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Effect of Planting Date and Spacing on Growth and Yield of Fennel (*Foeniculum vulgare* Mill.) Under Irrigated Conditions

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Abstract: Fennel (*Foeniculum vulgare* Mill.) plant is a medicinal aromatic herb and belongs to Apiaceae family. It has a rich nutritional value and has many medicinal usages. Very limited information is available in the literature about fennel cultivation and production practices. Therefore, this study was carried out to evaluate the effect of planting date and plant spacing and their interactive effects on yield, yield components and growth of Fennel under irrigation. Three planting dates (Oct. 1st, Nov. 1st and Dec. 1st) and four plant spacings (10, 20, 30 and 40 cm with constant row width, 60 cm) were used. Fruit yield was significantly ($p<0.05$) influenced by plant spacing and planting date and their interaction. Early planting significantly increased the fruit yield combined with higher number of branches per plant, number of umbrella per plant, number of fruit per plant and plant height. The percentage of increases in Oct. 1st were 34.4 and 32.2% in fruit and biological yield respectively compared with Dec. 1st. Harvest index and thousand fruit weight was not significantly affected by planting date. Increase plant spacing to 30 cm led to more than 15% increase in fruit and biological yield. The early planting date with 30 cm plant spacing resulted in higher fruit (4136 kg ha^{-1}) and biological yield (10114 kg ha^{-1}).

Key words: Fennel, plant spacing, sowing date, fruit yield, yield components

INTRODUCTION

Fennel (*Foeniculum vulgare* Mill.) belongs to Apiaceae family, one of the most common medicinal and aromatic herbs, known since antiquity and grown in Mediterranean basin. It is involved in different pharmaceutical purposes and food industry. Fennel is a cure for pediatric colic and respiratory disorders due to its antispasmodic effects (Liu *et al*., 2010; Sajomsang *et al*., 2009). Also it is used in cooking for liqueurs (Bhati *et al*., 1988). Its fruits contain 1-3% volatile oils. Fennel volatile oils are important because of their diuretic, anti-inflammatory, analgesic and antioxidant activities (Choi and Hwang, 2004).

To increase the productivity of a crop, two strategies could be used: following the optimum agricultural practicices and/or selecting high yielding varieties. With increasing demand on herbal, aromatic and medicinal plants with limited cultivated areas, optimum agricultural practices are essential to increase the productivity of fennel per unit. The most essential agricultural practices include fertilizer and pesticide applications and optimum planting date and planting densities.

Using high yielding crop varieties tolerating pest and abiotic stresses combined with the optimum agricultural practices will be the best viable avenue for increasing crops productivity and improving the benefit: cost ratio of poor small scaled farmers (Tbaileh *et al*., 2007; Talafih *et al*., 2007).

Very limited information is available about fennel cultivation and production practices. Damato *et al*. (1994) reported significant effect of sowing date and plant density on seed yield of fennel. Grain yield loss of agricultural crops such as fennel (*Foeniculum vulgare* Mill.) was reported due to unsuitable sowing date. Damato *et al*. (1994) reported that early sowing produced higher seed yield, while shortening of the growing cycle decreased the amount of radiation intercepted during the growing season and thus total dry weight of plant (Andrade, 1995). On the other hand, the number of plants per unit area is the most important among yield components (Kafi, 2003). Using optimum plant density, plants are completely adapted in environmental conditions such as water, air, light, soil and inter- or intra specific competition will be at the minimum level (Sadeghi *et al*., 2009; Verzalova *et al*., 1990) indicating that

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increasing plant density was found to produce taller plants, but thinner stems, lesser branches number in fennel.

The information regarding interactive effect of planting date and plant spacing on growth and yield of fennel is lacking in Jordan. The present study was, therefore, carried out to evaluate the effect of different planting date and plant spacing on growth and yield of fennel under irrigated conditions of south Jordan valley area, Jordan.

MATERIALS AND METHODS

Site description: The field experiment was carried out at private farm in South Jordan valley area, south Karak district, Jordan during the 2009/2010 and 2010/2011 seasons. The soil of the experimental site was sandy loam, having following physical composition: 50.16% sand, 31.12% silt, 17.08% clay and 1.74 organic matters. The soil chemical analysis showed that pH value of 7.22 and EC value of 104 dS m^{-1}.

