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Weed competition affecting growth and yield in ajwain (*Trachyspermum ammi*)

RAVINDRA SINGH[1], SHARDA CHOUDHARY[1], R S MEHTA[2], O P AISHWATH [1] and G LAL[3]

ICAR-National Research Centre on Seed Spices, Tabiji, Ajmer, Rajasthan 305 206, India

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ABSTRACT

Weeds compete with crop plants throughput the plant growth period and causes significant losses in quality, productivity and profitability. Seed spices are more sensitive to crop weed competition as they are grown under arid conditions where moisture is the limiting factor. A study was carried out to identify the critical period of weed competition in ajwain (*Trachyspermum ammi* Sprague) during 2012–13 to 2014–2015 at ICAR-National Research Centre on Seed Spices, Ajmer, Rajasthan. Treatments included weedy and weed-free condition for different growth periods, i.e. 15, 30, 45, 60, 75, 90, 105, 120 days after sowing (DAS) along with weed free throughout growth period and weedy throughout growth period. Weedy period up to 30, 45, 60, 75, 90, 105, 120 DAS and weedy throughout growth period reduced the seed yield significantly to the tune of 321.4, 463.0, 607.7, 705.9, 852.9, 950.4, 1072.9 and 1162.4 kg/ha respectively as compared with the weed free throughout growth period. Weed free up to 15 DAS to 120 DAS decreased the seed yield from 1039.4 to 99.0 kg/ha as compared to the weed free throughout growth period. Weedy period up to 75 DAS gave tough competition to the crop for growth which was reflected in yield attributes and seed yield of ajwain. The maximum yield of 1244.5 kg/ha was obtained with the treatment weed free throughout growth period, this was also found economically viable which resulted in highest gross return of ₹ 136891/ha, net returns ₹ 102953/ha and B: C ratio of 3.03. Critical period for weed competition in ajwain was found to be 54 days after sowing.

Keywords: Ajwain, Critical period, Economics, Growth parameters, Weed management, yield

Ajwain (*Trachyspermum ammi* Sprague) is a medicinal spice herb and it is of Indian origin. From India it spreads in many South East Asian countries namely Persia, Iran, Egypt, Afghanistan, Pakistan and also to North Africa. India has produced 27940 tons of ajwain seed from 34500 ha area with productivity of 809.8 kg/ha during 2017-18 (Anonymous 2018). Ajwain is a good source of phenolics and flavanoids content (Choudhary *et al.* 2017). Present productivity of ajwain is 583 kg/ha (DASD 2017). In India, Rajasthan alone is contributing nearly 37.7 and 44.7% in total ajwain production and area, respectively (Anonymous 2018). In Rajasthan it grows in Chittorgarh, Udaipur, Pratapgarh, Jhalawar, Rajsamand, Kota and Bhilwara districts.

Ajwain is gaining importance day by day both at national and international levels therefore, the present productivity levels of the crop needs to be increased by developing and adopting best management practices (BMPs). Ajwain seed takes 15-18 days for germination and have very slow initial growth; hence they are more prone to severe weed competition for nutrients, light, water and space since germination as weed seeds start germinating after 2-3 days of sowing which resulted in heavy losses in terms of productivity and profitability to the farmers. Ajwain being a long duration crop (180-210 days) and having slow initial growth which takes more time to cover the field which provide conducive condition for higher growth of weeds which results in substantial reduction of crop growth and yield. Therefore, it is necessary to identify the critical period of weed control in ajwain to develop effective and economical weed control practices. Hence, the present investigation was carried out with the objectives: i) optimum crop-weed competition period; ii) impact of weeds on crop yields at different growth stages; iii) Evaluate the crop yields and profitability with best management practices (BMPs).

