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Effect of plant geometry and nutrition on yield and quality parameters of transplanted ajowan (*Trachyspermum ammi* l. Sprague) in the red loamy soils of Andhra Pradesh

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Abstract
The present investigation entitled Effect of plant geometry and nutrition on yield and quality parameters of transplanted ajowan (*Trachyspermum ammi* L. Sprague) in the red loamy soils of Andhra Pradesh. was carried out at College of Horticulture, Venkataramannagudem, West Godavari district of Andhra Pradesh during Rabi 2017-2018. The experiment was laid out in a factorial randomized block design with 18 treatments replicated thrice. The treatments include plant geometries 30 cm x 20 cm, 45 cm x 20 cm and 30 cm x 30 cm at six fertilizer levels i.e. 75% RDF (15: 30:15 NPK kg $hectare^{-1}$), 100% RDF (20: 40:20 NPK kg $hectare^{-1}$), 125% RDF (25: 50 :25 NPK kg $hectare^{-1}$), 150% RDF (30: 60: 30 NPK kg $hectare^{-1}$), 175% RDF (35: 70: 35 NPK kg $hectare^{-1}$), and 200% RDF (40: 80: 40 NPK kg $hectare^{-1}$). Among the different fertilizer levels and plant geometry more number of umbels per plant (189.33), number of umbellate per plant (20.00), number of seeds per umbel (165.67), number of seeds per umbellate (19.00), number of seeds per plant (24.05 thousand) at 200% RDF with plant geometry 45 cm x 20 cm. However, the number of days taken to 50% flowering (55), days taken from flowering to transplanting (115), test weight (1.50 g) and seed yield per plant (7.40 g) were found significant and also maximum with the fertilizer levels 200% RDF with plant geometry 30 cm x 30 cm, but seed yield per hectare (1150.86 kg ha^{-1}) found significant at 200% RDF with plant geometry 30 cm x 20 cm. Among the quality parameters essential oil content (3.25%) was found significantly more with 200% RDF with plant geometry 45 cm x 20 cm. Protein content (19.03%) was found significantly higher at 200% RDF with plant geometry 30 cm x 20 cm.

Keywords: Transplanted ajowan, plant geometry, NPK, nutrition, yield, quality, umbel

Introduction

Ajowan or Bishop's weed (*Trachyspermum ammi* L. Sprague) is an annual herb belonging to the family Apiaceae. It originated in the Central Asiatic and Abyssinian regions (Vavilov and Dorofeev, 1992) [15]. It is cultivated in the Mediterranean region and in South West Asian countries such as Iraq, Iran, Afghanistan, Pakistan and India. In India, it is cultivated on a commercial scale in the states of Rajasthan, Gujarat, Uttar Pradesh, Haryana, Punjab, Andhra Pradesh and West Bengal. Since the crop is generally grown in small patches, authentic data regarding the area under its cultivation and the production are not available. However, in India it is estimated that, production was to the extent of 16 thousand tons with an area of 24 thousand hectares during the year 2016-17 (NHB 2016) [8]

Ajowan fruits are consumed as spice because of its characteristic aroma and pungent taste. It is known as adjuncts, used in small quantities for flavouring the numerous food as antioxidant and also as a preservative in confectionary, beverages and pan mixtures.

Ajowan is used as a household remedy for indigestion and it is much valued for its antispasmodic stimulant, tonic and carminative properties. It is administered in flatulence, dyspepsia, diarrhoea and often recommended for cholera. Ajowan is also effective in relaxing sore throat and in bronchitis and often as an ingredient of cough mixtures. The paste of crushed fruits is applied externally for relieving colic pains. The roots of ajowan plant are reported to possess diuretic and carminative properties and are used in febrile conditions and in stomach disorders.

Scientific information on the effect of plant geometry and nutrition of ajowan is lacking especially in the red loamy soils of Andhra Pradesh. Geometry is an important factor for better growth and yield of the plant. Optimum number of plants is required per unit area to utilize the available production factors efficiently such as water, nutrient, light and CO_2. Normally, maximum yields are obtained from plant populations which do not allow plants to achieve their individual maximum potential of the vegetative growth. Thus, the entire community of plants considered for higher production rather than individual plant performance (Donald, 1963) [3].

Application of N promotes higher photosynthetic activity and vigorous vegetative growth and as a result, the plants turn into dark green colour (Balasubramaniyan and Palaniappan, 2005) [2]. Phosphorus, being the constituent of nucleic acid, phospholipids, is also very essential for proper development of crops. It imparts hardness to shoot, improves grain quality, regulates photosynthesis, governs physicochemical processes, help in the enlargement of cell and develop resistant to diseases. Potassium plays a major role in transport of water and nutrients throughout the plant in xylem and improves drought tolerance to plants (Reddy and Reddi, 2002) [11].