Treatments and design: The experiment consisted from three planting dates (October 1st, Nov 1st and Dec 1st) and four plant spacing (10, 20, 30 and 40 cm) in the two seasons. The experimental plot consisted of four rows, 2.4 m in length with 0.6 m apart. The experimental design was randomized complete block with factorial arrangement of the treatments (planting date and plant spacing.) with three replications. Each plot occupied an area of 5.76 m^2. Entire phosphorus dose (40 kg ha^{-1}) was applied at sowing time, while nitrogen dose of 75 kg ha^{-1} was applied in two equal doses (one and two months after sowing time) using Fertigator connected to a drip irrigation system.

Data collection and statistical analysis: All other agronomic practices were kept normal and uniform for all the treatments. Ten plants were randomly selected from each plot to record the following plant basis parameters: number of branches per plant, number of umbrella per plant and plant height. For number of fruits per umbrella, ten umbrellas were selected randomly from each plot. Thousand fruit weight was sampled from each plot to estimate 1000- fruit weight. Data were analyzed by two ways analysis of variance using the SAS statistical package (SAS, 2003) and the differences between the means were compared using Fisher's least significant difference (LSD) at $p \leq 0.05$ (Steel and Torrie, 1980).

RESULTS AND DISCUSSION

There was a significant ($p < 0.01$) interaction of plant date by plant spacing for both yield, yield contributing traits and height. Planting date within seasons was significant ($p<0.01$) for studied parameters. Yield and yield contributing traits at 30-40 com plant spacing was greater than at 10 and 20 cm spacing. Height significantly ($p < 0.01$) increased with narrower plant spacing. Yield and yield components were significantly affected ($p<0.01$) by planting date. Early planting (October 1st) gave significantly higher grain yield and greater growth than late plantings (December 1st).

Analysis of variance:. The results obtained in the first season (Table 1) were consistent with those obtained in the second season (Table 2). Late planting dates caused significant ($p<0.01$) reductions in yield and yield contributing traits ($p<0.05$). Late planting dates had a more pronounced effect on yield and yield contributing traits. The earliest planting date reduced yield and yield contributing traits to a lesser extent than moderate (November 1st) and late planting date (December 1st) (Table 1). The yield and yield contributing traits were significantly ($p<0.01$) reduced by decreasing plant spacing. Contrastingly, plant height was significantly increased by decreasing plant spacing. The effects of planting date×plant spacing interaction on the grain yield, yield contributing and plant height were significant ($p<0.01$).

Effect of planting date: Early planting date on October 1st and Nov. 1st significantly ($p<0.01$) increased the fruit yield and biological yield as compared with

Table 1: Analysis of variance results (Mean of Square) for different traits of fennel (*Foeniculum vulgare* Mill.) under varying planting dates and plant spacing during the growing 1st season of 2009/2010

Parameters	Replicate	Sowing date	Plant density	Plant density ×sowing date	Error
Fruit yield	439.6	7720916	1581804.94**	472609.8	5593.24
Aboveground biomass	1408.63	40575752.07**	8943542.73**	2557580.28**	58523.21
No. of branches/plant	0.67	3.5	35.63**	0.94	6
No. of umbrella per plant	0.003	41.87**	895.23**	2.87**	0.16
No. of fruit per umbrella	5.14	34990.52**	294497.43**	540.25**	117.29
1000- Fruit weight	0.0002	1.49	0.046	0.002	0.004
Harvest index	0.149	4.68	0.29	0.65	1.73
Plant height	16.06	11726.72**	396.22	198.61**	411.94

*,**Significant at 5 and 1% probability levels, respectively

Table 2: Analysis of variance results (Mean of Square) for different traits of fennel (*Foeniculum vulgare* Mill.) under varying planting dates and plant spacing. during the growing 2nd season of 2010/2011

