Weed Management and Dynamics of Weed Seedbank in *rabi* fennel (*Foeniculum vulgare*)

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ABSTRACT

A field experiment was conducted during rabi season of 2011-12 at Junagadh to find out most effective and economical method of weed control in rabi fennel (Foeniculum vulgare Mill.). The dominant weed species observed were Cyperus rotundus L., Chenopodium album L., Digera arvensis Forsk and Asphodelus tenuifolius L. Cav. Results revealed that besides weed free treatment, significantly higher plant height, number of branches/plant, number of umbels/plant, number of seeds/umbellate, test weight, seed weight per plant, and seed and stover yields of fennel were recorded with pre-emergence (PRE) application of pendimethalin @ 0.90 kg/ha + post-emergence (POE) application of fenoxaprop @ 75 g/ha at 45 DAS, which was at par with pendimethalin @ 0.90 kg/ha PRE + hand weeding (HW) at 45 DAS and HW twice at 15 and 45 DAS. These treatments also recorded lower weed density and dry weight of weeds along with higher net returns and B: C ratio owing to lower weed index and higher weed control efficiency. The highest depletion of weed seedbank was observed with pendimethalin @ 0.90 kg/ha PRE + HW at 45 DAS.

Keywords: Pendimethalin, Fenoxaprop, Quizalofop, oxadiargyl, glyphosate, propaquizafop.

1. INTRODUCTION

India occupies prime position in seed spices and plays very important role in earning foreign exchange through export of seed spices. India is the world's largest producer, consumer and exporter of the spices. Fennel (*Foeniculum vulgare* Mill.) is an important seed spice. Gujarat ranks first with respect to production and productivity in India. Area under *rabi* direct seeded fennel is increasing day by day, because it is more profitable than other *rabi* crops like wheat, gram, cumin, mustard etc. Lake of production technologies and weed control particularly for *rabi* drilled fennel are important constraints in boosting up the production. Initial slow growth of seed spices leads to severe weed crop competition and reduces growth as well as yield as high as 91.4% (Mali and Suwalka, 1987). Application of herbicides in fennel effectively controls the weeds and increases seed yield from 43.2 to 86.9 % (Voevodin and Borisenko, 1981).

Soil weed seedbank is reserve of viable seeds present on the surface and in the soil. It consists of new seeds recently shed by a weed plant as well as older seeds that have persisted in the soil for several years. The seedbank is an indicator of past and present weed populations in soil. It is the main source of weeds in agricultural fields. Therefore, knowledge of seedbank dynamics can help in designing weed management practices related to a particular microclimate in an area. With this view, a seedbank study was conducted.

2. MATERIALS AND METHODS

A field experiment was conducted at Instructional Farm, Department of Agronomy, College of Agriculture, Junagadh Agricultural University, Junagadh (Gujarat, India) during *rabi* season of 2011-12. The soil of experimental field was clayey in texture, slightly alkaline in reaction (pH 8.0 and EC 0.56 dS/m), low in available N (238 kg/ha), medium in available P_2O_5 (36.8 kg/ha) and K_2O (221 kg/ha). The experiment comprised ten treatments, viz., pendimethalin @ 0.90 kg/ha as pre-emergence (PRE) + hand weeding (HW) at 45 DAS, oxadiargyl @ 75 g/ha as early post-emergence (POE) at 7 DAS + HW at 45 DAS, glyphosate @ 1.0 kg/ha as early POE at 7 DAS + HW at 45 DAS, pendimethalin @ 0.90 kg/ha as PRE + quizalofop @ 40 g/ha as POE at 45 DAS, pendimethalin @ 0.90 kg/ha as PRE + fenoxaprop @ 75 g/ha as POE at 45 DAS, pendimethalin @ 0.90 kg/ha as PRE + propaquizafop @ 75 g/ha as POE at 45 DAS, pendimethalin @ 0.90 kg/ha as PRE + oxadiargyl @ 75 g/ha as POE at 45 DAS, HW twice at 15 and 45 DAS, weed free and unweeded check were laid in randomized block design with three replications. The mean maximum and minimum temperature during the crop growth and development period ranged between 27.5 to 39.9^{0}C and 9.4 to 22.1^{0}C, respectively. The range of average relative humidity, bright sun shine, wind speed and daily evaporation was 25.6-57.0%, 4.8-10.2 h, 2.4-6.9 km/h and 3.8-10.7 mm, respectively. The fennel variety 'GF-11' was sown in second week of November at a spacing of 60 × 20 cm using seed rate of 8 kg/ha and fertilized with 90-30-0 kg N-P_2O_5-K_2O/ha by applying half dose of N and full doses of P as basal application in form of urea and DAP at sowing and remaining half dose of N was top-dressed in two equal splits in form of urea at 45 and 75 DAS and crop harvested at first week of April. All the standard package of practices including appropriate plant protection measures were followed throughout the cropping season. Herbicidal solutions as PRE at 2 DAS and POE application at 45 DAS were sprayed with the help of knapsack sprayer using flat fan nozzle and a spray volume of 500 l/ha. As per schedule hand weeding in the respective plots was done manually. In weed free plots, the weeds were removed manually after every ten days for ensuring weed free condition. Weed index (WI), weed control efficiency (WCE) and herbicidal efficiency index (HEI) were worked out as per formula given by Gill and Kumar (1969), Kondap and Upadhyay (1985) and Krishnamurthy *et al*. (1995), respectively to assess the efficiency of different weed management practices. Data on species wise weed count at 30 DAS, 60 DAS and at harvest by counting weeds present in 1 m × 1 m quadrate, relative weed density, dry

