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RESEARCH ARTICLE

Growth and Yield Response of Ajwain (*Carum copticum* L.) to Sowing Date and Row Spacing

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ABSTRACT

A study was conducted at research farm of PMAS-Arid Agriculture University, Rawalpindi, during 2004-05 to investigate the effect of sowing date and row spacing on the yield and yield components of *Carum copticum* L. Randomized Complete Block Design (RCBD) with a split plot arrangement was used. The sowing dates were assigned to main plots with row spacing to sub-plots. The seeds of *C. copticum* were planted on seven different dates (Nov. 11, 2004, Nov. 30, 2004, Dec. 12, 2004, Mar. 03, 2005, Oct. 01, 2005, Oct. 27, 2005 and Nov. 16, 2005), each accompanied by three different row spacings (10, 20 and 30cm) and replicated thrice. Data showed that the maximum number of seeds umbel^{-1} (342.67) 1000 seed weight (0.24 g), weight of seeds umbel^{-1}(0.87 g), and seed yield (714.40 kg ha^{-1}) were recorded, when crop was planted on October 27, 2005. Delay in sowing (October to March) gradually decreased yield of the *Ajwain* and it was decreased to 287.80 kg ha^{-1}, when sowing was done on March 03. Data further revealed that wide row spacing significantly increased the yield parameters of *Ajwain*. Overall, seed yield decreased from 716.70 to 523.80 kg ha^{-1}, when rows were spaced from 30 to 10 cm apart. However, the interaction of the sowing date and row spacing was found non-significant in influencing the crop seed yield. Seeds were also found rich in their volatile oils composition for the crop sown on October 27 at 30 cm row spacing as it showed highest number of bands (7), when analyzed by thin layer chromatography. In the light of the present results, it is suggested that planting of *Ajwain* during October with 30 cm row spacing gave better yield under rainfed condition.

INTRODUCTION

There is an increasing demand for plant-based drugs and pharmaceuticals in the world market. Therefore, need for intensive agriculture studies leading to genetic improvement, improved cultivation method and expansion of area under medicinal plants is needed to fulfill the demand of the world market. Several medicinal plants are cultivated and extensively used in Pakistan and elsewhere (Khan et al., 2009; 2014 and Hashim et al., 2014). *Carum* (*C.*) *copticum* (Ajwain) is also called Bishops weed and is a popular minor crop grown in several countries of the world including Pakistan. It is one of the natural sources that provide compounds that are used in drugs as well as possess antifungal activities with potential practical applications as antimicrobial and as food preservatives (Iqbal et al., 2014; Zomorodian et al., 2011).

Ajwain or Bishops weed belongs to family Apiaceae and its seeds have similar but stronger sensory quality like thyme. The alcoholic extract from the seeds contain highly hygroscopic saponnins. A yellow, crystalline flavor and a steroidal substance have also been isolated from its fruit (Bairwa et al, 2012). The principle constituent of the essential oil from the fruit is phenol, mainly thymol and some carvacrol. The remainder of the act is thymine (Gerbach and Reddy, 2002).

Thymol is an important compound that is extensively used in medicine. Leaves of tender plants are used as vermicide and seeds are used to flavor savory dishes,

including curries, legumes bread and pastry snack in several countries of the world (Balaji et al., 2012). Seeds have 17.1% protein, 21.8% fiber; minerals are 7.9% that include calcium, phosphorus sodium thiamine and riboflavin. Sugar tannins and glysides are also reported to in seeds (Raj et al., 2007). Iqbal et al. (2014) studied several plants and found that *C. copticum* proved the most effective in suppressing the growth of the pathogen. These facts suggest that the essential oils from *C. copticum* should be investigated further for possible use in antimicrobial potential (Zomorodian et al., 2011).While, Nickavar and Abolhasani (2009) found that essential oils extracted from *C. copticum* acts as antioxidant. Therefore, significance of ajwain as an important medicinal plant cannot be denied in anyways. Since environmental factors explicitly affect growth, development and yield of medicinal herbs, investigating the effect of these factors, *e.g.*, sowing date and plant density, on medicinal herbs is critically important. Therefore, to harvest the maximum yield of a crop introduced in a certain region, its interaction with agronomic, genetic and climatic factors must be examined (Moosavi et al., 2015; Agha et al., 2010).