Parameters	Replicate	Sowing date	Plant density	Plant density * sowing date	Error
Fruit yield	732.57	5623023.72**	1133659.07**	119182.69**	3504.22
Above ground biomass	4789.88	30512624.17**	7225496.09**	369021.63**	21585.78
No. of branches per plant	1.5	2.66*	40.97**	0.44	6
No. of umbrella per plant	0.019	23.41**	769.74**	1.61**	0.48
No. of fruit per umbrella	14.74	37937.16**	290069.88**	358.99*	174.99
1000-fruit weight	0.00007	1.66	0.076	0.007	0.0015
Harvest index	0.057	4.4	0.42	2.91	0.49
Plant height	9.72	11758.22**	418.57**	71.11	212.94

*,**significant at 5 and 1% probability levels, respectively

Table 3: Effect of planting dates plant spacing on fruit yield, biological yield (kg ha^{-1}) and harvest index of fennel (*Foeniculum vulgare* Mill.) during the two seasons of 2009/2010 and 2010/2011

	First season			Second season		
Treatments	Fruit yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index (%)	Fruit yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index (%)
Planting dates* (A)						
PD1	4083.71^{a}	9915.68^{a}	41.08^{a}	3798.31^{a}	9276.84^{a}	40.82^{a}
PD2	3941.18^{b}	9544.74^{b}	41.06^{a}	3709.85^{b}	9009.48^{b}	40.89^{a}
PD3	3037.83^{c}	7501.13^{c}	41.08^{a}	2919.21^{c}	7203.97^{c}	40.91^{a}
Plant spacing (B)**						
PS1	3394.33^{d}	8283.68^{d}	40.98^{a}	3257.42^{d}	7943.78^{d}	40.93^{a}
PS2	3643.49^{c}	8882.34^{c}	40.96^{a}	3404.69^{c}	8301.01^{c}	41.02^{a}
PS3	3980.59^{a}	9674.69^{a}	41.00a	3745.58^{a}	9169.81^{a}	40.98^{a}
PS4	3731.90^{b}	9108.36^{b}	41.03^{a}	3495.58^{b}	8572.44^{b}	40.97^{a}
Interaction: A×B	**	**	ns	**	**	ns

*Planting dates: PD1 = Oct. 1st, PD 2 = Nov. 1st and PD 3 = Dec. 1st. **Plant Spacing: PS1 = 10 cm, PS2 = 20 cm, PS3 = 30 cm, PS4 = 40 cm. Values with different letters are significantly different at p≤0.01

Table 4: Effects of planting dates and plant spacing on yield components of fennel (*Foeniculum vulgare* Mill.) during the growing 1st season of 2009/2010

Treatments	No. of branches	No. of umbrella per plant	No. of fruit per umbrella	1000 Fruit weight (g)	Plant height per plant (cm)
Planting dates* (A)					
PD1	4.58^{a}	19.30^{a}	394.11^{a}	7.96^{a}	162.25^{a}
PD2	4.33^{b}	18.40^{b}	369.88^{b}	7.94^{a}	155.17^{b}
PD3	3.83^{b}	15.92^{c}	319.28^{c}	7.94^{a}	120.92^{c}
Plant spacing (B)**					
PS1	2.91^{c}	11.61^{d}	221.69^{d}	7.86^{a}b	151.11^{a}
PS2	3.56^{b}	16.20^{c}	341.82^{c}	7.86^{a}b	147.11^{b}
PS3	5.28^{a}	21.14^{b}	427.62^{b}	7.89^{a}	143.22^{c}
PS4	5.49^{a}	24.81^{a}	453.24^{a}	7.90^{a}	143.00^{d}
Interaction: A×B	*	**	**	ns	*

*Planting dates: PD1 = Oct. 1st, PD 2 = Nov. 1st and PD 3 = Dec. 1st. **Plant spacing: PS1 = 10 cm , PS2 = 20 cm, PS3 = 30 cm, PS4 = 40 cm. Values with different letters are significantly different at p≤0.01

Dec.1st (Table 3). The percentage of increases on October 1st and Nov 1st, respectively were 34 and 30% in first season and 30 and 27% in second season in fruit yield and 32 and 27% in first season and 29 and 25% in second season in biological yield compared with Dec. 1st (Table 3). Early planting (Oct. 1st, Nov. 1st) could extend growth period and can allow plant to accumulate more heat units than late plantations Dec. 1st. In consequence early planting allows plant to better utilize soil nutrients and soil moisture and consequently accumulate more carbohydrate in their tissue which reflected in the total plant biomass and economic yield (Yousaf *et al*., 2002).