weight of weeds and number of weed seeds in soil per core sample before sowing and after harvest of the crop as per the FAO protocol (Forcella *et al.*, 2011) were worked out. The experimental data recorded for growth parameters, yield attributes and yield parameters and economics were statistically analyzed for level of significance.

3. RESULTS AND DISCUSSION

Weed flora

The weed flora observed in the experimental field constituted monocot weeds *viz*., *Brachiaria* spp. (7.7%), *Indigoflora glandulosa* L. (7.0%), *Asphodelus tenuifolius* L. Cav. (5.0%) and *Dactyloctenium aegyptium* Beauv (1.3%), dicot weeds *viz*., *Digera arvensis* Forsk (18.7%), *Chenopodium album* L. (16.3%), *Physalis minima* L. (7.7%), *Portulaca oleracea* L. (5.7%), *Euphorbia hirta* L. (4.0%) and *Leucas aspera* Spreng (1.3%), and sedge weed *Cyperus rotundus* L. (25.3%).

Weed parameters

The results indicated that application of different weed management practices significantly influenced weed population (Table 2) and dry weight of weed (Table 3). Among the weed management treatments, maximum weed population and dry weight of weeds at harvest were recorded in unweeded check. Besides, weed free treatment, the lowest weed population was recorded with HW twice, which remained at par with pendimethalin as PRE + HW and pendimethalin as PRE + fenoxaprop as POE. Next to weed free, HW twice or pendimethalin as PRE + HW or pendimethalin PRE + oxadiargyl as POE reduced dry weight of weeds over unweeded check. This can be attributed to the effective control of early as well as late flushes of weeds and did not allow weeds to regenerate, 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. The unweeded check 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 conformity with those reported by Thakral *et al.* (2007) and Meena and Mehta (2009).

Besides weed free treatment, the highest WCE (93.63) was obtained with HW twice, followed by pendimethalin as PRE + HW (93.31). Next to weed free, minimum WI (0.52) and maximum HEI (98.84%) were obtained with pendimethalin PRE + fenoxaprop POE, closely followed by pendimethalin PRE + HW (0.91 and 98.06%). 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. Whereas the highest WI (49.97%) observed in the unweeded check indicated reduction in seed yield by about 50.0 per cent

due to uncontrolled weeds as compared to weed free. The result confirms the findings of Meena and Mehta (2009) and Nagar *et al*. (2009).

Weed seedbank

The dynamics of weed seedbank in soil drastically influenced by different weed management treatments (Table 2). The lowest weed seedbank was recorded with pendimethalin as PRE + HW. Pendimethalin as PRE controlled weeds right from the start and weeds those escaped and emerged later were controlled by hand weeding at 45 DAS, hence did not allow to set the weed seeds, which was almost same to the weed free and remained at par with pendimethalin as PRE + oxadiargyl as POE and HW twice. The treatments *viz*., pendimethalin as PRE + quizalofop as POE, pendimethalin as PRE + fenoxaprop as POE and pendimethalin as PRE + propaquizafop as POE were found to increase weed seedbank. This might be ascribed to the fact that the post-emergent herbicides *viz*., quizalofop, fenoxaprop and propaquizafop are grassy weed killers, leaving dicot weeds to produce seeds. The unweeded check recorded the highest size of weed seedbank due to production of large number of weed seeds under uncontrolled condition leading to 978 % increase in the initial weed seedbank.

