International J. Seed Spices 5(2), July 2015:32-37

Production, productivity and quality of ajwain (*Trachyspermum ammi* L. Sprague) as affected by plant geometry and fertilizer levels

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Abstract

An experiment was conducted during *rabi* season of 2012-13 at Horticulture farm, College of Horticulture, Mandsaur to study the effect of spacing and fertilizer levels on the growth, yield and quality attributes of ajwain. The experiment consisting of 3 spacing (30 x 30 cm, 45 x 30 cm and 60 x 30 cm) and 4 levels of fertilizer (20:10:10, 40:20:20, 60:30:30 and 80:40:40 NPK kg ha^{-1}) was conducted. Spacing of 45 x 30 cm significantly increased the plant height (cm), fresh weight per plant (g), dry weight per plant (g), number of umbels per plant, number of umbellets per umbel, 1000 seed weight (g), yield per plant (g), seed yield (q ha^{-1}), straw yield (q ha^{-1}) biological yield (q ha^{-1}), chlorophyll content of leaves (Spad), carotenoids content of leaves (mg g^{-1}) and essential oil content in seed (%). However the spacing of 60 x 30 cm significantly increased the number of primary and secondary branches per plant at harvest. Closer spacing of 30 x 30 cm significantly increased the days to 50% flowering. Among the various levels of fertilizer tried, the 60:30:30 kg ha^{-1} level of fertilizer significantly increased the growth, yield and quality attributes of ajwain. However the levels of fertilizers non significantly affected the fresh weight per plant (g) at 90 DAS and harvest index (%). The maximum benefit: cost ratio (2.05:1) was found with 45 x 30 cm + 60:30:30 kg NPK ha^{-1}.

Key words: Ajwain, plant geometry, fertilizer, quality.

Introduction

Seed spices have been known for ages as effective therapeutic food. The capacity of spices to impart biological activity is now slowly reemerging as an area of interest for human health. Ajwain or Bishop's weed (*Trachyspermum ammi* L. Sprague) is an important seed spice that belongs to family *apiaceae*. Seed are 2-3 mm, long, greyish brown in colour. Its characteristic odour and taste due to presence of an essential oil (2-4%). Ajwain oil is principal source of thymol. Its characteristic aromatic smell and pungent taste is widely used as a spice in curries. It employed either alone or in mixture with other spices and condiments. More important use of ajwain is medicinal and it is a household remedy for indigestion. Its seed and oil is much valued for its antispasmodic, stimulant, tonic and aromatic carminative properties (Rathore *et al.*, 15). In India, it is cultivated on commercial scale in the states of Madhya Pradesh, Andhra Pradesh, Gujarat, Maharashtra, Uttar Pradesh, Rajasthan, Bihar and West Bengal. The total area and production of ajwain in India is about 25.8 thousand hectare and 22.2 thousand MT with average productivity of 0.9 MT per hectare respectively, NHB (10).

Looking to the importance of this crop there is an urgent need for enhancing the productivity and quality of this crop by adopting suitable agronomic practices such as population densities per hectare and nutritional status of the soil. Optimum number of plants is required per unit area to utilize efficiently the available production factors such as water, nutrient, light and CO_2. Maximum exploitation of these factors are achieved when the plant population puts forth maximum pressure on all the factors of production. As a result, individual plants are put under severe stress because of inter-plant competition. Normally maximum yields are obtained from plant populations which do not allow plants to achieve their individual maximum potential. Thus, the entire community of plants considered for higher production rather than individual plant performance (Balasubramaniyam and Palaniappan 2). Plant growth is adversely affected due to deficiency of nitrogen as it is a constituent of proteins, enzymes, hormones, vitamins, alkaloid, chlorophyll etc. Phosphorus is a constituent of sugar phosphates, nucleotides, nucleic acids, coenzymes and phospholipids. The process of anabolism and catabolism of carbohydrates proceed when organic compounds are esterised with phosphoric acid. Potassium is not a constituent of any organic

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compound, however, it is required as a cofactor for 40 or more enzymes. It controls movement of stomata and maintains electro-neutrality of plant cells (Reddy and Reddi 14).