Harvest index was not significantly affected by planting date (Table 3) That could be explained changes in genital and vegetative parts had the same rate, as with changing the planting date, the decrease or increase in aboveground biomass of plant was proportional to the decrease or increase of fruit yield (Ball *et al*., 2000).

The highest percentage of increases in number of branches were obtained from October 1st and Nov. 1st plantations which was 20 and 13% respectively in first season and 18 and 10% respectively in second season compared with late planting date Dec 1st (Table 4, 5). Similarly, Damato *et al*. (1994) found that late planting decreased the number of branches per plant and consequently led to significant losses in yield. Early planting date had a significant effect on the number of umbrella per plant and number of fruit per umbrella (Table 4, 5). The highest increases in the number of umbrella per plant and number of fruit per umbrella was achieved in the first planting date (Oct. 1st, Nov. 1st) which was 21 and 13%, respectively in first season and 26

Table 5: Effects of planting dates and plant spacing on yield components of fennel (*Foeniculum vulgare* Mill.) during the growing 2nd season of 2010/2011

Treatments	No. of branches per plant	No. of umbrella per plant	No. of fruit per umbrella	1000 Fruit weight (g)	Plant height
Planting dates* (A)					
PD1	4.42^{a}	17.82^{a}	402.09^{a}	7.85a	145.58^{a}
PD2	4.14^{b}	16.59^{b}	383.41^{b}	7.86a	144.92^{b}
PD3	3.75^{b}	14.16^{c}	325.82^{c}	7.85a	106.92^{c}
Plant spacing (B)**					
PS1	2.67^{c}	10.76^{d}	234.60^{d}	7.84^{a}	136.44^{a}
PS2	3.44^{b}	15.10^{c}	347.60^{c}	7.85^{a}b	135.22^{b}
PS3	5.00^{a}	19.75^{b}	435.50^{b}	7.84^{a}b	129.27^{c}
PS4	5.22^{a}	22.96^{a}	464.62^{a}	7.86^{a}	128.56^{d}
Interaction: A×B	*	**	*	ns	*

*Planting dates: PD1= Oct. 1st, PD 2 = Nov. 1st and PD 3 = Dec. 1st. ** Plant Spacing: PS1 = 10 cm, PS2 = 20 cm, PS3 = 30 cm, PS4 = 40 cm. Values with different letters are significantly different at $p \leq 0.01$

and 17%, respectively in second season in number of umbrella per plant and 23 and 16%, respectively in first season and 23 and 18%, respectively in second season in number of fruit per umbrella compared with Dec 1st. The results are quite in line with those of Mohan *et al.* (2001) and Ayub *et al.* (2008) who reported that shorter growth period the plants by late sowing was unable to make full use of the available resources which slowed down the vegetative growth and resulted in lower accumulations of dry matter, smaller plant sizes, reduced number of umbrella per plant and number of fruit per umbrella and eventually the lower yield was obtained. Thousand fruit weight was not significantly affected by planting date (Table 4, 5).

It seems that environmental conditions and cultural factors did not influence fruit weight because the plant provides the least required nutrients for each seed by reducing the number of seed (Lafond, 1994). The effect of planting date on plant height was significant, results revealed that plant height increased with early date of planting. The tallest plants were recorded on Oct. 1st, heights were 162.25 and 145.58 cm in first and second seasons respectively compared with 120.92 and 106.92 cm on Dec. 1st in first and second seasons, respectively (Table 4, 5). The increase in plant height with early planting could be attributed to longer period of vegetative growth and higher temperature at early growth stages which might have a positive influence on the vegetative growth of crop plants (Ayub *et al.*, 2008).

Effect of plant spacing: The data confirmed that changing the plant spacing had shining influences on both fruit and biological yield which were increased by increasing space between plants (Table 4, 5). The highest fruit yield and biological yield was obtained at 30 cm with 3980.59 and 3745.58 kg ha^{-1} fruit yield in first and second seasons, respectively and 9674.69 and 9169.81 kg ha^{-1} biological yield in first and second seasons, respectively. Conversely, the lowest fruit and biological yield was obtained at 10 cm spacing with 3394.33 and 3257.42 kg ha^{-1} fruit yield in first and second seasons, respectively and 8283.69 and 7943.78 kg ha^{-1} biological yield in first and second seasons, respectively. The increase of fruit and biological yield by plant spacing was more than 17 and 15%, respectively. The reductions in fruit and biological yield could be due to the reduction in the number of plants per unit area coupled with low plant-to-plant competition (Badran *et al.*, 2007; Damato *et al.*, 1994).