Material methods

An experiment was conducted in college of horticulture, Venkataramannagudem during the *rabi* season, 2017-2018. This experiment was laid out in factorial randomized block design with 3 replications and 18 treatments. Two factors include 6 levels of ferilizers [15:30:15 NPK Kg ha $^{-1}$(F_1), 20:40:20 NPK Kg ha^{-1}(F_2), 25:50:25 NPK Kg ha^{-1}(F_3), 30:60:30 NPK Kg ha^{-1}(F_4), 35:70:35 NPK Kg ha^{-1} (F_5)and 40:80:40 NPK Kg ha^{-1} (F_6) and Spacings [30cm x 20cm (S_1), 45cmx 20cm (S_2), 30cm x 30cm (S_3)]. Different level of fertilizers applied according to the treatments with suitable spacings, Nitrogen and Potassium applied at 30, 60 and 90 days whereas Phosphorous applied as basic dose.

Random selection of five plants per plots for recorded the characters like number of umbels per plant, number of umbellate per plant, number of seeds per umbel, number of seeds per umbellate, number of seeds per plant, number of days taken to 50% flowering, days taken from flowering to transplanting, test weight, seed yield per plant, seed yield, essential oil content and Protein content at 60, 90, 120 days after sowing.Data recorded on growth, yield and quality parameter was subjected to analysis of variance (ANOVA, $p \leq 0.05$) and means comparisons were done at $P\leq 0.05$.

Result and discussion

Days taken to 50% flowering

The data related to days taken to 50% flowering are presented in the Table 1. The effect of fertilizer doses, plant geometry and their interaction was significant on days taken to 50% flowering.

The perusal of data of days taken to 50% flowering revealed that plants grown with higher doses of fertilizers need more days for flowering, similar is the case with widely spaced plants. The plants grown with highest fertilizer dose of 200% RDF (40:80:40 NPK kg ha^{-1}) (50.83) needed significantly more number of days for 50% flowering. Similarly, the plant geometry of 30 cm x 30cm required significantly more number of days for 50% flowering (49.83) compared to the other two arrangements.

Among the interactions between the fertilizer doses and plant geometry, the maximum number of days required for 50% flowering (55 days) was recorded with the fertilizer dose of 200% RDF (40:80:40 NPK kg ha^{-1}) with plant geometry 30 cm x 30 cm. Minimum number of days taken for flowering is (43.67 days) was observed in the 75% RDF (15:30:15 NPK kg ha^{-1}) with plant geometry 30 cm x 20cm treatment.

The above results showed that plant grown at wider spacing with highest dose of fertilizers required more days to 50% flowering whereas plant with closer spacing with lowest doses of fertilizers required less days for 50% flowering.

The delay in flowering in plants with high doses of fertilizer and wider spacing was probably due to increased vegetative growth observed in these plants, which might have needed more time for flowering compared to plants grown with lowest fertilizer doses under closer spacing.

Days taken to harvest from transplanting

Appraisal of data for days taken to harvest from transplanting (Table 1) indicated that effect of different fertilizer levels, plant geometry and their combinations was significant.

Among the fertilizer doses evaluated, significantly more number of days taken to harvest was observed with the application of 200% RDF (40:80:40 NPK kg ha^{-1}) (110.83 days) however minimum number of (105.11 days) days required for harvesting is recorded with 75% RDF (15:30:15 NPK kg ha^{-1}).The perusal of data revealed that plant grown with plant geometry 30 cm x 30 cm required significantly more number of days (109.83 days) for harvesting. The minimum number of days required for harvesting (105.39 days) was recorded with plant geometry 30 cm x 20 cm.

Regarding the interaction between fertilizer levels and plant geometry, the plants grown with 200% RDF (40:80:40 NPK kg ha^{-1}) and plant geometry of 30 cm x 30 cm required more number of days (115 days) for harvesting. The minimum number of days for harvesting was observed with 75% RDF (15:30:15 NPK kg ha^{-1}) with plant geometry 30 cm x 20 cm (103.67 days).

The above results indicated that plant grown at wider spacing and high doses of fertilizer required more days for harvest due to late flowering compared to plants grown in closer spacing and lower doses of fertilizer.

Number of umbels per plant

The number of umbels per plant was significantly influenced by the fertilizer doses, plant geometry and their interactions are presented in Table 2.

Significantly maximum number of umbels per plant was noticed with highest dose of fertilizer 200% RDF (40:80:40 NPK kg ha^{-1}) (178.89) followed by (176.49) at 175% RDF, (35:70:35 NPK kg ha^{-1}) which were on par with each other and significantly superior to all other fertilizer doses.

Among the different plant geometries evaluated, significantly more number of umbels was observed with 45 cm x 20 cm (177.31) plant geometry. Among the interactions among different fertilizer levels and plant geometries, significantly more number of umbels was found at 200% RDF (40:80:40 NPK kg ha^{-1}) with plant geometry 45 cm x 20 cm (189.33).

The above results indicated that plant grown with wider spacing and with 200% RDF (40:80:40 NPK kg ha^{-1}) leads to profuse branching in turn increased in number of primary and secondary branches leads to greater accumulation terminal shoots which converted in to more flowering in the plant in turn leads to more number of umbels per plant.