MATERIALS AND METHODS

A field experiment was conducted at experimental farm of ICAR-NRCSS, Ajmer, Rajasthan during *rabi* 2012–13 to 2014–2015. The location lies on 740 35' 39" to 740 36' 01" E longitude and 260 22' 12" to 260 22' 31" N latitude at an altitude of 460.17 m amsl. This region falls under agro-climatic zone III of Rajasthan, India. The average annual rainfall of this region is 540 mm with a mean maximum temperature of 21.71–33.81ºC and minimum

Present address: [1]National Research Centre on Seed Spices, Tabiji, Ajmer; [2]Central Arid Zone Research Institute-RRS, Pali-Marwar, Pali, Rajasthan; [3]Cauvery Water Management Authority, Ministry of Jal Shakti (GOI), New Delhi. *Corresponding author e-mail: mahla_rs@yahoo.com.

temperature 2.43–18.83ºC during growing season. Soil of the experiment was sandy loam in texture having a *p*H of 8.0 - 8.3 and EC 0.07 - 0.12 dS/m. Soils were low in organic carbon (0.15-0.23%), available nitrogen (178.5 kg/ha), phosphorus (12.0 kg/ha), and potassium (85.0 kg/ha) but medium to high in Ca (214.7 kg/ha), Mg (258.0 kg/ha) and sulphur (27.0 kg/ha).

Experimental design and treatments: There were 18 treatments comprising initial weed free periods of 15, 30, 45, 60, 75, 90, 105, 120 days after sowing (DAS) and weedy up to 15, 30, 45, 60, 75, 90, 105, 120 DAS along with weed free till harvest (weed-free check) and weedy till harvest (un-weeded check) in ajwain. The experiment was conducted in a randomized block design with three replications.

Crop management: The ajwain cultivar Ajmer Ajwain 1 was sown in mid-October during all the years (2012–2014) at a row spacing of 30 cm and harvested during mid-April to first week of May. The total crop duration was 198, 188 and 183 days during 2012–13, 2013–14 and 2014–15, respectively. The weed population was removed manually after every 15 days for ensuring complete weed free conditions in weed free plots as per treatment. In the weedy plots, weeds were manually removed as per the treatment.

Weed observations: To work out the weed count per unit area, a quadrant of size 0.5 m × 0.5 m was thrown at random at one places in every plot and weed population was counted (count/0.25 m^2) at 15, 30, 45, 60, 75, 90, 105, 120 DAS and at harvest. In weedy check weeds were allowed to grow throughout crop-growth period. After uprooting of weeds the weeds were sun dried completely till reached to constant weight and finally the dry weight (g/0.25 m^2) was recorded for each treatment. Monocot, dicot and sedge weed population at one representative site from each plot were taken at 15, 30, 45, 60, 75, 90, 105, 120 days and at harvesting stage using 0.25 m^2 quadrate.

Weed-control efficiency: The weed-control efficiency was computed at different stages as well as at maturity using following formula suggested by Kondap and Upadhaya (1969).

$$\text{WCE \%} = \frac{\text{DWC} - \text{DWT}}{\text{DWC}} \times 100$$

where, WCE, Weed control efficiency (%); DWC, Dry weight of weeds in control plots (weedy check); DWT, Dry weight of weeds in treated plot.

Weed index (%): Weed index (WI) or weed competition index is defined as the reduction in yield due to presence of weeds in comparison to weed free plots.

$$\text{WI \%} = \frac{\text{X} - \text{Y}}{\text{X}} \times 100$$

where, X, Yield from weed-free plot; Y, Yield from treated plot for which WI was worked out.

Crop growth and yield attributes: The plant height (cm) of randomly selected plants from each plot was measured at 60, 90,120 DAS and at harvest. The plant height was measured from ground level to the leaf/flower. The primary and secondary branches from five randomly selected plants from each plot were counted at 60, 90,120 DAS and at harvest. The average was computed and expressed as number of primary branches per plant. Leaf area was measured from five randomly selected plants. Mean of five plants of each treatment were recorded as leaf area (cm^2).

Crop productivity and profitability: After threshing and winnowing clean grain obtained from individual plot were weighed and the weight was recorded in kilogram (kg) per plot and then converted to kg per ha (kg/ha). The average price of the ajwain seed was ₹ 110.0/kg. The net return was calculated by subtracting cost of cultivation for each treatment from the gross return calculated based on economic yield. The B : C ratio was computed by dividing gross return with cost of cultivation for each treatment.

Statistical analysis: All the data obtained with regard to the weed count, weed biomass, crop growth and yield parameters have been analyzed separately for each attribute according to the analysis of variance technique of Panse and Sukhatme (1985). The critical differences were calculated to assess the significant differences between treatment means.