Harvest index in the two seasons was not significantly affected by plant spacing (Table 3). The data pertaining to number of ranches per plant are presented in Table 4 and 5 which exhibited a significant increase ($p<0.01$) an increase by increasing plant spacing. The maximum number of branches per plant recorded by 40 cm between plants increased by 89 and 95% in the first and second seasons respectively, compared with 10 cm plant spacing. These results were in harmony with those of other authors (Badran *et al.*, 2002, 2007). Increasing plant spacing could lead to an increase the availability of nutrients, light and water for lower number of plant per unit area and consequently vegetative growth and number of branches per plant are increased.

Number of umbrella per plant and number of fruit per umbrella were significantly ($p<0.01$) increased by the gradual increase of plant spacing. Number of umbrella/plant and number of fruit per umbrella were increased due to plant spacing of 40 cm (Table 4, 5), this increase reached 114% for number of umbrella per plant in the first and second seasons, respectively and 104 and 98% for number of fruits per umbrella in the first and second seasons respectively in comparison with 10 cm plant spacing. This might be due to low competition for growth factors at high plant spacing than at low spacing. These results are in agreement with those of Damato *et al.* (1994) and Kafi (2003). The data presented in Table 1 showed that plant height was significantly ($p<0.01$) increased by decreasing plant spacing, Maximum plant heights were recorded at 10 cm. Plant height recorded at 10 cm spacing resulted in plant heights of 151.11 and 136.44 cm in first and second seasons, respectively, while heights obtained at 40 cm

Table 6: Interactive effect of planting dates and plant spacing on fruit yield, biological yield and harvest index of fennel (*Foeniculum vulgare* Mill.) during the two seasons of 2009/2010 and 2010/2011

Treatments		First season			Second season		
Planting dates *	Plant spacing**	Fruit yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index (%)	Fruit yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index (%)
PD1	PS1	3938.80^{bcd}	9589.80^{bcd}	41.07^{a}	3677.77^{bc}	8896.50^{bcd}	41.06^{a}
	PS2	4074.97^{b}	9861.70^{b}	41.03^{ab}	3752.63^{b}	9082.37^{b}	41.04^{a}
	PS3	4273.90^{a}	10356.73^{a}	41.00^{b}	4003.70^{a}	9871.03^{a}	41.04^{a}
	PS4	4047.20^{bc}	9854.47^{bcd}	41.03^{ab}	3759.13^{bc}	9257.47^{bc}	41.06^{a}
PD2	PS1	3761.03^{cd}	9077.50^{cd}	41.09^{a}	3510.97^{cd}	7511.73^{cd}	41.07^{a}
	PS2	3847.20^{ef}	9316.97^{ef}	41.10^{a}	3611.10^{ef}	8761.67^{ef}	41.03^{a}
	PS3	4221.83^{ab}	10224.90^{ab}	41.09^{a}	3992.43^{ab}	9698.80^{ab}	41.01^{ab}
	PS4	3934.67^{bcd}	9559.60^{bcd}	41.05^{ab}	3724.90^{bcd}	9065.70^{bcd}	41.00^{ab}
PD3	PS1	2483.17^{g}	6182.73^{g}	41.03^{ab}	2583.23^{g}	6423.10^{g}	41.04^{a}
	PS2	3003.30^{fg}	7468.37^{fg}	41.00^{b}	2850.30^{fg}	7059.00^{fg}	40.98^{b}
	PS3	3446.03^{de}	8442.43^{de}	41.01^{b}	3240.60^{de}	7939.60^{de}	40.96^{b}
	PS4	3213.83^{ef}	7922.00^{ef}	40.99^{b}	3002.70^{ef}	7394.17^{ef}	40.97^{b}

