing. All herbicidal solutions were aerial sprayed using conventional nap sack sprayer with flat fan/cut nozzle. Half the nitrogen (15 kg/ha), full phosphorus (8.5 kg/ha) and sulphur (30 kg/ha through gypsum) were applied basal. Remaining nitrogen (15 kg/ha) was top dressed 35 days after sowing with irrigation water. After germination of the crop, 3 more irrigations were given at branching, flowering and seed-development stages of the crop. The crop was harvested in the first fortnight of March during both the years. Since weed flora in the field was dominated by broad-leaf weeds, during both the seasons it was not categorized further in different classes.

To study persistency/phyto-toxicity of herbicides, pearl millet seeds @ 200/plot were sown as succeeding crop in the net plot area within one week of harvesting of cumin. The plots were irrigated and next day pearl millet seeds were placed in furrows with the help of hand plough without disturbing the soil. Pearl millet was raised as irrigated crop up to 60 days stage and thereafter harvested to record dry matter. The plant count of the succeeding crop was also recorded before harvesting.

RESULTS AND DISCUSSION

Weed count and biomass

During both seasons, weed flora in the experiment field was dominated by *Chenopodium album* L., *Chenopodium murale* L., *Asphodelus tenuifolius*, *Rumex dentatus*, *Launaea asplenifolia* L., *Plantago pumela*, *Melilotus indica* L., *Convolvulus arvensis* L., *Fumaria parviflora*

Lam., *Spergula arvensis*, *Melilotus alba* L., *Trianthema portulacstrum* L. etc. Weed count and weed biomass were significantly influenced with different weed-control treatments (Table 2). Herbicides applied alone were found less effective but when they were super-imposed with 1 hand-weeding, complete control equivalent to season-long weed free condition was observed. Minimum weed dry matter and maximum weed control efficiency (WCE) were recorded with post-emergence application of oxadiargyl @ 50 g/ha + 1 hand-weeding at 30 days. Yadav *et al.* (2004b) and Mehriya *et al.* (2007) also reported that oxadiargyl and oxyfluorfen can effectively control weeds in cumin. Pre-plant incorporation of trifluralin @ 1 kg/ha and pre-emergence application of pendimethalin liquid @ 750 g/ha super-imposed with weeding also reduced weed count and weed dry matter to significant extent and gave WCE of 96 and 99% respectively.

Pre-emergence application of pendimethalin CS @ 484 g/ha followed by 1 hand-weeding at 30 days after sowing also reduced the weed count and weed dry matter significantly compared to weedy check. The respective values were at par with oxadiargyl and oxyfluorfen 50 g/ha + weeding. Further increase in dose of pendimethalin CS from 484 to 580 and 580 to 677 g/ha did not show any advantage in reducing weed growth over 484 g/ha.

Plant count, yield attributes and seed yield

The initial plant population was found to be at par under all the treatments, while the plant count recorded at harvest declined significantly by 7–8/m row length in weedy check plot compared to other treatments (Table 1). Dense population of weeds in weedy check plot, suppressed the crop growth to maximum extent, even killed the crop plant due to smothering effect resulting significant reduction in plant stand in cumin (Mehariya *et al.*, 2008).

There was a significant improvement in primary branches/plant, umbels/plant, umbellate/umbel, seeds/umbel and 500-seed weight by 50.0, 66.7, 42.8, 33.3 and 12.7%, respectively, owing to pendimethalin CS applied @ 484 g/ha + 1 hand-weeding at 30 days over weedy check. Further increase in the dose of pendimethalin CS from 484 to 580 and 580 to 677 g/ha did not influence these traits. Pendimethalin CS @ 484 g/ha without weeding was less effective, as it improved these traits by 40.0, 60.0, 25.0, 25.0, and 3.3% only respectively, compared to weedy check. Similar pattern of decrease in the efficiency was observed in other herbicidal treatments when their sole application was not super-imposed with weeding. Longer weed-free period prevailed under the treatments where herbicidal application was followed by weeding at 30 days, increased the yield attributes and decreased dry-

Table 1. Growth and yield attributes of cumin as influenced by different weed-management practices (pooled data of 2 years)