Similar results were found by Yadav *et al.* (2000) [16] in fennel, Jenny *et al.* (2006) [4] in Ajowan, Naruka *et al.* (2012) [7] in ajowan.

Number of umbellate per umbel

The number of umbellate per umbel was significantly influenced by different fertilizer levels, different plant geometries and their interactions presented in table 2.

Among the fertilizer doses evaluated, significantly more number of umbellate per umbel was observed in 200% RDF (40:80:40 NPK kg ha^{-1}) (16.38). The minimum number of umbellate per umbel was noticed at lower dose fertilizers 75% RDF (11.33). Regarding the different plant geometries evaluated, plant grown with 45 cm x 20 cm (15.25) produced significantly more umbellate per umbel. The minimum number of umbellate per umbel was found with plant geometry of 30 cm x 20 cm (12.63).

Among the interactions between fertilizer levels and plant geometry, plant grown with 200% RDF (40:80:40 NPK kg ha^{-1}) with plant geometry of 45 cm x 20 cm (20.00) had produced significantly highest number of umbellate per umbel. The minimum number of umbellate per umbel was observed with the fertilizer dose of 75% RDF (15:30:15 NPK kg ha^{-1}) and plant geometry 30 cm x 20 cm (10.80).

The above results indicated that the plants grown at wider spacing with higher doses of fertilizer recorded more number of umbellate per umbel, which was due to more availability of photosynthates which was indicated by growth parameters like plant height, branching and dry matter accumulation.

The results was found by Naruka *et al.* (2012) [7] in ajowan; Amin and Patel (2001), Rai *et al*. (2002) [10] in fennel crop.

Number of seeds per umbel

The data of number of seeds per umbel is presented in Table 3 and significant differences were observed among different fertilizer levels, plant geometry and their interaction.

The data indicated that among the fertilizer doses evaluated, plants grown with fertilizer dose of 200% RDF (40:80:40 NPK kg ha^{-1}) recorded significantly more number of seeds per umbel (159.56) over all other fertilizer doses evaluated.

Significantly more number of seeds per umbel was noticed with plant geometry 45 cm x 20 cm (150.44) compared to the other two plant geometries studied.

Among the interactions between fertilizer levels and plant geometry, significantly higher number of seeds per umbel was observed in the treat with 200% RDF (40:80:40 NPK kg ha^{-1}) and plant geometry 45 cm x 20 cm (165.67).

From the above result, it is clearly illustrated that plants grown with wider spacing, high doses of fertilizer and in combinations, resulted in more number of seeds per umbel. This might be due to high availability of photosynthates, which was evident from plant growth in respective treatments, resulted in increased production of florets in umbels. Comparable results were reported by Jenny *et al.* (2006) [4] in ajowan.

Number of seeds per umbellate

The data pertaining to number of seeds per umbellate is furnished in the Table 3 and Fig. 2 There was significant increase in number of seeds per umbellate with different fertilizers levels, plant geometry and their interaction.

The results obtained indicated that significantly higher number of seeds per umbellate was recorded with the fertilizer application of 200% RDF (40:80:40 NPK kg ha^{-1}) (17.00) over all other fertilizer doses studied. Among plant geometries evaluated, significantly more number of seeds per umbellate was recorded with plant geometry 45 cm x 30 cm (15.53).

Among the interaction effects between fertilizer levels and plant geometry, maximum number of seeds per umbellate was observed with fertilizer dose of 200% RDF (40:80:40 NPK kg ha^{-1}) and plant geometry 45 cm x 20 cm (19.00), Whereas minimum was recorded with 75% RDF (15:30:15 NPK kg ha^{-1}) with 30 cm x 20 cm.

The results indicated that that plants grown with wider spacing, high doses of fertilizer and in combinations, resulted in more number of seeds per umbellate, which was due more availability of photosynthates for production of florets in each umbellate. Similar results was found by Yadav *et al.* (2000) [16] in fennel and Naruka *et al.* (2012) [7] in ajowan.

Test weight (g)

The data on test weight, which is furnished in the Table 4 indicated that the test weight was significantly influenced by the fertilizer doses, plant geometries and their interaction.

Regarding the fertilizer doses evaluated, it was observed that highest test weight was recorded with 200% RDF (40:80:40 NPK kg ha^{-1}) (1.42 g) followed by the treatment of 175% RDF (35:70:35 NPK kg ha^{-1}) (1.38 g), which were on par with each other and significantly superior over all other treatments. Among the different plant geometries evaluated, significantly higher test weight was observed with plant geometry of 30 cm x 30 cm had maximum (1.25).

With respect to the interaction between fertilizer levels and plant geometry, maximum test weight was observed with 200% RDF (40:80:40 NPK kg ha^{-1}) and plant geometry 30 cm x 30 cm (1.50 g). However, minimum test weight was found at 75% RDF (15:30:15 NPK kg ha^{-1}) with plant geometry 30 cm x 20 cm (0.86 g).