*Planting dates: PD1 = Oct. 1st, PD 2 = Nov. 1st and PD 3 = Dec. 1st, **Plant spacing: PS1 = 10 cm, PS2 = 20 cm, PS3 = 30 cm, PS4 = 40 cm. Values with different letters are significantly different at $p \leq 0.01$

Table 7: Interactive effect of planting dates and plant spacing on yield components of fennel (*Foeniculum vulgare* Mill.) during the growing 1st season of 2009/2010

Treatments						
Planting dates*	Plant spacing**	No. of branches per plant	No. of umbrella per plant	No. of fruit per umbrella	1000 fruit weight (g)	Plant height (cm)
Sd1	PS1	3.36^{ef}	12.23^{ef}	254.22^{fg}	7.96^{ab}	170.67^{a}
	PS2	3.67^{de}	16.76^{cd}	382.47^{cd}	7.97^{ab}	161.70^{b}
	PS3	5.32^{bc}	21.94^{b}	457.91^{ab}	7.98^{a}	157.63^{de}
	PS4	6.00^{a}	26.26^{a}	481.84^{a}	8.01^{a}	159.00^{cd}
Sd2	PS1	3.00^{fg}	12.54^{ef}	228.03^{fg}	8.00^{a}	160.00^{bc}
	PS2	3.68^{de}	16.74^{cd}	348.08^{de}	7.97^{ab}	159.52^{cd}
	PS3	5.32^{b}	21.91^{b}	435.65^{abc}	7.99^{a}	151.69^{ef}
	PS4	5.34^{b}	25.22^{a}	467.79^{ab}	7.98^{a}	149.34^{ef}
Sd3	PS1	2.65^{g}	10.07^{f}	182.82^{g}	7.96^{ab}	122.64^{fg}
	PS2	3.31^{ef}	15.09^{de}	294.92^{ef}	7.96^{ab}	120.00^{fg}
	PS3	4.65^{c}	19.56^{bc}	389.29^{cd}	7.96^{ab}	121.66^{fg}
	PS4	4.67^{c}	22.95^{ab}	410.09^{bc}	7.98^{a}	121.31^{fg}

*Planting dates: PD1 = Oct. 1st, PD 2 = Nov. 1st and PD 3 = Dec. 1st, **Plant Spacing: PS1 = 10 cm , PS2 = 20 cm, PS3 = 30 cm, PS4 = 40 c. Values with different letters are significantly different at $p \leq 0.01$

plant spacing were 143.00 and 128.56 cm in first and second seasons, respectively. The increase in plant height using decreased plant spacing was more than 8%. These results agree with those of Tbaileh *et al.* (2007). Such an increase in plant height with decreased plant spacing may be explained by increased activity of stem growth hormone due to light deficiency (Brummell and Hall, 1980) .

Interactive effect: The interaction between planting date and plant spacing on fruit and biological yield in both seasons are presented in Table 6. The highest values of fruit yield and biological yield were obtained with early planting (Oct. 1st) combined with 30 cm plant spacing in both seasons; fruit yield was 4273.90 and 4003.70 kg ha^{-1} and biological yield was 10356.73 and 9871.03 kg ha^{-1} in first and second seasons, respectively. Conversely, the lowest fruit yield (2483.17 and 2583.23 kg ha^{-1}) and the lowest biological yield (6182.73 and 6423.10 kg ha^{-1}) in first and second seasons, respectively were obtained with late planting (Dec. 1st) combined with 10 cm plant spacing. The increase in fruit yield and biological yield as affected by early planting date and wide plant spacing was more than 72 and 54% in fruit yield in first and second seasons respectively and 67 and 53% in biological yield in first and second seasons, respectively as compared with late planting combined with narrow plant spacing.

Planting date and plant spacing were significantly ($p<0.01$) interacted on number of branches per plant, number of umbrella per plant and number of fruit per umbrella obtained with early planting (Oct. 1st) and plant spacing (40 cm) in the two seasons (Table 7, 8). The increase in two seasons respectively was 124 and 147 % in number of branches per plant, 160 and 137% in number of umbrella per plant and 163 and 158% in number of fruit per umbrella compared with late planting (Dec. 1st) and narrow plant spacing (10 cm). Early planting combined with wide plant spacing were reported earlier studies (Damato *et al*., 1994; Heidari *et al*., 2009).