RESULTS AND DISCUSSION

Effect on weed population/weed count and weed biomass (dry matter): The weed flora emerged during the experimentation were *Cynodon dactylon* L, *Digitaria sanguinalis* L, sedges like *Cyperus rotundus* L. and broad leaved weeds like *Chenopodium album* L.; *Chenopodium murale* L.; *Melilotus alba* L.; *Anagalis arvensis*. Among weed count, the major population at all the growth satages (80-85%) were from *Chenopodium album* and *Chenopodium murale*. The weed count and dry matter accumulation decrease with the increase in weed free period from 15 DAS to 120 DAS after sowing (Table 1). At harvest the weed population reached to minimum of 38.0/0.25 m^2 at complete weedy conditions (T_9) to 248.3/0.25 m^2 at 15 DAS. The observations recorded at all the nine stages shows decreasing trend in the weed population with the increase of crop duration. The maximum weed dry biomass at harvest was recorded at weedy throughout growth period (272.2 g/0.25 m^2), whereas it was lowest at 15 DAS (8.5 g/0.25 m^2), this might be due to more accumulation of biomass in weed at harvest when the weed-free period extended up to 75 DAS or longer, strong crop canopy cover suppressed new flushes of weed which was emerged at subsequent crop stages thus the crop smothered the late emerging weed which resulted in significantly lower in weed population and dry matter accumulation under the weed-free treatment. At 15 days after sowing, weed count were in the range of 217.3-261.2/0.25 m^2 with the dry biomass of 7.3-8.5 g/0.25 m^2, whereas at harvest the number of weeds were reduce to 38.0/0.25 m^2 at weedy throughout growth period with the weed dry biomass 272.2 g/0.25 m^2.

Growth parameters: Severe weed infestation in the plot maintain weedy up to 75 DAS or onwards up to maturity

Table 1 Weed count and dry biomass in weedy and weed free treatments at different growing stages in ajwain (3 years' mean)

Treatment	Weed count (number/0.25 m^2)									Weed dry biomass (g/0.25 m^2)								
	15 DAS	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS	105 DAS	120 DAS	Harvest	15 DAS	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS	105 DAS	120 DAS	Harvest
Weedy up to 15 days (T_1)	253.4	0	0	0	0	0	0	0	0	7.4	0	0	0	0	0	0	0	0
Weedy up to 30 days (T_2)	217.3	163.0	0	0	0	0	0	0	0	7.3	19.8	0	0	0	0	0	0	0
Weedy up to 45 days (T_3)	261.2	193.0	103.2	0	0	0	0	0	0	7.5	18.7	54.0	0	0	0	0	0	0
Weedy up to 60 days (T_4)	225.5	169.2	121.2	144.3	0	0	0	0	0	8.2	19.4	53.3	104.4	0	0	0	0	0
Weedy up to 75 days (T_5)	227.5	190.0	129.9	128.0	83.3	0	0	0	0	8.1	18.8	55.0	105.0	129.8	0	0	0	0
Weedy up to 90 days (T_6)	226.9	170.3	110.9	119.7	90.0	70.3	0	0	0	7.8	20.0	53.0	102.4	138.6	198.3	0	0	0
Weedy up to 105 days (T_7)	257.8	200.2	118.0	110.4	87.8	72.5	61.9	0	0	7.9	19.4	55.5	109.1	146.2	209.2	213.8	0	0
Weedy up to 120 days (T_8)	251.5	185.2	113.9	117.2	91.3	76.8	63.6	55.4	0	8.5	19.0	53.0	100.0	145.9	179.3	238.9	195.1	0
Weedy throughout growth period (T_9)	248.3	183.2	111.5	110.8	94.8	83.0	68.9	58.5	38.0	8.5	20.5	56.5	111.1	156.9	185.2	242.5	262.1	272.2
Weed free up to 15 days (T_{10})	0	13.7	15.9	21.5	28.4	36.9	38.3	24.8	20.8	0	3.0	11.9	26.5	36.0	42.5	58.9	62.9	76.2
Weed free up to 30 days (T_{11})	0	0	9.4	13.7	27.3	31.5	28.7	20.9	18.4	0	0	3.0	12.4	24.7	37.0	47.7	52.6	66.6
Weed free up to 45 days (T_{12})	0	0	0	7.5	13.7	22.2	25.5	16.4	16.7	0	0	0	3.4	15.7	28.8	53.5	41.7	60.4
Weed free up to 60 days (T_{13})	0	0	0	0	8.0	13.4	18.7	15.8	14.5	0	0	0	0	6.1	13.1	22.4	25.1	41.0
Weed free up to 75 days (T_{14})	0	0	0	0	0	7.3	15.7	14.8	13.2	0	0	0	0	0	4.1	10.0	14.6	23.7
Weed free up to 90 days (T_{15})	0	0	0	0	0	0	6.8	9.1	3.1	0	0	0	0	0	0	6.6	10.8	15.3
Weed free up to 105 days (T_{16})	0	0	0	0	0	0	0	1.2	1.0	0	0	0	0	0	0	0	0.6	1.1
Weed free up to 120 days (T_{17})	0	0	0	0	0	0	0	0	0.7	0	0	0	0	0	0	0	0	0.4
Weed free throughout growth period (T_{18})	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SE(m)	0.2	0.1	0.1	0.3	0.1	0.1	0.1	0.1	0.1	0.06	0.07	0.09	0.15	0.85	1.12	1.23	1.19	1.16
CD	0.7	0.3	0.2	0.8	0.2	0.3	0.2	0.3	0.3	0.21	0.24	0.31	0.43	2.61	3.26	3.72	3.59	3.42

