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Ajwain (*Trachyspermum ammi* L. Sprague) based intercropping for higher system productivity of semiarid tropics of Northern Karnataka

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Abstract

Field trials were executed at the University of Horticultural Sciences, Bagalkot, Karnataka during the kharif season of 2016 and 2017 to study the growth and productivity of ajwain and leafy vegetables under intercropping system including economic profitability of such cropping systems in Northern Karnataka. The experiments were carried out with thirteen treatments comprising sole ajwain and sole crops of leafy vegetables (fenugreek, coriander, dill and amaranthus) and various combinations of ajwain and leafy vegetables in 1:1 and 1:2 ratios adopting randomized complete block design with three replications. Results showed that the sole crop of ajwain exhibited superior growth and yield. However, in intercropping systems, the combination of ajwain and coriander at a 1:1 ratio demonstrated the highest growth and yield parameters. The sole crop of ajwain recorded the maximum plant height (84.64 and 84.55 cm), number of branches per plant (52.38 and 52.19), number of umbels per plant (166.54 and 164.93), number of umbellates per umbel (12.44 and 12.34), and seed yield (12.95, 12.88 q ha^{-1} during both the years, respectively). This performance was comparable to intercropping with ajwain + coriander (1:1). Sole crops of fenugreek, coriander, dill, and amaranthus yielded higher fresh market yields compared to different intercropping systems. Notably, growing ajwain as an intercrop with coriander at 1:1 ratio resulted in a significantly higher land equivalent ratio (1.61) and a higher benefit–cost ratio (2.99) followed by ajwain + fenugreek (1:1) and (2.98) respectively.

Keywords: Ajwain, intercropping, leafy vegetables, oil content, B:C ratio, Land Equivalent Ratio (LER) and Ajwain Equivalent Yield (AEY)

Introduction

India is considered as the leading producer, consumer and exporter of seed spices in the world. Ajwain (*Trachyspermum ammi* L. sprag) is a well–known seed spice with multiple medicinal properties used for culinary purposes. In India, it is predominantly grown in Rajasthan and Gujarat and in lesser quantities in Madhya Pradesh, Uttar Pradesh, Andhra Pradesh, Tamil Nadu, and West Bengal. Usually, it is grown in the rabi season and prefers a cool and dry climate. The area and production of ajwain are 36000 hectares and 23000 tons, respectively (Anon. 2020). The increasing demand for vegetables, has led to a focus on inter–cropping practices which not only increases the area use efficiency but also improves physical, biological and chemical properties of the soil (Mehta *et al.,* 2010). Thus, inclusion of other crops in the existing cropping system can increase productivity of the system with a change in crop configuration. Intercropping helps in maintenance of soil fertility and reduces soil erosion, water and nutrient loss. An increase in fertilizer use efficiency is evident under intercropping systems because of the different rooting patterns of crops and variations in nutrient uptake pattern (Rahman *et al.,* 2006; Sakala *et al.,* 2000). At present, the emphasis is on growing leafy vegetables as intercrops with ajwain, which can help in meeting the ever–increasing demand for sustainable food supply at reasonable prices. Therefore, present study was conducted to understand the effect of ajwain based intercropping along with leafy vegetables with an objective to find the most suitable intercrop and to achieve higher productivity.

Materials and methods

Field trials were laid out at the University of Horticultural Sciences, Bagalkot, Karnataka during the kharif 2016 and 2017 to study the growth and productivity of ajwain and leafy vegetables under intercropping system and the cost economics of cropping systems of semi–arid tropics of Northern Karnataka under irrigated condition. The experiment consisted of thirteen treatments *viz*. sole ajwain variety (Ajmer Ajwain–93), sole fenugreek variety (Pusa early bunching), sole coriander (DWD–3), sole dill (Local cultivar), sole amaranthus (Arka Suguna), ajwain + fenugreek (1:1) and (1:2), ajwain + coriander (1:1), and (1:2), ajwain + dill (1:1), and (1:2), ajwain + amaranthus (1:1) and (1:2) ratios, laid out in a randomized complete block design with three replications. The soil of the experiment farm was sandy loam, poor in fertility and water retention, pH 8.61 and organic carbon 0.63%, available nitrogen 246.18 kg ha^{-1}, P2O5 17.35 kg ha^{-1}, K2O 185.6 kg ha^{-1}. The recommended fertilizer application comprised 100 kg ha^{-1} of nitrogen, 50 kg P2O5 ha^{-1}, and 50 kg K2O ha^{-1}, which was administered to both sole ajwain and vegetable crops. In the case of the intercropping system, 100% of the NPK dose was applied to ajwain, and the corresponding vegetables received the full recommended dose. At the time of sowing, 1/3rd of the nitrogen, along with the entire phosphorus and potash, was applied. The remaining nitrogen was provided as split doses at 30 and 60 days after sowing (DAS).