Keeping in view of the above, the present study was designed to compare row spacing at different sowing dates as an effort to develop production technology for better yield of *Ajwain* under rainfed conditions of Rawalpindi.

MATERIALS AND METHODS

Ajwain was planted on seven different dates at three row spacing to investigate the growth and yield of this minor crop. The experiment was laid out during 2004 05 according to Randomized Complete Block Design (RCBD) with split plot arrangement at the research farm of PMAS-Arid Agriculture University, Rawalpindi, Pakistan. Seeds of *Ajwain* were planted on seven different dates (Nov 11, 2004, Nov 30, 2004, Dec 12, 2004, Mar 03, 2005, Oct 01, 2005, Oct 27, 2005 and Nov 16, 2005). At each sowing date three different row spacings (10, 20 and 30cm) were used and replicated thrice. The sowing dates were assigned to main plots while row spacing to sub plots. The plot size for 10cm row spacing was 2.5 x 1.5 m, for 20 cm, row spacing was 2.5 x 3m, and for 30 cm, row spacing was 2.5 x 4.5 m. Each plot had 15 rows of *Ajwain*. There were 15 rows of *Ajwain* in each treatment. Planting was done on well prepared soil with single row hand drill. Two manual weeding were done in order to avoid the weed competition and maintain healthy stand of *Ajwain*. The plot was irrigated once, after planting. On maturity of the *Ajwain*, as per sowing date, the crop was harvested on May 05, 2005, June 18, 2005, July 07, 2005, Aug 02, 2005, June 07, 2006, June 07,2006 and June 23, 2006, respectively. The following data was recorded during the course of the experiment.

1. To record the number of seedsumbels^{-1}, ten randomly selected umbels were threshed manually and the numbers were noted and mean was determined. The weight of seeds umbels ^{1} was recorded by randomly selecting ten umbels from each treatment and mean was calculated. For recording 1000 seed weight, sample was collected from the seeds of each plot and weighed.

2. **Seed yield (Kg ha^{-1})**

At maturity, each plot was harvested and sun dried. After threshing, total seed yield per plot was recorded and the data for seed was converted into kg ha^{-1}.

Volatile oil composition

To study the effect of different sowing dates and row spacing on presence of different volatile compounds, chemical analysis of the seeds was carried out using the biochemical techniques of thin layer chromatography (TLC), after extracting the oil from seeds and their R_f value was calculated by using the following formula:

$$Rf = \frac{\text{distance traveled by sample}}{\text{distance traveled by solvent}}$$

Extraction Procedure and TLC analysis

Extraction of volatile compounds was performed by diethyl ether. In 200 mg of *Ajwain* seeds, 1.0 ml of diethyl was added, vortex briefly and incubated in Eppendrof tubes at 37 ^{0}C overnight. 50 µl of sample were loaded onto TLC plates (20 x 20 cm Silica Gel 60) in a small amount to make the spots compact. The plates were run in a chamber containing 200 ml of benzene and di-isopropyl ether in 1:1 ratio as mobile phase. Before running the TLC plates, the chamber was saturated for half an hour. After running, the plates were dried and visualized in UV light of 365 nm by using Minor Light Lamp UVGL 58 (Upland, CA91786, USA). The bond showing fluorescence was marked on TLC plates and their R_f values were calculated by dividing the distance of band with the distance of solvent front (Touchstone and Dobinns, 1983).

Statistical analysis

Statistical analysis was done to compare the effect of date of sowing with different row spacing using appropriate statistical techniques (Steel et al., 1997).