*Original data were square root transformed (√x+1) for statistical analysis.

Table 2 Growth, yield attributes, seed yield, net returns, benefit : cost ratio (BCR), weed-control efficiency (WCE) and weed index (WI) as influenced by weedy and weed free treatments at different growing stages in ajwain (3 years' mean)

Treatment	Plant height at harvest (cm)	No. of primary branches	No. of secondary braaches	No. of umbels/ plant	Test weight (g)	Seeds/ umbellate	Seed yield (kg /ha)	Net return (₹)	B:C ratio	WCE (%)	WI (%)
Weedy up to 15 days (T_1)	77.1	12.8	81.8	61.3	1.71	29.8	1072.6	86109	2.70	96.8	9.2
Weedy up to 30 days (T_2)	73.2	11.9	63.7	58.4	1.52	28.7	923.1	69149	2.13	92.0	22.0
Weedy up to 45 days (T_3)	71.9	11.6	58.3	53.5	1.39	28.0	781.5	53060	1.61	79.1	30.0
Weedy up to 60 days (T_4)	70.9	8.8	53.5	49.9	1.24	26.6	636.8	36626	1.10	59.9	44.7
Weedy up to 75 days (T_5)	68.3	8.7	51.8	33.1	1.17	26.2	538.6	25820	0.77	51.3	52.2
Weedy up to 90 days (T_6)	66.9	8.1	45.4	28.7	1.05	25.6	391.6	10174	0.31	26.3	62.6
Weedy up to 105 days (T_7)	56.0	7.8	42.5	26.2	0.98	24.8	324.1	2746	0.08	22.2	65.6
Weedy up to 120 days (T_8)	42.9	6.0	15.6	23.1	0.95	23.7	171.6	-14026	-0.43	9.7	82.0
Weedy throughout growth period (T_9)	34.4	5.2	12.6	17.4	0.74	20.2	82.1	-16641	-0.65	0.0	89.7
Weed free up to 15 days (T_{10})	78.8	8.5	42.8	21.1	0.96	20.5	205.1	-5694	-0.20	71.4	75.2
Weed free up to 30 days (T_{11})	90.1	10.0	50.8	24.4	1.11	20.7	444.3	20101	0.70	75.9	48.2
Weed free up to 45 days (T_{12})	93.0	10.8	55.4	29.4	1.18	21.9	619.0	38801	1.32	80.2	33.6
Weed free up to 60 days (T_{13})	98.0	11.3	57.5	33.2	1.18	23.0	806.5	58906	1.98	87.6	13.8
Weed free up to 75 days (T_{14})	101.4	11.5	59.0	36.0	1.21	23.1	902.7	68971	2.27	93.6	9.6
Weed free up to 90 days (T_{15})	103.0	11.7	65.5	41.4	1.32	23.2	975.3	76448	2.48	95.1	8.3
Weed free up to 105 days (T_{16})	103.6	12.0	67.5	43.8	1.34	24.2	1061.1	85366	2.72	99.7	5.1
Weed free up to 120 days (T_{17})	104.3	14.0	70.1	65.0	1.37	24.6	1145.7	94159	2.95	99.9	1.4
Weed free throughout growth period (T_{18})	106.4	14.8	78.6	85.7	1.86	34.6	1244.5	102953	3.03	100.0	0.0
SE(m)	2.6	0.3	0.7	3.1	0.06	0.6	75.9	4696	0.19	0.20	2.4
CD (P=0.05)	5.0	0.8	2.3	7.1	0.19	1.8	218.1	15188	0.55	0.59	6.9