Number of seeds per plant

The number of seeds per plant was significantly influenced by the fertilizer doses, plant geometry and their interactions (Table 4).

Significantly more number of seeds per plant found in with the fertilizer application of 200% RDF (40:80:40 NPK kg ha^{-1}) (23.27 thousand) over all other fertilizer doses considered under the study.

Regarding the different plant geometries evaluated, maximum number of seeds was recorded in plants grown at 45 cm x 20 cm (20.34 thousands) followed by plants grown at 30 cm x 30 cm (19.49 thousands) which were on par with each other and significantly superior to 30 cm x 20 cm plant geometry.

Among the interactions among different fertilizer levels and plant geometries, maximum number of seeds per plant was recorded with fertilizer dose of 200% RDF (40:80:40 NPK kg ha^{-1}) and plant geometry 45 cm x 20 cm (24.05). However, minimum number of seeds was observed with fertilizer dose of 75% RDF (15:30:15 NPK kg ha^{-1}) and plant geometry 30 cm x 20 cm (14.41 thousands).

The aforementioned results clearly indicated that either increasing the fertilizer doses or inter-plant spacing, the number of seeds produced by plant was increasing. This trait is related to production of primary and secondary branches, overall growth, and availability of photosynthates as evidenced by dry matter production, which were higher in the treatments under consideration. The profuse branching seems to have led to greater initiation of flowering and retention of flowers due to adequate supply of metabolites. These factors might have encouraged more seed set and seed growth. This was ultimately reflected in increased seed yield per plant. Similar results were reported by Krishnamoorthy and Madalageri (2000); Ajay *et al.* (2016).

Seed yield per plant (g $plant^{-1}$)

The seed yield per plant was significantly influenced by different fertilizer levels, different plant geometries and their interactions (Table 5).

The seed yield per plant recorded with the application of 175% RDF (35:70:35 NPK kg ha^{-1}) (7.45 g plant^{-1}) and 200% RDF (40:80:40 NPK kg ha^{-1}) (7.22 g plant^{-1}) was on par and significantly higher over all other fertilizer doses evaluated. The lowest seed yield per plant (3.96 g plant^{-1}) was observed with lowest dose of fertilizers applied i.e. 75% RDF (15:30:15 NPK kg ha^{-1}).

Among the different plant geometries evaluated, significantly higher seed yield per plant (6.20 g plant^{-1}) was recorded with the plant geometry 30 cm x 30 cm. The lowest seed yield per plant was observed in plant geometry 30 cm x 20 cm (5.54 g plant^{-1}).

Among the interactions among different fertilizer levels and plant geometries, maximum seed yield per plant was observed with fertilizer application of 175% RDF (35:70:35 NPK kg ha^{-1}) and plant geometry 30 cm x 30cm (7.93 g plant^{-1}). Minimum seed yield per plant was recorded with fertilizer dose of 75% RDF (15:30:15 NPK kg ha^{-1}) and plant geometry 30 cm x 20 cm (3.73 g plant^{-1}).

The improvement in seed yield due to nutrient supplementation might be due the significant promotion of growth by their applications which enhanced the capacity of plant to partition the photosynthates to the sink efficiently. At higher populations, inter and intra-plant competition between source and sink for photosynthates increases. As florets develop after considerable vegetative growth, the extreme competition among vegetative bud and reproductive parts affects reproduction as a whole. More plant population per unit area increases respiration and decreases photosynthesis which leads to the decrease in the transfer of assimilates to seeds and consequently, seed yield loss. Similar results were reported by Krishnamoorthy and Madalageri (2000) Ajay *et al.* (2016).

Seed yield per hectare (kg ha^{-1})

Seed yield (kg ha^{-1}) was significantly influenced the fertilizer doses, plant geometry and their interactions were presented in Table 5 and Fig. 3.

Regarding fertilizer doses, significantly higher seed yield was recorded with the application of fertilizer dose of 175% RDF (35:70:35 NPK kg ha^{-1}) (922.22 kg ha^{-1}) over all other fertilizer doses studied. The lowest seed yield was observed with the fertilizer dose of 75% RDF (15:30:15 NPK kg ha^{-1}) (463.56 kg ha $^{-1}$), which was significantly inferior to all other treatments.

Among the different plant geometries evaluated, significantly higher seed yield was recorded with the plant geometry 30 cm x 20 cm (887.52 kg ha^{-1}). The significantly lowest seed yield was observed with the plant geometry 45 cm x 20 cm (602 kg ha^{-1}).

Among the interactions among different fertilizer levels and plant geometries, significantly higher seed yield per hectare was recorded with the fertilizer dose of 175% RDF (35:70:30 NPK kg ha^{-1}) and plant geometry 30 cm x 20 cm (1150.86 kg ha^{-1}) followed by the fertilizer dose of 200% RDF and plant geometry 30 cm x 20 cm (1133.20 kg ha^{-1}), which were on par with each other and significantly superior to all other combinations. The lowest seed yield was noticed with the lowest fertilizer application (75% RDF) (15:30:15 NPK kg ha^{-1}) and plant geometry 45 cm x 20 cm (395.63 kg ha^{-1}).