RESULTS

Number of seeds umbel^{-1}

Means of the data showed that number of seeds umbel ^{1}were significantly ($P \leq 0.05$) affected when *Ajwain* was planted at different dates (Table1). Delay in sowing from March to October increased the number of seed umbel^{-1}. The maximum number of seeds umbel^{-1} (280.83) was recorded in plot where *C. copticum* was planted on October 01, which was statistically at par with the sowing on October 27, Nov. 16 and Nov. 30. The values were 264.33, 257.33 and 262.67, respectively. The minimum (137.22) was found in sowing on March 03. Row spacing also affected number

Table 1: Number of seeds umbel [1] as influencedby sowing dates and row spacing

Planting dates	Row spacing (cm)			Means
	30	20	10	
Nov 11, 2004	174.63 bc	243.20 b-e	207.60 e-h	241.81 B
Nov 30, 2004	341.00 a	233.67 c-f	213.33 d-h	262.67 AB
Dec 12, 2004	190.00 e-j	172.33 g-k	157.00 h-k	173.11 C
Mar 03, 2005	150.00 i-k	141.67 jk	120.00 k	137.22 D
Oct 01, 2005	300.53 ab	268.23 b-d	273.73 bc	280.83 A
Oct 27, 2005	342.67 a	266.00 b-d	184.33 f-j	264.33 AB
Nov 16, 2005	340.00 a	228.33 c-g	203.67 e-i	257.33 AB
Means	276.98 A	221.92 B	194.29 C	

LSD (P<0.05) Sowing dates = 33.17, Row spacing = 21.71, Sowing datesx Row spacing= 57.45

Table 2: Weight of seeds umbel^{-1}(g) as influenced by sowing dates and row spacing

Planting dates	Row spacing (cm)			Means
	30	20	10	
Nov 11, 2004	0.28*^{ns}	0.19	0.16	0.21 B*
Nov 30, 2004	0.28	0.19	0.17	0.22 AB
Dec 12, 2004	0.20	0.15	0.13	0.16 C
Mar 03, 2005	0.20	0.16	0.13	0.17 C
Oct 01, 2005	0.21	0.17	0.16	0.17 C
Oct 27, 2005	0.30	0.24	0.19	0.24 A
Nov 16, 2005	0.28	0.20	0.16	0.22 AB
Means	0.25 A	0.19 B	0.16 C	

LSD (P<0.05) Sowing dates =0.03, Row spacing = 0.02*ns= Non significant

Table 3: 1000 seeds weight (g) as influenced by sowing dates and row spacing

Planting dates	Row spacing (cm)			Means
	30	20	10	
Nov 11, 2004	0.80*^{ns}	0.78	0.72	0.75B
Nov 30, 2004	1.00	0.82	0.81	0.87 A
Dec 12, 2004	0.64	0.79	0.77	0.76 BC
Mar 03, 2005	0.75	0.65	0.59	0.65 C
Oct 01, 2005	0.79	0.75	0.74	0.76 B
Oct 27, 2005	0.90	0.77	0.76	0.88 A
Nov 16, 2005	0.84	0.83	0.79	0.82 AB
Means	0.81 A	0.76 AB	0.74 B	

LSD (P<0.05) Sowing dates =0.09, Row spacing =0.059*ns= Non significant

Table: 4: Seed yield (kg ha^{-1}) as influenced by sowing dates and row spacing

Sowing dates	Row spacing (cm)			Means
	30	20	10	
Nov 11, 2004	740.00*ns	606.70	520.00	622.20 B
Nov 30, 2004	910.00	653.30	580.00	714.40 A
Dec 12, 2004	666.70	653.30	583.30	633.30 AB
Mar 03, 2005	296.70	283.30	283.30	287.80 C
Oct 01, 2005	650.00	560.00	586.70	598.90 B
Oct 27, 2005	973.30	616.70	553.30	714.40 A
Nov 16, 2005	780.00	613.30	563.30	652.20 AB
Means	716.70 A	569.50 B	523.80 B	

LSD (P<0.05) Sowing dates = 8.86, Row spacing =5.80 *ns= Non significant

of seeds umbel^{-1} significantly (Table 1). The highest number of seeds umbel^{-1} (276.98) was found in crop sown at row spacing of 30cm while the lower (194.24) were calculated in closest row spacing of 10 cm. When interaction of sowing date and row spacing was studied, the maximum (342.67) and the minimum number of seeds umbel^{-} were recorded for the crop sown on October 27 at 30cmapartrows and on March 03 with10cm.