adversely affected the growth attributing character of ajwain namely plant height, number of primary branch, number of secondary branch, leaf area and crop plant dry matter accumulation. Keeping the crop free from weeds up to 90 DAS or weedy up to 15 DAS and there after removal of weeds gave better plant height, more number of primary of secondary, increased leaf area and crop dry matter accumulation then weed free up to 75 DAS or weedy up to 60 DAS. These results are in conformity with earlier finding Patel *et al.* (2007) in coriander. The data presented in Table 2 reveals that days taken for initiation of flowering and 50% flowering was influenced significantly with different weed free and weedy period practices followed. The earliest initiation of flowering (113.67 days) and completion of 50% flowering (124.67 days) was recorded in weed free throughout growth period (T_{18}) followed by T_{17} (weed free up to 120 DAS) and T_1 (weedy up to 15 DAS).

Yield attributes and seed yield: Severe infestation of weeds in the plots maintained weedy for initial 60 DAS adversely affected the yield attributing characters compared to season long weed free condition and weed free up to 60 DAS. Data (Table 2) showed that lowest number of umbels/plant (17.4), number of umbellates/umbel (4.9), test weight (0.74 g), seed yield (82.1 kg/ha) were recorded at weedy throughout growth period. Maximum number of umbels/plant, number of umbellates/umbel, test weight (g) and seed yield to the tune of 85.7, 15.6, 1.86 and 1244.5 kg/ha were recorded at weed free throughout growth period. The perusal of data (Table 2) shows that maximum seed yield of 1244.5 kg/ha was recorded under treatment weed free throughout growth period, whereas the yield was lowest (82.1 kg/ha) in the treatment weedy throughout growth period. Presence of weed for different period from 15 DAS to 120 DAS significantly reduced the seed yield from 171.9 kg/ha at weedy up to 15 DAS to 1072.9 kg/ha at weedy up to 120 DAS as compared with weed free throughout growth period. The treatments weedy up to 30, 45, 60, 75, 90, 105, 120 DAS and weedy throughout growth period reduced the seed yield significantly to the magnitude of 149.5, 291.1, 435.8, 534.0, 681.0, 748.5, 901.0, 990.5 kg/ha respectively as compared with the treatment T_1 (weedy up to 15 DAS). Keeping the crop weed free up to 15 DAS to 120 DAS decreased the seed yield from 1039.4 to 99.0 kg/ha as compared to the weed free throughout growth period. If we compare the data of weed free throughout growth period to weedy throughout growth period, the yield losses were 1162.4 kg/ha. The increase weed density and their biomass (Table 1) to such an extreme level under weedy check (T_9) might be attributed to uninterrupted growth of weed which ultimately suppressed the growth and yield attributing characters of ajwain.

Weed-control efficiency: Data (Table 2) reveals that weed-control efficiency decreased from 96.8% at weedy conditions up to 15 DAS to 92.0, 79.1, 59.9, 51.3, 26.3, 22.2, and 9.7 to 0.0 at weedy conditions up to 30, 45, 60, 75, 90, 105, 120 DAS and throughout growth period, respectively. Weed-control efficiency improved gradually with the increasing weed-free period from 15 DAS to 120 DAS. Weed-control efficiency improved from 71.4 % with the treatment weed-free up to 15 DAS to 100% with the treatment weed free throughout growth period. The combined effect of hand weeding and smothering effect by the crop canopy over the weeds after 45 DAS resulted in remarkably less dry weight of weeds (Table 1) observed under these treatments were responsible for higher weed-control efficiency. These findings are akin to report of Patel *et al.* (2007) and Mehriya *et al.* (2007).