The above results indicated that plant with closer spacing with high doses of fertilizer leads to more seed yield per hectare compared to wider spacing that might be due to more plant population per unit area resulted in higher yield per hectare. Similar results were reported by Muvel *et al.* (2015), Tripathi and Diwedi (2009) and Premnath *et al.* (2008).

Seed quality

Essential oil content (%)

The essential oil content was significantly influenced by fertilizer doses, plant geometry and their interaction (Table 6). The results indicated that plant grown at 200% RDF (40:80:40 NPK kg ha^{-1}) had significantly more essential oil content (3.08%) than all other fertilizer doses evaluated. The least essential oil content was found when plant grown at 75% RDF (15:30:15 NPK kg ha^{-1}) (2.04%).

The essential oil content in the plants growth with plant geometry 45 cm x 20 cm (2.78%) was significantly higher compared to the other two plant geometries evaluated.

Among the interactions between the fertilizer doses and plant geometry, significantly more essential oil was recorded with the application of 200% RDF (40:80:40 NPK kg ha^{-1}) and plant geometry 45 cm x 20 cm (3.25%) The least essential oil content was observed with 75% RDF (15:30:15 NPK kg ha^{-1}) application and plant geometry 30 cm x 20 cm (1.90%).

The above results indicated that plant grown with higher doses of fertilizer and wider spacing resulted in higher essential oil content. As the nitrogen plays an important role in development and divisions of new cells containing essential oil. It also plays important role in essential oil channels secretary ducts development and growth of glandular trichrome. Hence, availability of soil N might have helped accumulation of essential oil in the plants and seed. Further, increased availability photosynthates in the plants grown in nutrient rich soil, might have increased the production of essential oils which actually engender from specific pathways which need regular availability of primary metabolites. Similar results was found by Naruka *et al.* (2008) and Sathyanarayana *et al.* (2015).

Protein content (%)

The protein content is presented in Table 6. There were significant changes in protein content with different fertilizers levels, plant geometry and their interaction.

The results obtained indicated that significantly higher protein content was recorded with 200% RDF (40:80:40 NPK kg ha^{-1}) (18.40%) compared to all other fertilizer treatments.

Regarding the effect of plant geometry on protein content of seed, significantly higher protein was observed with plant geometry 30 cm x 20 cm (16.59%) compared to the other two geometries.

Among the interaction effect between the fertilizer levels and plant geometry, the maximum protein content was found at 200% RDF (40:80:40 NPK kg ha^{-1}) with plant geometry 30 cm x 20 cm (19.03%). The least protein content was found at 75% RDF (15:30:15 NPK kg ha^{-1}) with plant geometry 45 cm x 20 cm (11.67%).

The higher protein content observed in plants grown with wider spacing and higher doses of fertilizer might have been due to continuous supply of nitrogen from the soil which in turn helped biosynthesis of protein. The increased availability of potassium in soil and plants might have helped in better utilization of nitrogen and synthesis proteins. Similar results was found by Sheeshpal *et al.* (2018).

Conclusion

From the results obtained in present day investigation it can concluded that significantly more number of umbels per plant, number of umbellate per plant, number of seeds per umbel, number of seeds per umbellate, number of seeds per plant at 200% RDF with plant geometry 45 cm x 20 cm. However, the number of days taken to 50% flowering, days taken from flowering to transplanting, test weight and seed yield per plant were found significantly with the fertilizer levels 200% RDF with plant geometry 30 cm x 30 cm, however seed yield per hectare was found significantly higher at 175% RDF with plant geometry 30 cm x 20 cm.

Among the quality parameters essential oil content was found significantly more with 200% RDF with 45 cm x 20 cm plant geometry. Protein content was found significantly higher in the seed with 200% RDF with plant geometry 30 cm x 20 cm.

Table 1: Effect of fertilizer levels (F) and plant geometry (S) on days to 50% flowering and days to harvest from transplanting in ajowan

Treatments	Yield parameters							
	Days taken to 50% flowering from transplanting				Days taken for harvest from transplanting			
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean
F_1	43.67	45.00	46.67	45.11	103.67	105.00	106.67	105.11
F_2	44.67	45.00	47.67	45.78	104.67	105.00	107.67	105.78
F_3	45.17	46.17	48.00	46.44	105.17	106.17	108.00	106.44
F_4	46.67	47.17	49.67	47.83	106.67	107.17	109.67	107.83
F_5	47.17	48.17	52.00	49.11	107.17	108.17	112.00	109.11
F_6	45.00	52.50	55.00	50.83	105.00	112.50	115.00	110.83
Mean	45.39	47.33	49.83	47.51	105.39	107.33	109.83	107.51
	S Em ±		CD at 5%		S Em ±		CD at 5%	
F	0.59		1.68		0.59		1.68	
S	0.41		1.19		0.41		1.19	
F X S	1.01		2.92		1.01		2.92	