Immediate irrigation was provided post–sowing. The yields of ajwain and leafy vegetables were converted into ajwain equivalent yields, aligned with prevailing market rates. Treatment assessments were then conducted, factoring in these adjusted yields. Following this, a comprehensive economic analysis was carried out to derive conclusive insights into the overall cost–effectiveness and performance of each treatment approach.

Results and discussion

Growth and yield characters of ajwain

Sole cultivation of ajwain exhibited significantly superior growth and yield (Table 1). Sole ajwain plants recorded the maximum height (84.64 and 84.55 cm), the highest number of secondary branches per plant (52.38 and 52.19), an extensive plant spread (67.23 and 66.40 cm), an increased number of umbels per plant (166.54, 164.93), a higher count of umbellates per umbel (12.44, 12.34), a greater number of seeds per umbellate (12.57, 12.48), and higher seed yield per plant (15.80 and 15.49 g) and per hectare (12.95 and 12.88 q) during 2016 and 2017, respectively. Notably, these results were statistically similar to the ajwain + coriander (1:1) intercropping ratio. The comparable growth and yield parameters observed in sole ajwain and the 1:1 intercropping ratio for all vegetable crops can be attributed to reduced competition for space, water, sunlight and nutrients. This reduced competition allows for a more efficient allocation of photosynthates from source to sink, ultimately contributing to the prominent yields and favorable yield characteristics of ajwain. Similar findings were noted by Tiwari *et al.* (2002) in the intercropping of fennel with vegetable crops.

Table 1. Effect of intercropping system on growth and yield attributes of ajwain

Treatment	Plant height (cm)		No. of secondary branches		Plant spread (cm)		No. of umbels plant^{-1}		No. of umbellates umbel^{-1}		No. of seeds umbellate^{-1}		Seed yield (g plant^{-1})		Essential oil content (%)		Essential oil yield (kg ha^{-1})	
	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017
Ajwain + Fenugreek (1:1)	80.14	80.12	47.43	46.15	63.44	62.31	146.21	145.28	11.18	11.16	12.05	11.93	13.91	13.73	4.03	4.20	46.56	47.97
Ajwain + Fenugreek (1:2)	78.12	78.00	44.83	44.01	61.48	59.94	140.49	138.18	10.98	10.98	12.44	12.35	13.33	13.00	4.03	4.13	42.88	43.10
Ajwain + Coriander (1:1)	81.83	81.80	51.49	48.38	65.72	64.84	150.73	149.65	11.68	11.67	11.92	11.95	14.30	14.03	4.07	4.30	49.57	51.64
Ajwain + Coriander (1:2)	78.76	78.73	46.23	45.77	62.86	59.99	141.15	140.30	11.00	10.97	12.15	12.10	13.28	13.12	4.00	4.20	43.14	44.47
Ajwain + Dill (1:1)	80.10	80.10	47.50	46.31	63.67	62.61	147.03	145.41	11.26	11.25	11.94	11.94	13.98	13.76	4.03	4.23	47.22	49.05
Ajwain + Dill (1:2)	78.34	78.32	45.41	44.94	61.88	60.34	141.12	139.82	11.00	10.98	11.96	11.93	13.49	13.19	4.00	4.20	42.78	44.37
Ajwain + Amaranthus (1:1)	78.15	77.95	46.52	46.06	62.35	61.03	141.94	140.94	11.06	11.05	11.93	11.85	13.34	13.21	4.00	4.20	44.23	45.97
Ajwain + Amaranthus (1:2)	77.27	77.79	44.67	43.67	61.44	60.33	138.04	138.26	10.97	10.95	12.57	12.48	12.97	12.74	4.00	4.17	42.38	43.37
Sole ajwain	84.64	84.55	52.38	52.19	67.23	66.40	166.54	164.93	12.44	12.34	0.37	0.39	15.80	15.49	4.10	4.30	53.21	55.40
S Em ±	1.40	1.40	1.62	1.51	1.12	1.05	5.36	5.26	0.30	0.29	1.10	1.18	0.52	0.51	0.14	0.15	2.57	2.71
CD at 5%	4.21	4.21	4.86	4.53	3.35	3.16	16.07	15.77	0.90	0.86	12.16	12.13	1.56	1.53	NS	NS	NS	NS

System productivity

Intercropping ajwain with leafy vegetables recorded a significantly increased ajwain equivalent yield (AEY) and land equivalent ratio (LER) in comparison to sole cropping, as outlined in Table 2. Among the various intercropping systems, the combination of ajwain intercropped with fenugreek at ratios of 1:2 and 1:1, as well as with dill at 1:2 ratio, demonstrated the highest ajwain equivalent yield. The land equivalent ratio for intercropping ajwain with coriander at ratios of 1:1 and 1:2 was the highest, reaching 1.61 and 1.60, respectively. The superior AEY and LER in the intercropping system were attributed to the additional yield of intercrops without a significant reduction in the main crop yield. These findings align with the results reported by Mehta *et al.* (2015), highlighting increased system productivity and LER in intercropping as compared to sole crops.