Crop growth and yield

Different weed management treatments significantly influenced the different growth and yield attributes of fennel crop. Perusal of data revealed that besides weed free treatment, higher plant height, number of branches/plant, number of umbels/plant, number of seeds /umbellate, 1000-seed weight, seed weight/plant, and seed and stover yields were recorded with pendimethalin as PRE + fenoxaprop as POE, which was at par with pendimethalin as PRE + HW and HW twice (Table 1). The improved growth and yield under these treatments might be due to effective weed control resulting in lesser competition of weeds which might have resulted in the better utilization of nutrients and moisture available in the soil by crop leading to increased rate of photosynthesis and supply of photosynthates to various metabolic sinks. These findings are in agreement with those of Meena and Mehta (2009) and Nagar *et al.* (2009).

Economics

It was evident that pendimethalin as PRE + fenoxaprop as POE gave the maximum net return (Rs. 81993/ha) and B:C ratio (3.22), followed by pendimethalin as PRE + HW, HW twice and weed free treatment (Table 3). The lower net returns and B:C ratio in weed free might be due to more cost required to create weed free condition for entire period in the crop season.

4. CONCLUSION

It is concluded that effective management of weeds and weed seedbank along with profitable production of direct seeded *rabi* fennel can be obtained with pendimethalin as PRE + fenoxaprop

as POE at 45 DAS or pendimethalin as PRE + HW at 45 DAS or HW twice at 15 and 45 DAS or keeping the crop weed free throughout crop period according to availability of labours.

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Table 1. Effect of different treatments on plant growth, yield attributes and yield of fennel

Treatments	Plant height (cm)	Branches/plant	Umbels/ plant	Umbellates /umbel	Seeds/ umbellate	1000-seed weight (g)	Seed weight/ plant (g)	Seed yield (kg/ha)	Stover yield (kg/ha)
Pendimethalin + HW	146.3	6.5	11.3	23.3	24.1	6.57	27.87	1824	4447
Oxadiargyl + HW	130.9	5.0	7.7	18.9	19.1	6.02	14.27	1045	2947
Glyphosate + HW	127.7	4.2	7.2	18.7	19.1	6.01	13.77	1086	2994
Pendimethalin + Quizalofop	137.1	4.9	8.4	21.9	20.1	6.05	15.47	1321	3664
Pendimethalin + Fenoxaprop	149.9	6.6	12.0	23.0	25.3	6.62	29.33	1831	4507
Pendimethalin + Propaquizafop	136.5	5.0	8.2	21.3	19.1	6.03	16.07	1325	3644
Pendimethalin + Oxadiargyl	137.4	5.2	8.3	22.9	19.2	6.14	15.43	1315	3557
HW twice	146.6	6.7	10.6	23.6	23.3	6.52	28.00	1799	4496
Weed free	153.1	7.1	12.7	23.7	25.5	7.30	31.10	1841	4512
Unweeded check	126.6	3.9	6.3	17.1	16.2	5.71	10.17	921	2668
LSD (P=0.05)	14.7	1.0	2.2	NS	4.1	0.82	4.27	368	821

Table 2. Effect of integrated weed management on weed population and soil weed seedbank dynamics