The interaction between planting date and plant spacing revealed that maximum plant height of 170.67 and 151.67 cm in first and second seasons respectively was attained by early planting date (Oct. 1st) and narrow plant spacing (10 cm), while minimum plant height of 119.67 and

Table 8: Interactive effect of planting dates and plant spacing on yield components of fennel (*Foeniculum vulgare* Mill.) during the growing 2nd season of 2010/2011

Treatments						
Planting dates*	Plant spacing**	No. of branches per plant	No. of umbrella per plant	No. of fruit per umbrella	1000 fruit weight (g)	Plant height (cm)
Sd1	PS1	3.00^{def}	11.21^{fg}	263.05^{gh}	7.88^{ab}	151.67^{a}
	PS2	3.70^{de}	15.73^{ef}	381.55^{de}	7.91^{a}	147.00^{ab}
	PS3	5.30^{b}	20.51^{bd}	463.91^{bcd}	7.90^{a}	141.00^{cd}
	PS4	5.65^{a}	23.83^{a}	499.88^{a}	7.88^{ab}	142.67^{cd}
Sd2	PS1	2.67^{ef}	11.03^{fg}	245.46^{gh}	7.90^{a}	150.00^{ab}
	PS2	3.29^{de}	15.45^{ef}	358.86^{ef}	7.87^{ab}	148.00^{bc}
	PS3	5.00^{bc}	20.36^{bd}	448.80^{bc}	7.91^{a}	140.00^{d}
	PS4	5.54^{ab}	23.54^{a}	480.55^{ab}	7.88^{ab}	141.67^{cd}
Sd3	PS1	2.36^{ef}	10.04^{g}	193.62^{h}	7.86^{ab}	111.67^{ef}
	PS2	3.32^{de}	14.12^{ef}	302.41^{fg}	7.87^{ab}	109.67^{ef}
	PS3	4.69^{cd}	18.38^{d}	393.81^{de}	7.85^{ab}	104.67^{f}
	PS4	4.71^{bcd}	21.50^{ab}	413.44^{cd}	7.89^{a}	104.67^{f}

*Planting dates: PD1 = Oct. 1st, PD 2 = Nov. 1st and PD 3 = Dec. 1st. **Plant spacing: PS1 = 10 cm, PS2 = 20 cm, PS3 = 30 cm, PS4 = 40 cm. Values with different letters are significantly different at $p \leq 0.01$

104.67cm in first and second seasons respectively was attained by late planting date (Dec. 1st) combined with 30 and 40 cm plant spacing (Table 7, 8). Similarly Damato *et al.* (1994) and Tbaileh *et al.* (2007) reported an increase in plant height with late plant with high planting intensity. However, Tbaileh *et al.* (2007) found no influence of the combined effect of plant date and planting density on harvest index and 1000-fruit weight.

CONCLUSION

In conclusion, fennel is sensitive crop to planting date and plant spacing. under the irrigated conditions of Jordan, early October planting is recommended for fennel, because it gave the highest fruit and biological yields, better plant growth and heavier seeds. 30-40 cm plant spacing was the optimum rate under the conditions of the study. The most important traits that contributed to fennel fruit and biological yield are number of branches, number of umbrellas and number of fruits per umbrella. These three characters should be considered by breeders in their attempt to develop high yielding fennel cultivars.

REFERENCES

Andrade, F.H., 1995. Analysis of growth and yield of maize, sunflower and soybeangrown at Balcarce, Argentina. Field Crop Res., 41: 1-12.

Ayub, M.A., A.Nadeem, M.Tanveer, M.T. Tahir, Y. Saqib and R. Nawaz, 2008. Effect of different sowing methods and times on the growth and yield of Fennel (*Foeniculum vulgare* Mill). Pak. J. Bot., 40: 259-264.

Badran, F.S., M.K. Aly, M.B. Abd- Elsamei and M.Z. Abd-Ellatif, 2002. Response of *Pimpinella anisum*, L. plants to planting density and P, Zn and Mn fertilization treatments. Proceedings of the Minia 1st Conference on Agriculture and Environment Science, March 25-28, 2002, Minia University, Egypt, pp: 1783-1696.