Weed index (%): The data pertaining to weed index as influenced by different treatments are presented in Table 2. Increase of weedy period from 15 DAS to 120 DAS increased the weed index gradually from 9.2–82.0% and reached to maximum 89.7% in weedy conditions throughout growth period. Among the weed free treatments, maximum weed index of the 75.2% was recorded in the treatment weed free up to15 DAS which decreased sharply and reached to zero in the treatment weed free throughout growth period treatment. This shows that reduction in the yield of ajwain was associated with presence or absence of weeds at different growth stages. The higher the weed biomass resulted more weed index and lower the weed biomass reduced the weed index at harvest. The findings are in agreement with the results reported by Yadav and Dahama (2003).

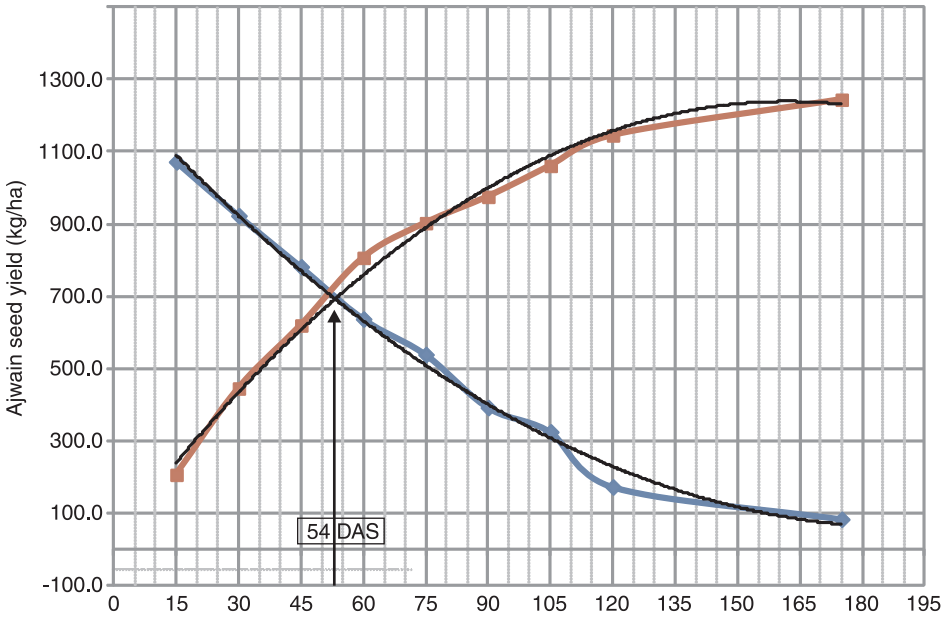

Fig 1 Critical stage (54 DAS) for weed competition in ajwain (Average of 3 years data).

Economics and critical period for weed-crop competition: Maximum gross return (₹ 136891/ha), net return (₹ 102953/ha) were obtained at weed free throughout growth period with the B : C ratio 3.03 among the weed free treatments (Table 2). Among the weedy treatments weedy up to 15 DAS to 30 DAS and there after removal of weeds also gave higher yield with net return of ₹ 86109-69149 with B:C ratio 2.70-2.13, when weeds were allowed to compete beyond 30 DAS significant reduction in seed yield of ajwain along with lower net returns were obtained. Hence the present study suggested maintenance of weed free crop up to 60 DAS to achieve better yield as well as higher return.

From the data (Table 2) it can be observed that reduction in seed yield of ajwain was greater when weeding was delayed from 15 DAS to 75 DAS when weedy period lasted only up to 15 DAS and thereafter weed-free period up to 90 DAS or more caused non-significant reduction in seed yield of ajwain. Data (Fig 1) reveal that the critical period for weed competition in ajwain is 54 DAS, wherein the linear lines of weedy or weed-free treatment intersected each other. The critical period for weed control (CPWC) is a key component of an integrated weed management (IWM) programme.

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