Treatment	Dose (g/ha)	Time of application	Initial plant count/ meter row	Final plant count/m row	Plant height at harvest (cm)	Primary branches/ plant	Umbels/ plant	Umbellate/ umbel	Seeds/ umbellate	500-seed weight (g)
Pendimethalin CS ¹	484	PE ²	16	15	24.9	5	25	5	5	2.12
Pendimethalin CS	580	PE	16	16	25.2	6	28	5	6	2.31
Pendimethalin CS	677	PE	16	16	25.3	6	28	4	6	2.27
Pendimethalin Liquid	750	PE	15	14	24.3	5	24	5	5	2.32
Oxadiazyl	50	Post ³	16	15	25.7	5	26	6	6	2.35
Oxyfluorfen	50	Post	16	16	24.4	6	28	5	6	2.34
Trifluralin	1,000	PPI ⁴	16	16	25.5	5	29	5	6	2.33
Pendimethalin CS + 1 hand-weeding 30 DAS	484	PE	16	16	25.7	6	30	7	6	2.35
Pendimethalin CS + 1 hand-weeding 30 DAS	580	PE	16	16	25.2	7	28	6	7	2.35
Pendimethalin CS + 1 hand-weeding 30 DAS	677	PE	16	15	25.7	7	25	6	7	2.44
Pendimethalin liquid + 1 hand-weeding 30 DAS	750	PE	15	15	26.8	6	30	7	6	2.27
Oxadiazyl g/ha + 1 hand-weeding 30 DAS	50	Post	16	16	27.7	7	31	7	8	2.35
Oxyfluorfen + 1 hand-weeding 30 DAS	50	Post	16	16	27.5	6	28	6	7	2.34
Trifluralin + 1 hand-weeding 30 DAS	1,000	PPI	16	16	28.4	7	26	5	5	2.22
Season-long weedy	-	-	16	7	23.0	3	10	4	4	2.05
Season-long weed free	-	-	16	16	29.0	7	30	7	8	2.33
SEm±			0.3	0.5	1.1	0.4	1.5	0.4	0.5	0.04
CD (P=0.05)			NS	1.4	3.3	1.0	4.4	1.1	1.3	0.12

¹capsule suspension form; ²pre-emergence; ³post-emergence; ⁴pre-plant incorporation; DAS, days after sowing

Table 2. Weed count, weed dry matter, seed yield, economics of cumin plant count and dry-matter of succeeding pearl millet as influenced by weed-management practices (pooled data of two years)

Treatment	Dose (g/ha)	Time of application	Weed count/m ² at harvest	Weed dry matter at harvest (g/m ²)	WCE (%)	WCI (%)	Seed yield (kg/ha)	Net returns (× 10 ³ ₹/ha)	Benefit: cost ratio	Succeeding crop pearl millet Plant count/200 seed sown	Dry matter 60 DAS (g/m ²)
Pendimethalin CS ¹	484	PE ²	3.1 (9)	73	92	32	475	33.2	2.84	165	595
Pendimethalin CS	580	PE	2.5 (6)	57	94	20	559	42.4	3.31	160	557
Pendimethalin CS	677	PE	2.3 (5)	65	93	23	538	40.2	3.16	140	477
Pendimethalin Liquid	750	PE	2.7 (7)	66	93	22	550	41.5	3.25	144	493
Oxadiargyl	50	Post ³	2.3 (5)	45	95	16	592	46.1	3.51	160	589
Oxyfluorfen	50	Post	2.5 (6)	62	93	20	563	42.9	3.32	163	568
Trifluralin	1,000	PP ⁴	3.2 (10)	44	95	20	559	42.4	3.32	163	559
Pendimethalin CS + 1 hand weeding 30 DAS	484	PE	2.3 (5)	23	98	2	684	55.7	3.94	165	596
Pendimethalin CS + 1 hand-weeding 30 DAS	580	PE	2.1 (4)	19	98	4	675	54.8	3.86	163	595
Pendimethalin CS + 1 hand-weeding 30 DAS	677	PE	1.8 (3)	18	98	8	646	51.5	3.73	132	518
Pendimethalin liquid + 1 hand-weeding 30 DAS	750	PE	2.2 (5)	14	99	8	642	51.1	3.68	143	523
Oxadiargyl g/ha + 1 hand-weeding 30 DAS	50	Post	1.6 (2)	8	99	-	715	58.4	4.08	165	577
Oxyfluorfen + 1 hand-weeding 30 DAS	50	Post	2.3 (5)	16	98	1	692	56.6	3.99	167	584
Trifluralin + 1 hand-weeding 30 DAS	1,000	PP ⁴	2.9 (8)	36	96	4	670	54.2	3.90	168	579
Season-long weedy			16.1 (260)	947	100	82	128	-3.5	0.84	168	640
Season-long weed-free							701	55.3	3.50	169	658
SEM±			0.03	9.5	-	-	35	-	-	5.1	31.3
CD (P=0.05)			0.09	27.4	-	-	102	-	-	14.8	90.3