Badran, F.S., N.M. Abdall, M.K. Aly and S.M. Ibrahim, 2007. Response of fennel plants to seeding rate and partial replacement of mineral NPK by biofertilization treatments. Proceedings of the 8th Conference on African Crop Science Society, Volume 8, October 27-31, 2007, El-Minia, Egypt, pp: 417-422.

Ball, R.A., L.C. Purcell and E.D. Vories, 2000. Short-season soybean production and yield compensation in response to plant population and water regime. Crop Sci., 40: 1070-1078.

Bhati, D.S., M.S. Shaktawat, L.L. Somani and H.R. Agarwal, 1988. Response of fennel (*Foeniculum vulgare* Mill.) to nitrogen and phosphorus. Trans. Indian Soc. Desert Technol., 13: 79-83.

Brummell, D.A. and J.L. Hall, 1980. The role of the epidermis in auxin-induced and Fusicoccin-induced elongation of *Pisum sativum* stem segments. Planta, 150: 371-379.

Choi, E.M. and J.K. Hwang, 2004. Anti-inflammatory, analgesic and antioxidant activities of the fruit of *Foeniculum vulgare*. Fitoterapia, 75: 557-565.

Damato, G., V.V. Belletti, P. Bianco and A. Girardi, 1994. Sowing dates, plant density and crown cutting on yield and quality of florence fennel seed. Acta Hort., 362: 59-66.

Heidari, H., S. Zolleh, G. Bahraminejad, A. Maleki and H. Papzan, 2009. Response of cumin (*Cuminum cyminum* L.) to sowing date and plant density. Res. J. Agric. Biol. Sci., 5: 597-602.

Kafi, M., 2003. Cumin-Production and Processing. Mashhad Publication, Mashhad, Iran, Pages: 195.

Lafond, G.P., 1994. Effect of row spacing, seeding rate and nitrogen on yield of barely and wheat under zero-till management. Can. J. Plant Sci., 74: 703-711.

Liu, J., J.G Luo, H. Ye, Y. Sun, Z.X. Lu and X.X, Zeng, 2010. Medium optimization and structural characterization of exopolysaccharides from endophytic bacterium *Paenibacillus polymyxa* EJS-3. Carbohydr. Polym., 79: 206-213.

Mohan, V.P., V.K. Batra and K.K. Thakral, 2001. Response of sowing dates and seed rate on growth and yield of fennel. Haryana J. Hort. Sci., 30: 271-273.

SAS, 2003. SAS 9.1 for Windows. SAS Inst., Cary, NC., USA.

Sadeghi, S., A. Rahnavard and Z.Y. Ashrafi, 2009. The effect of plant density and sowing date on yield of Basil (*Ocimum basilicum* L.) in Iran. J. Agric. Technol., 5: 413-422.

Sajomsang, W., P. Gonil and S. Tantayanon, 2009. Antibacterial activity of quaternary ammonium chitosan containing mono or disaccharide moieties: Preparation and characterization. Int. J. Biol. Macromol., 44: 419-427.

Steel, R.G.D. and J.H. Torrie, 1980. Principles and Procedures of Statistics. Mcgraw-Hill, New York.

Talafih, K.A., N.I. Haddad, B.I. Hattar and K. Kharallah, 2007. Effect of some agricultural practices on the productivity of black cumin (*Nigella sativa* L.) grown under rainfed semi-arid conditions. Jordan J. Agric. Sci., 3: 385-397.

Tbaileh, A.M., N.I. Haddad, B.I. Hattar and K. Kharallah, 2007. Effect of some agricultural practices on cumin (*Cuminum Cyminum* L.) productivity under rain fed conditions of Jordan. Jordan J. Agric. Sci., 3: 103-116.

Verzalova, J., B. Kocourkova and J. Stavkova, 1990. The response of two cultivars of fennel (*Foeniculum vulgare* var. vulgare, Mill, Thell) to row spacing. Spornik Uztiz Zahradnictvi, 15: 101-106.

Yousaf, M., A. Ahmad, M. Jahangir and T. Naseeb, 2002. Effect of different sowing dates on the growth and yield of canola (Sarson) varieties. Asian J. Plant Sci., 1: 634-635.