Table 2. Effect of intercropping systems on yield of ajwain, ajwain equivalent yield and land equivalent ratio (LER)

Treatment	Seed yield (q ha^{-1})			Ajwain Equivalent Yield (q ha^{-1})			Land Equivalent Ratio		
	2016	2017	Average	2016	2017	Average	2016	2017	Average
Ajwain + Fenugreek (1:1)	11.54	11.41	11.47	21.44	20.91	21.17	1.51	1.49	1.50
Ajwain + Fenugreek (1:2)	10.64	10.45	10.54	22.93	22.21	22.57	1.59	1.56	1.57
Ajwain + Coriander (1:1)	12.18	11.99	12.08	20.89	20.52	20.71	1.62	1.61	1.61
Ajwain + Coriander (1:2)	10.77	10.58	10.67	20.80	20.19	20.50	1.61	1.58	1.60
Ajwain + Dill (1:1)	11.67	11.54	11.60	19.36	19.38	19.37	1.41	1.43	1.42
Ajwain + Dill (1:2)	10.71	10.58	10.64	21.99	21.27	21.63	1.57	1.55	1.56
Ajwain + Amaranthus (1:1)	11.03	10.90	10.96	15.79	15.52	15.66	1.31	1.30	1.31
Ajwain + Amaranthus (1:2)	10.58	10.38	10.48	16.69	16.30	16.49	1.41	1.39	1.40
Sole ajwain	12.95	12.88	12.92	12.95	12.88	12.92	1.00	1.00	1.00
Sole fenugreek	–	–	–	16.10	15.75	15.92	1.00	1.00	1.00
Sole coriander	–	–	–	12.95	12.61	12.78	1.00	1.00	1.00
Sole dill	–	–	–	15.21	14.80	15.01	1.00	1.00	1.00
Sole amaranthus	–	–	–	10.38	10.22	10.30	1.00	1.00	1.00
S Em ±	0.30	0.35	0.31	0.32	0.35	0.27	0.02	0.03	0.02
CD at 5%	0.89	1.05	0.94	0.93	1.03	0.80	0.07	0.09	0.06

Yields attributes of intercrops

The data on marketable yield (t ha^{-1}) of respective leafy vegetables under different intercropping ratios in two harvests and total yield during 2016 and 2017 are presented in Table 3. The yields of intercrops were higher in their respective sole crops compared to intercropping with ajwain. The total yield of intercrops, including fenugreek (14.31 and 14.00 t ha^{-1}), coriander (10.36 and 10.09 t ha^{-1}), dill (15.21 and 14.80 t ha^{-1}), and amaranthus (10.38 and 10.22 t ha^{-1}) during 2016 and 2017, respectively), were higher in their respective sole crops compared to intercropping with ajwain. The increased yield of leafy vegetables in sole crops is attributed to a higher plant population and the accommodation of more rows, facilitating better growth and independent development of these crops. Additionally, the data reveals that at different intercrop ratios, higher yields of intercrops were observed in the 1:2 ratio compared to the 1:1 ratio. This finding aligns with similar results reported by Tiwari *et al.* (2002) in fennel, as well as by Islam *et al.* (2014), Mehta *et al.* (2015) and Mehta *et al.* (2010) in coriander.

Table 3. Marketable yield (t ha^{-1}) of leafy vegetables as influenced by intercropping ratios

Treatment	*Kharif*, 2016			*Kharif*, 2017		
	First harvest (t ha^{-1})	Second harvest (t ha^{-1})	Total yield (t ha^{-1})	First harvest (t ha^{-1})	Second harvest (t ha^{-1})	Total yield (t ha^{-1})
Ajwain + Fenugreek (1:1)	4.46	4.35	8.80	4.31	4.14	8.44
Ajwain + Fenugreek (1:2)	5.50	5.42	10.92	5.32	5.13	10.45
Sole fenugreek	7.24	7.07	14.31	7.08	6.92	14.00
Ajwain + Coriander (1:1)	3.52	3.45	6.97	3.44	3.38	6.82
Ajwain + Coriander (1:2)	4.11	3.91	8.02	3.89	3.81	7.70
Sole coriander	5.28	5.08	10.36	5.11	4.98	10.09
Ajwain + Dill (1:1)	3.97	3.73	7.70	4.03	3.81	7.84
Ajwain + Dill (1:2)	5.81	5.48	11.29	5.38	5.31	10.70
Sole dill	7.69	7.52	15.21	7.57	7.24	14.80
Ajwain + Amaranthus (1:1)	2.42	2.3 5	4.76	2.32	2.31	4.63
Ajwain + Amaranthus (1:2)	3.12	2.99	6.11	2.97	2.94	5.91
Sole amaranthus	5.26	5.12	10.38	5.09	5.13	10.22