Materials and methods

The field experiment was conducted during rabi season of 2012-2013 at Horticulture Farm, RVSKVV, College of Horticulture, Mandsaur (M.P.) on light black loamy soil having pH 7.1, EC 0.24 dS/m, available nitrogen (140 Kg ha^{-1}), available phosphorus (21 Kg ha^{-1}) and available potassium (144 Kg ha^{-1}). The average annual rainfall is 750 mm. The experiment was laid out in split plot design with four replications. There were 12 treatment combinations with 3 spacing (30 x 30 cm, 45 x 30 cm and 60 x 30 cm) and 4 levels of fertilizer (20:10:10, 40:20:20, 60:30:30 and 80:40:40 NPK kg ha^{-1}). The pure, healthy, disease and insect free vigorous and good quality ajwain seed variety AA-1 was used for sowing. Seeds sown in furrows opened as per the treatment row spacing and covered with soil properly in prepared plot. Thinning was done at 45 DAS to remove the excess plants to maintain uniform plant spacing of 30 cm. A basal dose of well decomposed FYM @ 30 tones per hectare was incorporated in the soil before one month of sowing. The calculated quantities of N, P and K were applied to the respective plot. The source of nitrogen, phosphorus and potash was urea (46 % N_2), single super phosphate (16 % P_2O_5) and muriate of potash (60 % K_2O) respectively. Nitrogen as per treatment was give to plot in three split doses. The half dose of nitrogen and full dose of P_2O_5 and K_2O were applied as basal dose, at the time of sowing. Remaining dose of nitrogen as per treatment was applied in two equal splits at 45 days and 75 days after sowing with irrigation through urea application. Two weeding and hoeing were done manually, first at 30 DAS and second at 60 days after sowing to control the season bound weeds. In order to safe guard the plants against aphids, daimethoate 30 EC was sprayed on the plants twice. First irrigation was given just after sowing followed by one light irrigation at 7 days after sowing to facilitate proper germination and establishment of the crop seedling. Subsequent irrigations were given as per requirement of the crop. The crop was hand harvested on 27th February 2013. The harvested material of each plot was made up in bundles, tagged and sun dried for thresing with the help of wooden sticks and winnowed traditionally to separate seed and straw. Seed were weighed and plot wise samples were recorded. Observations were recorded on growth attributes *viz*., plant height (cm) at 60, 90 and 120 DAS, number of primary branches per plant at harvest, number of secondary branches per plant at harvest and fresh and dry weight (g) of plant at 60 and 90 DAS, yield attributes *viz*., days to 50% flowering, number of umbels per plants, number of umbellets per umbel, 1000 seed weight (g), yield per plant (g), seed yield (q ha^{-1}), straw yield (q ha^{-1}), biological yield (q ha^{-1}) and harvest index (%). The quality attributes *viz*., chlorophyll content of leaves at 60 and 90 DAS (spad value) was measured by spad meter, carotenoids content of leaves at 60 and 90 DAS (mg g^{-1}) was recorded by spectrophotometer and essential oil content of seed (%) was estimated by hydro distillation method as suggested by A.O.A.C. (1). Data were statistically analysed as per method suggested by Pansey and Sukhatme (11).