F = Fertilizer level (NPK kg ha^{-1})
F_1: (75% RDF - 15:30:15) F_4: (150% RDF- 30:60:30)
F_2: (100% RDF - 20:40:20) F_5: (175% RDF - 35:70:35)
F_3: (125% RDF -25:50:25) F_6: (200% RDF - 40:80:40)

S = Plant geometry (spacing)
S_1: (30 cm x 20 cm)
S_2: (45 cm x 20 cm)
S_3: (30 cm x 30 cm)

Table 2: Effect of fertilizer levels (F) and plant geometry (S) on number of umbel per plant and umbellate per umbel in ajowan

Treatments	Yield parameters							
	Number of umbels per plant				Number of umbellates per umbel			
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean
F_1	160.00	167.33	163.67	163.67	10.80	12.00	11.20	11.33
F_2	162.00	171.00	167.48	166.83	18.27	13.17	12.30	12.24
F_3	161.33	174.17	169.96	168.49	12.67	14.17	12.80	13.21
F_4	163.29	179.03	173.97	172.10	13.13	15.33	13.47	13.98
F_5	172.10	183.00	174.37	176.49	13.83	16.83	14.00	14.89
F_6	172.00	189.33	175.33	178.89	14.07	20.00	15.07	16.38
Mean	165.12	177.31	170.80	171.07	12.63	15.25	13.14	13.67
	S Em ±		CD at 5%		S Em ±		CD at 5%	
F	1.06		3.04		0.37		1.06	
S	0.75		2.15		0.26		0.75	
F X S	1.83		5.27		0.64		1.84	

F = Fertilizer level (NPK kg ha^{-1})
F_1: (75% RDF - 15:30:15) F_4: (150% RDF- 30:60:30)
F_2: (100% RDF - 20:40:20) F_5: (175% RDF - 35:70:35)
F_3: (125% RDF - 25:50:25) F_6: (200% RDF- 40:80:40)

S = Plant geometry (spacing)
S_1: (30 cm x 20 cm)
S_2: (45 cm x 20 cm)
S_3: (30 cm x 30 cm)

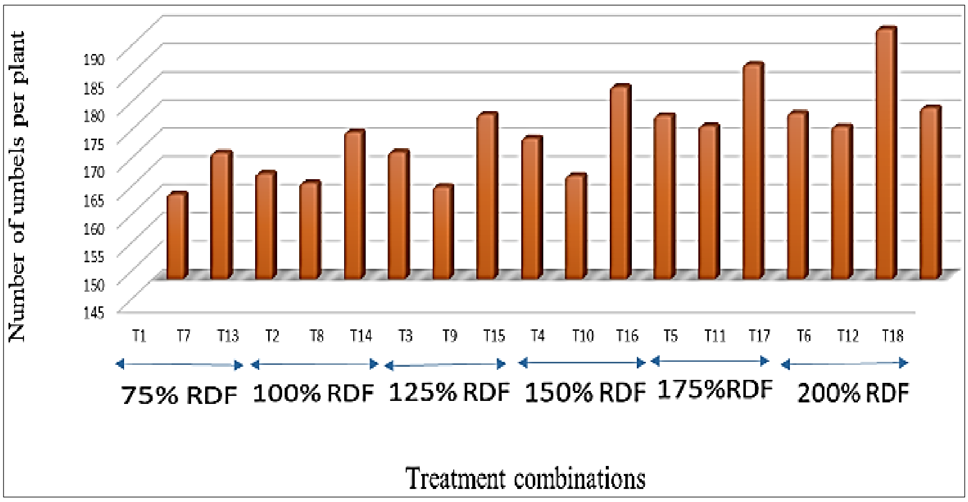

Fig 1: Effect of fertilizer levels (F) and plant geometry(S) on number of umbels per plant

Table 3: Effect of fertilizer levels (F) and plant geometry (S) on number of seeds per umbel and number of seeds per umbellate in ajowan

Treatments	Yield parameters							
	Number of seeds per umbel				Number of seeds per umbellates			
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean
F_1	135.50	140.67	136.33	137.50	11.17	12.50	12.17	11.94
F_2	138.67	141.00	139.00	139.56	12.42	13.00	12.67	12.69
F_3	141.67	144.33	143.33	143.11	13.08	14.00	13.50	13.53
F_4	144.00	148.00	147.33	146.44	14.00	16.67	15.00	15.22
F_5	149.00	163.00	153.33	155.11	14.92	18.00	15.72	16.21
F_6	155.67	165.67	157.33	159.56	15.83	19.00	16.17	17.00
Mean	144.08	150.44	146.11	146.93	13.57	15.53	14.20	14.43
	S Em ±		CD at 5%		S Em ±		CD at 5%	
F	0.72		2.07		0.26		0.75	
S	0.51		1.46		0.18		0.53	
F X S	1.25		3.58		0.45		1.30	