Treatments	Monocot weeds/m^2 at			Dicot weeds/m^2 at			Sedge weeds/m^2 at			Weed seedbank/core		
	30 DAS	60 DAS	Harvest	30 DAS	60 DAS	Harvest	30 DAS	60 DAS	Harvest	Initial	Final	Addition(+)/ Depletion(-)
Pendimethalin + HW	1.22 (1.00)	1.17 (1.00)	1.05 (0.67)	2.27 (4.67)	1.34 (1.33)	1.44 (1.67)	2.60 (6.33)	1.56 (2.00)	1.66 (2.33)	210	74	-136 (-65)
Oxadiargyl + HW	1.34 (1.33)	1.68 (2.33)	1.77 (2.67)	2.38 (5.33)	2.54 (6.00)	2.40 (5.33)	3.27 (10.33)	2.67 (6.67)	2.68 (6.67)	210	147	-63 (-30)
Glyphosate + HW	1.86 (3.00)	1.84 (3.00)	1.56 (2.00)	4.22 (17.33)	2.57 (6.67)	2.59 (6.33)	2.53 (6.33)	2.18 (4.33)	2.78 (7.33)	210	161	-49 (-23)
Pendimethalin + Quizalofop	1.46 (1.67)	2.60 (6.33)	2.61 (6.33)	2.66 (6.67)	3.67 (13.00)	3.39 (11.00)	3.36 (11.00)	3.76 (13.67)	3.52 (12.00)	210	278	68 (32)
Pendimethalin + Fenoxaprop	1.34 (1.33)	1.22 (1.00)	1.17 (1.00)	2.65 (6.67)	3.58 (12.33)	3.13 (9.33)	2.67 (6.67)	1.58 (2.00)	1.72 (2.67)	210	242	32 (15)
Pendimethalin + Propaquizafop	1.46 (1.67)	2.04 (3.67)	1.74 (2.67)	2.54 (6.00)	3.76 (13.67)	3.52 (12.00)	3.22 (10.00)	2.95 (8.33)	2.72 (7.00)	210	221	11 (5)
Pendimethalin + Oxadiargyl	1.34 (1.33)	2.08 (4.00)	1.68 (2.33)	2.81 (7.67)	0.88 (0.33)	1.05 (0.67)	3.13 (9.33)	2.85 (7.67)	2.80 (7.33)	210	99	-111 (-53)
HW twice	1.05 (0.67)	1.22 (1.00)	1.17 (1.00)	1.34 (1.33)	1.34 (1.33)	1.44 (1.67)	1.34 (1.33)	1.34 (1.33)	1.68 (2.33)	210	125	-85 (-40)
Weed free	0.71 (0)	0.71 (0)	0.71 (0)	0.71 (0)	0.71 (0)	0.88 (0.33)	0.71 (0)	0.88 (0.33)	1.17 (1.00)	210	76	-134 (-64)
Unweeded check	2.78 (7.33)	4.41 (19.00)	4.63 (21.00)	5.95 (35.33)	7.26 (52.33)	7.33 (53.67)	4.03 (16.00)	4.93 (24.67)	5.04 (25.33)	210	2264	2054 (978)
LSD (P=0.05)	0.41	0.52	0.51	0.73	0.71	0.67	0.77	0.71	0.72	-	73	-

Note: $\sqrt{x+0.5}$ *transformation (Figures in parenthesis are original values in case of weed count and per cent addition/depletion of seedbank).*

Table 3. Effect of different weed management practices on dry weight of weeds, weed indices and economics of fennel

Treatments	**Dry weight of weeds (kg/ha)**	**Weed index (%)**	**Weed control efficiency (%)**	**Herbicidal efficiency index (%)**	**Cost of cultivation (Rs/ha)**	**Net returns (Rs/ha)**	**B : C ratio**
Pendimethalin + HW	84	0.91	93.31	98.06	36882	81442	3.21
Oxadiargyl + HW	237	43.22	81.01	13.49	36976	31622	1.86
Glyphosate + HW	282	41.02	77.40	17.88	36402	34717	1.95
Pendimethalin + Quizalofop	494	28.23	60.43	43.45	36745	49841	2.36
Pendimethalin +	196	0.52	84.30	98.84	36882	81993	3.22

Fenoxaprop							
Pendimethalin + Propaquizafop	303	28.03	75.73	43.84	36711	50052	2.36
Pendimethalin + Oxadiargyl	104	28.54	91.66	42.82	36840	49186	2.34
HW twice	80	2.28	93.63	-	36608	80301	3.19
Weed free	0	0.00	100.00	-	39751	79703	3.01
Unweeded check	1248	49.97	0.00	-	33603	26984	1.80
LSD (P=0.05)	84	-	-	-	-	-	-

Market Price:		**Herbicides**	**Rs/kg or lit**	**Herbicides**	**Rs/kg or lit**
Commodity	**Rs/kg**	Pendimethalin	: 400	Quizalofop	: 1350
Fennel seeds	: 60.00	Oxadiargyl	: 930	Fenoxaprop	: 1500
Fennel stover	: 2.00	Glyphosate	: 270	Propaquizafop	: 140