Results and discussion

Effect of spacing

It was observed that plants under closer spacing (S_1) attained greater plant height (Table 1) as compared to the plants that were grown at wider spacing (S_3). However, number of primary, secondary branches, fresh and dry weight of plant (Table 1) was improved due to increase in spacing from S_2 to S_3. Significant increase in plant height right from early stage of close growth under closer spacing seem to be due to mutual shading because of dense population. This might have decreased the availability of light to the plants. The reduced light intensity at the base of the plant stem might have accelerated elongation of lower internodes resulting in greater plant height. The observed crop behavior under closer spacing is in close conformity with the findings of Donald (3) who reported that in many crops up to a certain level of population, plant elongates rapidly due to mutual shading but beyond this, elongation is checked due to reduced availability of photosynthates. These observations are in close conformity with findings of Naruka *et al*., (8) in ajwain. The results indicated that crop raised under wider spacing (S_3) recorded highest number of primary and secondary branches, however, the fresh and dry weight per plant was higher under (S_2) spacing. Significant improvement in aforesaid parameters due to increase in spacing or in other words reduction in plant population per unit area could be ascribed to availability of more area per plant which implied that individual plant at wider spacing received higher growth inputs (sunlight, water and nutrients) with least competition as compared to the plants grown under two closer spacing. Thus, greater inputs under wider spacing (S_2 and S_3) resulted in profuse branching which in turn might have helped in larger canopy development and delayed plants to attain

Table 1: Effect of row spacing and fertilizer levels on growth and quality attributes of ajwain

Treatments	Plant height (cm)			Fresh weight plant^{-1} (g)		Dry weight plant^{-1} (g)		Chlorophyll content of leaves (spad value)		Carotenoids content of leaves (mg g^{-1})		No. of primary branches plant^{-1}	No. of secondary branches plant^{-1}
	60 DAS	90 DAS	120 DAS	60 DAS	90 DAS	60 DAS	90 DAS	60 DAS	90 DAS	60 DAS	90 DAS	90 DAS	90 DAS
Row Spacing (cm)													
30 x 30 (s_1)	46.8	97.4	122.5	41.15	247.43	11.69	60.86	2.99	6.42	0.713	0.875	11.0	43.3
45 x 30 (s_2)	50.8	104.8	126.8	57.51	275.14	17.21	68.06	2.99	8.14	0.744	0.859	12.3	51.1
60 x 30 (s_3)	40.0	86.4	116.0	31.44	202.26	8.53	47.85	2.26	5.03	0.669	0.832	13.9	63.1
SEm ±	1.01	1.28	0.47	0.432	11.557	0.496	2.289	0.111	0.097	0.0094	0.006	0.18	1.16
CD at 5%	3.49	4.43	1.62	1.495	39.994	1.716	7.920	0.383	0.336	0.032	0.023	0.62	4.01
Fertilizer levels (NPK kg ha^{-1})													
20:10:10	43.7	92.3	119.4	36.77	224.97	10.61	54.72	2.74	5.86	0.658	0.817	11.9	47.7
40:20:20	45.2	95.2	120.9	40.88	238.10	11.88	57.60	2.94	6.24	0.708	0.837	12.2	50.3
60:30:30	46.6	97.3	122.8	46.95	245.57	13.38	60.68	3.16	6.80	0.725	0.888	12.6	54.8
80:40:40	47.9	100.0	123.9	48.87	257.80	14.03	62.69	3.49	7.23	0.742	0.880	13.1	57.2
SEm ±	0.77	0.97	0.59	0.825	8.307	0.582	1.638	0.100	0.195	0.020	0.019	0.15	1.23
CD at 5%	2.23	2.84	1.72	2.395	NS	1.689	4.753	0.289	0.327	0.059	0.056	0.46	3.58

Table 2: Effect of row spacing and fertilizer levels on yield, quality attributes and economics of ajwain