F = Fertilizer level (NPK kg ha^{-1})
F_1: (75% RDF - 15:30:15) F_4: (150% RDF- 30:60:30)
F_2: (100% RDF - 20:40:20) F_5: (175% RDF - 35:70:35)
F_3: (125% RDF - 25:50:25) F_6: (200% RDF- 40:80:40)

S = Plant geometry (spacing)
S_1: (30 cm x 20 cm)
S_2: (45 cm x 20 cm)
S_3: (30 cm x 30 cm)

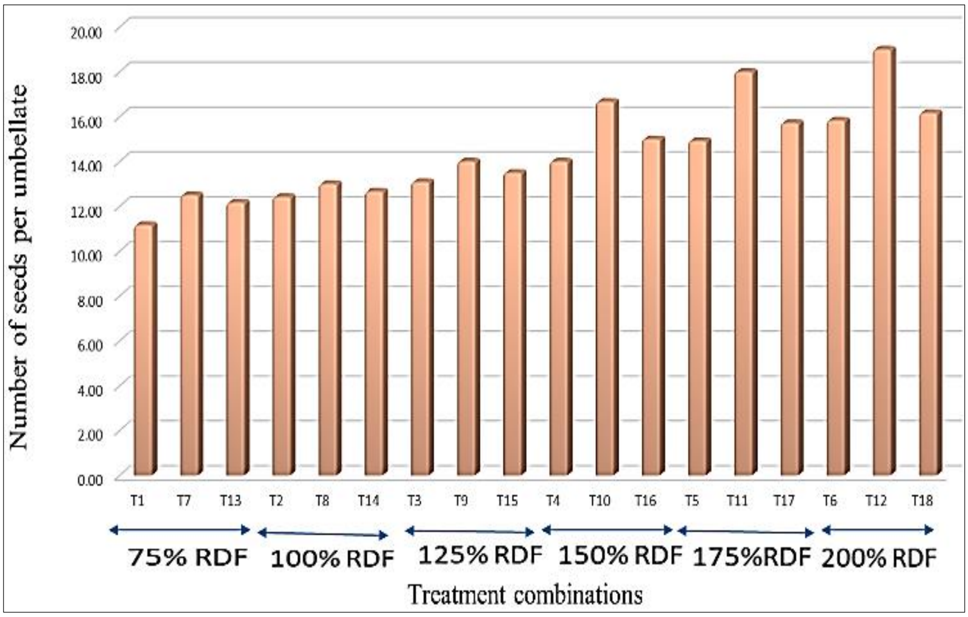

Fig 2: Effect of Fertilizer levels (F) and Plant geometry (S) on number of seeds per umbellate in ajowan

Table 4: Effect of fertilizer levels (F) and plant geometry (S) on test weight and number of seeds per plant in ajowan

Treatments	Yield parameters							
	Test weight (g $plant^{-1}$)				Number of seeds per plant in (000)			
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean
F_1	0.86	0.88	0.93	0.89	14.41	17.91	16.40	16.24
F_2	0.88	0.93	1.03	0.95	15.67	18.47	17.67	17.27
F_3	1.01	1.05	1.27	1.11	17.13	19.08	18.33	18.18
F_4	1.08	1.22	1.34	1.21	19.33	20.00	19.70	19.68
F_5	1.25	1.43	1.45	1.38	21.17	22.53	21.50	21.73
F_6	1.28	1.48	1.50	1.42	22.42	24.05	23.33	23.27
Mean	1.06	1.17	1.25	1.16	18.35	20.34	19.49	19.39
	S Em ±		CD at 5%		S Em ±		CD at 5%	
F	0.01		0.04		0.48		1.37	
S	0.01		0.03		0.34		0.97	
F X S	0.02		0.07		0.82		2.36	

F = Fertilizer level (NPK kg ha^{-1})
F_1: (75% RDF - 15:30:15) F_4: (150% RDF- 30:60:30)
F_2: (100% RDF - 20:40:20) F_5: (175% RDF - 35:70:35)
F_3: (125% RDF - 25:50:25) F_6: (200% RDF- 40:80:40)

S = Plant geometry (spacing)
S_1: (30 cm x 20 cm)
S_2: (45 cm x 20 cm)
S_3: (30 cm x 30 cm)

Table 5: Effect of fertilizer levels (F) and plant geometry (S) on seed yield per plant and seed yield per hectare in ajowan

Treatments	Seed yield							
	Seed yield per plant (g plant^{-1})				Seed yield per hectare (kg ha^{-1})			
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean
F_1	3.73	3.93	4.20	3.96	574.42	395.63	420.63	463.56
F_2	4.87	5.07	5.73	5.22	782.89	524.27	599.67	636.09
F_3	4.93	5.34	5.87	5.38	784.34	565.44	614.16	654.65
F_4	5.60	5.73	6.07	5.80	897.94	590.58	635.38	707.97
F_5	7.13	7.27	7.93	7.45	1150.86	779.79	836.02	922.22
F_6	7.00	7.27	7.40	7.22	1133.20	757.70	783.14	891.35
Mean	5.54	5.77	6.20	5.83	887.52	602.24	648.17	712.55
	S Em ±		CD at 5%		S Em ±		CD at 5%	
F	0.20		0.58		8.00		23.02	
S	0.14		0.41		5.66		16.28	
F X S	0.35		1.00		13.87		39.88	