Weight of seeds umbel^{-1}

The effect of sowing date and row spacing on weight of seeds umbel [1] was found significant ($P \leq 0.05$), while their interaction was found insignificant (Table 2). Weight of seeds umbel^{-1} decreased from 0.24 to 0.16 g when sowing of *Ajwain* was done on October 27 and March 03, 2005, respectively. Row spacing also affected weight of seeds umbel [1]asshown in Table 2. The data showed that in a dense population (10 cm), the lowest weight of seeds umbel^{-1} (0.160 g) was recorded, whereas, in the case of sparsely sown rows (30 cm), seeds gained the highest weight umbel^{-1} (0.25 g).

1000 Seeds weight (g)

The data regarding 1000 seeds weight is presented in Table 3. It was observed that 1000seeds weight varied due to sowing date and row spacing with non-significant interaction of the two factors. Delayed sowing from October to March showed a decreased in 1000 seed weight from 0.87 to 0.65 g (Table 3). The highest 1000 seed weight (0.88 g) was recorded in a crop planted on Oct 27, which was at par with the crop sowed on Nov 16 (0.82 g) and Nov 30 (0.87 g).According to these results, the lowest 1000 seed weight (0.65 g) was measured in plants sown on Mar 03. The data shown in Table 3 also revealed that1000 seeds weight increased with increasing the planting density, as plants' rows spaced from 10 to 30 cm, 1000 seeds weight raised from 0.76 to 0.81 g.

Seed yield (kg ha^{-1})

Significant differences among the sowing dates were recorded for the seed yield of *Ajwain* (Table 4). Data showed that statistically the highest seed yield (714.40 kg ha^{-1}) was found in crop sown on October 27at par with that planted on Nov 16 (652 kg ha^{-1}) and Nov 30 (714 kg ha^{-1}), and the lowest (287.80 kg ha^{-1}) was recorded in delayed sowing crop, *i.e.*, on March 03. Row spacing also affected seed yield of *Ajwain* significantly (p <0.05) as shown in Table 4.The highest seed yield (716.70 kg ha^{-1}) was calculated in 30 cm row spacing that was significantly different from other two row spacings (10 and 20 cm). The lowest seed yield (523.80 kg ha^{-1}) was found in the case of crop planted at 10 cm row spacing that was at par with 20 cm spaced crop (569.50 kg ha^{-1}).

Volatile oil components

The change in the quality of volatile compounds due to prevailing environment during the life cycle was assessed through thin layer chromatography (TLC). The presence of different bands showed the compound of

Table 5: R_f values obtained from oil of *Ajwain* sown at different sowing dates and row spacing

Sample	Solvent front	R_f Value							
		band 1	band 2	band 3	band 4	band 5	band 6	band 7	band 8
*D_1 R_1	12.5	0.07		0.65	0.78	0.89			0.97
D_1 R_2	12.5	0.05		0.63	0.76	0.86			0.98
D_1 R_3	12.6	0.05		0.63	0.77	0.85			0.95
D_2 R_1	12.6	0.06		0.62	0.73	0.83			0.96
D_2 R_2	12.7	0.07			0.74	0.84			0.96
D_2 R_3	12.9								0.97
D_3 R_1	12.8	0.09							
D_3 R_2	12.8	0.07							
D_3 R_3	12.9	0.07		0.62	0.76	0.78		0.94	
D_4 R_1	12.9	0.07	0.54	0.66	0.74	0.79		0.93	
D_4 R_2	12.1	0.07	0.21	0.62	0.72	0.80		0.93	
D_4 R_3	12.0	0.07	0.50	0.62	0.73	0.80		0.93	
D_5 R_1	12.0	0.06	0.50			0.80		0.93	
D_5 R_2	12.8	0.07	0.50	0.63	0.74			0.94	
D_5 R_3	12.7	0.07	0.50	0.63	0.74				0.96
D_6 R_1	12.7	0.07	0.50	0.63	0.74	0.85	0.93		
D_6 R_2	12.6	0.07	0.50	0.63	0.74	0.88			0.96
D_6 R_3	12.5	0.07	0.50	0.63	0.74	0.88	0.93		0.97
D_7 R_1	12.3	0.07	0.50	0.66	0.81				0.98
D_7 R_2	13.0	0.05	0.43	0.57			0.90	0.92	
D_7 R_3	13.2	0.05	0.43	0.56	0.67		0.90		