Treatments	Days to 50% flowering	No. of umbels plant^{-1}	No. of umbellets umbel^{-1}	1000 seed weight (g)	Yield plant^{-1} (g)	Seed yield (q ha^{-1})	Straw yield (q ha^{-1})	Biological yield (q ha^{-1})	Harvest index (%)	Essential oil (%)	Gross return (₹ ha^{-1})	Net return (₹ ha^{-1})	B:C ratio
Row Spacing (cm)													
30 x 30 (s_1)	88.6	266.5	12.8	1.31	26.47	8.49	21.53	30.02	28.26	2.81	42473	23788	1.27:1
45 x 30 (s_2)	86.4	373.3	14.0	1.41	36.08	10.83	26.63	37.46	28.79	3.05	54147	35692	1.92:1
60 x 30 (s_3)	82.8	202.2	11.6	1.23	18.72	6.92	19.61	26.53	25.89	2.45	34597	16372	0.89:1
SEm ±	0.35	10.32	0.16	0.025	1.716	0.152	0.388	0.441	0.434	0.027	759.9	759.9	0.04
CD at 5%	1.23	35.71	0.56	0.088	5.939	0.526	1.341	1.527	1.501	0.095	2629.0	2629.8	0.14
Fertilizer levels (NPK kg ha^{-1})													
20:10:10	84.6	244.3	12.4	1.27	23.13	7.73	21.13	28.85	26.51	2.63	38630	21130	1.20:1
40:20:20	85.5	266.4	12.5	1.29	25.73	8.17	21.94	30.11	26.86	2.72	40833	22693	1.24:1
60:30:30	86.6	294.8	13.0	1.33	28.07	9.36	23.21	32.57	28.72	2.81	46813	28063	1.49:1
80:40:40	87.2	317.2	13.3	1.37	31.42	9.74	24.09	33.83	28.51	2.93	48679	29249	1.50:1
SEm ±	0.32	3.30	0.15	0.021	1.320	0.375	0.421	0.669	0.789	0.026	1874.7	1874.7	0.10
CD at 5%	0.92	26.98	0.44	0.060	3.832	1.088	1.223	1.942	NS	0.074	5439.9	5439.9	NS

reproductive phase. The larger canopy development associated with profuse branching has increased interception, absorption and utilization of solar energy resulting in formation of higher photosynthates and finally dry matter per plant. Significant improvement in growth with increase in spacing is in close conformity with the findings of Yadav *et al.*, (16) in fennel, Nath *et al.*, (9) and Naruka *et al.*, (8) in ajwain.

It was observed that successive increase in spacing from S_1 to S_2 significantly improved various yield attributes of the crop. Days to 50% flowering, number of umbels per plant, number of umbellets per umbel, 1000 seed weight and yield per plant (Table 2) were improved due to each increase in spacing and the maximum value for these estimates were obtained at the wider spacing (S_2). However, results in respect to productivity revealed that crop grown under wider spacing (S_2) produced higher seed yield (10.83 q ha^{-1}), straw yield (26.63 q ha^{-1}) and biological yield (37.46 q ha^{-1}) compared to other spacing S_1 and S_3 (Table 2). Marked improvement in yield attributes of the crop with increase in spacing appear to be on account of vigorous growth of the plants as evident from profuse branching and higher biomass accumulation per plant. The profuse branching seems to have led to greater initiation of flowering and adequate supply of metabolites due to the increase in biomass per plant which might have helped in retention of flower thereby, greater seed formation and seed growth. This was ultimately reflected in increased seed yield per plant. The observed crop behavior with respect to yield potential under the influence of spacing could be mainly ascribed to primary function of number of plant per hectare and secondarily growth and development of the crop. Further it was observed that variation in spacing from S_1 to S_2 resulted in marked difference in number of plant per unit area whereas, variation in seed yield was too marginal (8.49 q ha^{-1} to 10.83 q ha^{-1}). Under the closer spacing growth and development of yield components and number of plants positively interacted with each other and might be due to increased biomass resulting in higher seed yield. These findings are in close conformity of Yadav *et al.*, (16) in fennel, Nath *et al.,* (9) and Naruka *et al.*, (8) in ajwain.

It was observed that each increase in spacing from S_1 to S_2 significantly improved chlorophyll and carotenoids content of leaves and essential oil content of seed (Table 1 and 2). Significantly higher chlorophyll content, carotenoids content of leaves and essential oil content of seed under wider spacing could be ascribed due to availability of large space per plant resulted in profuse vegetative growth and delayed plants to attain reproductive growth. The similar results have also been reported by Menaria and Maliwal (6) in fennel and Naruka *et al*., (8) in ajwain.