F = Fertilizer level (NPK kg ha^{-1})
F_1: (75% RDF - 15:30:15) F_4: (150% RDF- 30:60:30)
F_2: (100% RDF - 20:40:20) F_5: (175% RDF - 35:70:35)
F_3: (125% RDF - 25:50:25) F_6: (200% RDF- 40:80:40)

S = Plant geometry (spacing)
S_1: (30 cm x 20 cm)
S_2: (45 cm x 20 cm)
S_3: (30 cm x 30 cm)

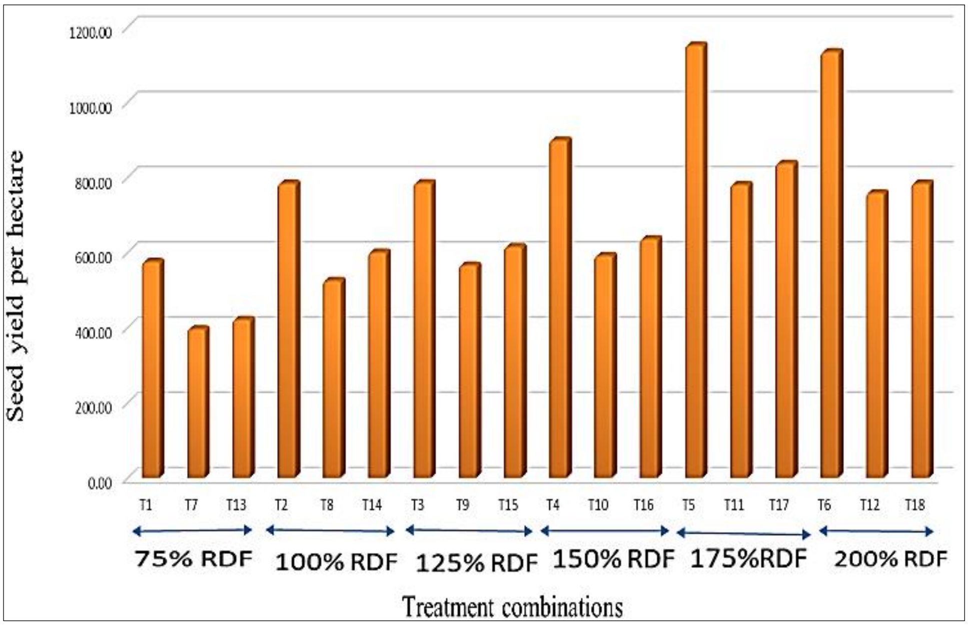

Fig 3: Effect of fertilizer levels (F) and plant geometry(S) on seed yield per hectare in ajowan

Table 6: Effect of fertilizer levels (F) and plant geometry (S) on essential oil content and protein content in ajowan

Treatments	Seed quality							
	Essential oil content (%)				Protein content (%)			
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean
F_1	1.90	2.11	2.10	2.04	13.17	11.67	12.23	12.36
F_2	2.24	2.55	2.37	2.39	14.33	12.21	13.25	13.26
F_3	2.36	2.82	2.79	2.66	16.83	14.17	13.81	14.94
F_4	2.46	2.92	2.84	2.74	17.67	14.83	15.17	15.89
F_5	2.67	3.04	2.89	2.87	18.50	15.25	17.49	17.08
F_6	3.03	3.25	2.95	3.08	19.03	18.00	18.17	18.40
Mean	2.44	2.78	2.66	2.62	16.59	14.35	15.02	15.32
	S Em ±		CD at 5%		S Em ±		CD at 5%	
F	0.04		0.11		0.31		0.90	
S	0.03		0.08		0.22		0.63	
F X S	0.07		0.19		0.54		1.55	

F = Fertilizer level (NPK kg ha^{-1})
F_1: (75% RDF - 15:30:15) F_4: (150% RDF- 30:60:30)
F_2: (100% RDF- 20:40:20) F_5: (175% RDF - 35:70:35)
F_3: (125% RDF - 25:50:25) F_6: (200% RDF- 40:80:40)

S = Plant geometry (spacing)
S_1: (30 cm x 20 cm)
S_2: (45 cm x 20 cm)
S_3: (30 cm x 30 cm)

Conclusion

From the results obtained in the present investigation, it can be concluded The present study indicated that crop grown at 200% RDF with plant geometry 45 cm x 20 cm is achieving higher yield in *rabi* recorded more number of umbels per plant, number of umbellate per umbel, number of seeds per umbel, number of seeds per umbellate, number of seeds per plant due to profuse branching and more number of secondary and primary branches. However, seed yield per hectare found was higher 200% RDF with plant geometry 30 cm x 20 cm due to more population per unit area.

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