¹Capsule suspension form, ²pre-emergence, ³post-emergence, ⁴pre-plant incorporation, ⁵data subject to square root transformation, figures in the parentheses are mean of original values; DAS, days after sowing; WCE, Weed-control efficiency

matter production and population of the weeds. Pendimethalin liquid @ 750 g/ha + 1 hand-weeding at 30 days produced yield attributing characters at par with pendimethalin CS 484 g/ha + 1 hand-weeding at 30 days. It shows that application of pendimethalin through capsule suspension form requires lesser dose to manage weeds of cumin. The affectivity of pendimethalin CS was more due to better spread and sticking nature of herbicidal solution compared to liquid formulation.

Seed yield of cumin recorded under various herbicidal treatments revealed that integration of hand weeding at 30 days along with herbicidal application provided better control of weeds for longer crop-growth period resulting in better yield advantage than sole application of herbicides (Table 2). Integration of 1 hand-weeding at 30 days with pendimethalin CS @ 484 g/ha, pendimethalin @ 750 g/ha liquid, oxadiargyl and oxyfluorfen @ 50 g/ha 20 days after sowing significantly increased the seed yield by 30.6, 14.3, 17.2 and 18.6% respectively, over their sole application. Parihar and Singh (1994) and Mehriya *et al.* (2007) reported better control of weeds in cumin with integrated method of weed control. Maximum seed yield of 715 kg/ha with WCE of 99% was observed under oxadiargyl @ 50 g/ha + weeding 30 days, which was at par with seed yield obtained under season-long weed-free plot and all other herbicidal treatments super-imposed with 1 hand-weeding at 30 days. Seed yield of cumin was negatively correlated with the dry matter of weed. The seed yield decreased exponentially as the weed dry matter increased and the weeds accounted for fifth fold reduction in yield of cumin.

Economics

Implication of any of the weed management practice results in better monetary return when compared with weedy check. Unweeded control was observed as a futile practice, as it gave negative benefit: cost ratio of 0.84. Post-emergence application of oxadiargyl @ 50 g/ha + 1 hand-weeding at 30 days recorded the maximum net return and benefit: cost ratio, which was closely followed by post-emergence application of oxyfluorfen @ 50 g/ha + 1 hand-weeding at 30 days. Increased cost of production due to engagement of more labourer in season-long weed-free crop resulted in comparatively lower net return and benefit: cost ratio as compared to the application of herbicides along with weeding.

Residual effect of herbicides

Germination and crop plant growth of succeeding pearl millet was significantly reduced due to increasing

dose of pendimethalin CS from 484 to 677 g/ha and pendimethalin liquid @ 750 g/ha either alone or followed by 1 hand-weeding in preceding crop cumin (Table 2). The biomass of crop recorded at 60 days was significantly decreased by 181 and 165 g/m², respectively, with sole application of pendimethalin CS @ 677 g/ha and pendimethalin liquid @ 750 g/ha compared to weed-free plot. Yadav *et al.* (2004a) reported that cereals are selective to the pendimethalin due to placement of crop seed below herbicidal layer. Covarelli (1993) observed tillage and irrigation influences persistency of herbicides. Application of oxyfluorfen, oxadiargyl or trifluralin with and without weeding in cumin did not have any adverse effect on succeeding pearl millet.

It was concluded that in cumin-pearl millet cropping sequence, weeds in cumin crop should be managed by early post-emergence (20 DAS) application of either oxadiargyl or oxyfluorfen @ 50 g/ha followed by 1 hand-weeding at 30 days. Pre-emergence application of capsule suspension form of pendimethalin @ 484 g/ha + 1 hand-weeding at 30 days can also be used to manage weeds in cumin. These herbicide applications do not have any harmful carry over effects on the succeeding pearl millet.

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