Effect of fertilizer

Significantly higher plant height at 60, 90 and 120 DAS, number of primary branches and secondary braches per plant at harvest, fresh and dry weight per plant at 60 and 90 DAS were recorded with increase levels of NPK fertilization (Table 1). Higher levels of NPK fertilization may result in better nutritional environment in the root zone as well as in the plant system. Thus, increased endogenous level of nitrogen in plant by virtue of its increased availability in the soil medium and there after efficient absorption and translocation in various growths by way of active cell division and elongation resulting in greater plant height, number of primary and secondary branches. The improvement in morphological parameters under the influence of NPK application might have resulted in larger canopy development and presumably higher chlorophyll content of leaves as nutrient actively participate in its formation. The findings of this investigation are in close conformity with those of Krishnamoorthy and Madalgiri (5), Nath *et al*., (9), Naruka *et al*., (8) in ajwain. Rana *et al.,* (13) in black cumin reported that plant height, number of primary and secondary branches per plant increased significantly with the NPK fertilization. Similar results were also reported by Naghera *et al*., (7) in coriander.

Data on yield components (Table 2) of the crop under influence of NPK application indicated that increased levels of NPK up to F_3 significantly improved days to 50% flowering, number of umbels per plant, number of umbellets per umbel, test weight, yield per plant, seed yield, straw yield and biological yield. In general, the significant improvement in yield attributes of ajwain with the NPK fertilization could be ascribed to overall improvement in vigour and crop growth. The faster growth of plants evidenced from increased biomass per plant at successive stages of crop growth with NPK subscribe to the views that there was better availability of metabolites and nutrients, which synchronized to the demand for the growth and development of each reproductive structure of the ajwain plant. Increased levels of NPK increased seed yield, straw yield and biological yield of the crop. This could be ascribed to its direct influence on dry matter accumulation at successive growth stages while indirect influence seems to be *viz*. improvement in various morphological and yield attributing characters. The present trend of increased in seed yield, straw yield and biological yield of ajwain with the application of NPK is in close conformity with the findings of Krishnamoorthy and Madalgari (5), Nath *et al*., (9) and Naruka *et al*., (8) in ajwain. Similar results were also reported by Rai *et al*., (12) in fennel and Rana *et al.,* (13) in black cumin

The results indicated that increasing levels of fertilizer significantly improved chlorophyll content of leaves, carotenoids content of leaves and essential oil of seed (Table 1 and 2). Significantly higher chlorophyll content of leaves, carotenoids content of leaves and essential oil of seed was recorded as a result of higher levels of NPK fertilization may be attributed to better nutritional environment in the root zone as well as in the plant system. The mark improvement in quality characters due to NPK is in close agreement with findings of Krishnamoorthy and Madalgari (4) and Naruka *et al*., (8) in ajwain. Similar results were also reported by Menaria and Maliwal (6) in fennel and Rana *et al.,* (13) in black cumin.

Economics

The maximum gross return (Table 2) of Rs 54147 ha^{-1} was recorded with the spacing (45 x 30 cm). Similarly, significantly maximum gross return of Rs 48679 ha^{-1} was recorded with fertilizer (80:40:40 NPK ha^{-1}). The maximum net return of Rs 35692 ha^{-1} was recorded with the spacing (45 x 30 cm). Similarly, significantly maximum net return of Rs 29249 ha^{-1} was recorded with fertilizer (80:40:40 NPK ha^{-1}). The data presented shows that different spacing significantly influenced the benefit cost ratio. The highest B:C ratio of (1.92:1) was recorded with spacing (45 x 30 cm). It is evident from the data presented that application of fertilizer did not bear significant effect on B: C ratio.

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Received : January 2015; Revised : March 2015;
Accepted : May 2015.