Economic analysis

The intercropping of leafy vegetables with ajwain demonstrated higher gross return, net return, and benefit–cost ratio (BCR) compared to sole ajwain cultivation (Table 4). Among different intercropping ratios, the 1:2 ratio recorded the highest cost of cultivation in comparison to the 1:1 ratio and respective sole crops. The highest gross returns were observed in ajwain + fenugreek in 1:2 ratio (Rs. 1,80,539 ha^{-1}), followed by ajwain + dill in 1:2 ratio (Rs. 1,73,096 ha^{-1}) and ajwain + fenugreek in 1:1 ratio (Rs. 1,69,394 ha^{-1}). Regarding net returns, the intercropping of ajwain with fenugreek in 1:2 ratio resulted in the highest net returns (Rs. 1,13,977 ha^{-1}), followed by the 1:1 ratio (Rs. 1,12,385 ha^{-1}) and ajwain + coriander in 1:1 ratio (Rs. 1,10,044 ha^{-1}). The highest benefit–cost ratio was recorded in ajwain + coriander in 1:1 intercropping system (2.99), closely followed by ajwain + fenugreek in a 1:1 ratio (2.98). These results suggest that intercropping strategies, especially with fenugreek and coriander, can enhance both the economic returns and cost–effectiveness of ajwain cultivation.

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Table 4. Economics of ajwain cultivation as influenced by different intercropping systems

Treatment	Cost of cultivation (Rs ha^{-1})			Gross returns (Rs ha^{-1})			Net returns (Rs ha^{-1})			BCR		
	2016	2017	Mean	2016	2017	Mean	2016	2017	Mean	2016	2017	Mean
Ajwain + Fenugreek (1:1)	54874	59144	57009	171520	167267	169394	116646	108123	112385	3.13	2.83	2.98
Ajwain + Fenugreek (1:2)	63629	69494	66562	183400	177677	180539	119771	108183	113977	2.88	2.56	2.72
Ajwain + Coriander (1:1)	53139	58064	55602	167140	164150	165645	114001	106086	110044	3.15	2.83	2.99
Ajwain + Coriander (1:2)	59914	67114	63514	166390	161610	164000	106476	94496	100486	2.78	2.41	2.59
Ajwain + Dill (1:1)	52909	58104	55507	154936	155040	154988	102027	96936	99482	2.93	2.67	2.80
Ajwain + Dill (1:2)	59984	68254	64119	175976	170216	173096	115992	101962	108977	2.93	2.49	2.71
Ajwain + Amaranthus (1:1)	52394	56574	54484	126344	124216	125280	73950	67642	70796	2.41	2.20	2.30
Ajwain + Amaranthus (1:2)	57654	63104	60379	133520	130344	131932	75866	67240	71553	2.32	2.07	2.19
Sole ajwain	41714	41714	41714	103600	103040	103320	61886	61326	61606	2.48	2.47	2.48
Sole fenugreek	51634	52024	51829	128763	126000	127382	95129	91976	93553	2.49	2.42	2.46
Sole coriander	39144	43674	41409	103570	100900	102235	73426	66226	69826	2.65	2.31	2.47
Sole dill	47964	53814	50889	121680	118424	120052	91716	82610	87163	2.54	2.20	2.36
Sole amaranthus	37804	41694	39749	83016	81736	82376	55212	50042	52627	2.20	1.96	2.07

Conclusion

In summary, the economic analysis of intercropping strategies involving ajwain, coriander and ajwain, fenugreek indicates that such practices yield higher gross returns, net returns, and benefit–cost ratios compared to sole ajwain cultivation. Specifically, the intercropping of ajwain with coriander in 1:1 ratio stands out as the most commercially sustaining selection, showcasing the highest benefit–cost ratio. These findings emphasize the significance of strategic intercropping, particularly with coriander and fenugreek, in enhancing both the economic returns and cost–effectiveness of ajwain cultivation. The study suggests that adopting intercropping practices can contribute to increased agricultural productivity and overall profitability.

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