*D_1= Nov 11, 2004; D_2=Nov 30, 2004; D_3=Dec 12, 2004; D_4=Mar 03, 2005; D_5=Oct 01, 2005; D_6=Oct 27, 2005; D_7=Nov 16, 2005; R_1= 10 cm; R_2= 20 cm; R_3= 30 cm

different polarity in the samples collected from various sowing dates and row spacing. Therefore, the qualitative differences existed in the chemical composition of essential oils (Table 5). The greatest number of bands (7) was obtained in October 27, at 30 cm row spacing that indicated the presence of the highest number of compounds of different polarity. While the least number of bands was noted at crop planted on December 12, 2005 at all three row spacings (10, 20 and 30 cm) indicating that chemical composition is effected with this sowing date and planting density.

DISCUSSION

Results obtained in the present study indicated that sowing date and row spacing significantly affected the yield and yield related traits of *Ajwain*. Number of seeds umbel^{-1}, 1000 seed weight, weight of seeds umbel ^{1}, and seed yield, were decreased with delay in sowing from October 27 to March 03. This might be dueto the fact that plants had sufficient time to grow vegetatively that consequently increased the seed yield, when planted on October 27. Delaying planting form October to March shortens the growth period to assimilate the maximum photosynthates in sinks (umbel and seed). *Ajwain* seeds are used as a spice, flavoring agents in many foods and preservatives in many medicinal formulations. Therefore, improved production technology is important for the valuable returns to the farmer. In the present study, number of seeds, weight of seeds umbel^{-1} and 1000 seeds weight are resulted in decreased in number and weight of seed formation due to late sowing (October to March), which is the main reproductive organ that contributes to seed yield (Ayub et al., 2008). According to the results, increasing the row spacing (30 cm) had positive correlation with yield and all yield components of *Ajwain*, investigated in the present study.

The higher seed yield, under widely spaced (30 cm) planted crop, is associated with the increase in number and weight of seed umbel^{-1} and 1000 seeds weight. Overall, healthy umbels were observed at 30 cm row spacing. While row spacing of 10 cm, the umbels were not well developed and seeds were smaller in size, weight and number due to congested space. Under higher plant density, plants have severe competition for space, light and nutrients and could not grow potentially (Moosavi, 2012). However, the results are in contradiction with some researchers who reported the increase in overall seed yield with increasing the row spacing because of less assimilate production by low number of plants inhabiting per unit area (Singh et al., 2005; Deroger et al., 2014).

Seeds of *Ajwain* contained number of volatile oilsthatare known for their antibacterial, antifungal, antihistaminic and analgesic effects (Rahman et al., 2015; Balaji et al., 2012). The composition of volatiles oil affectedly greatly by sowing date and row spacing. The highest bands appeared in crop sown in October 27, with 30 cm apart rows; whereas, in delayed sowing (December-March) and closely spaced crop (10 cm row spacing), minimum number of band appeared. The

variation in number of bands represents the presence of various chemical components in seeds. The rich essential oil composition is related to the higher seed yield, maximum number and weight of seed umbel^{-1} obtained at optimum sowing time and row spacing in this study. It might be due to the fact of that altering the prevailing environmental conditions at specific time along with proper planting density may alter the chemical composition and seriously reducing fruit and oil yield (Moosavi et al., 2015; Soleimani et al., 2011).

Conclusion

In conclusion, the results of the present study suggest that higher seed yield of *Ajwain* can be achieved if the seeds were planted after mid of October with 30 cm row spacing. In such a case, crop avail longer growth period duration and thus the growth and development correspond with favorable environmental conditions and produce more photosynthetic assimilates. While delay in planting and narrow rows decrease the yield and yield attributing traits that consequently affect the yield and chemical composition of *Ajwain*.

Author's contributions

All authors have equally contributed in the manuscript.

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