J. Agric. Sci. Mansoura Univ., 32 (4): 2937 - 2955, 2007

INFLUENCE OF PLANTING DATES AND DISTANCES ON GROWTH AND ESSENTIAL OIL PRODUCTIVITY OF *Rosmarinus officinalis* L. PLANT

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ABSTRACT

The aim of this work was to investigate the influence of planting date and distance on growth, essential oil content and composition of *Rosmarinus officinalis* L. plant, grown at the Experimental Station of Medicinal and Aromatic Plants, Fac. Agric., Mansoura Univ. during two successive seasons 2004 / 2005 and 2005 / 2006.

The results showed significant differences in all investigated characteristics occurred between the four planting dates (February, March, October and November), three planting distances (40, 50 and 60 cm) and their interactions. The results showed that the tallest plants, highest yield of dried leaves and essential oil were obtained from February planting date compared with the other planting dates. The closer planting distance (40 cm) gave the tallest plants and heaviest dried leaves yield / fed, while increasing plant distance (50 to 60 cm) decreased plant height and yield. The wider space (60 cm) increased the number of branches, fresh and dry weights of herb / plant, as well as produced highest essential oil percentage and content / plant compared with the closer spacing.

Most of the interaction treatments exhibited significant effect on the all investigated characteristics. The early planting date (1st February) with the narrow planting distance (40 cm) gave the best results of plant height, dried leaves yield, but the wide spacing between plants resulted in maximum number of branches, heaviest fresh and dry weights of herb per plant, yield of dried leaves and essential oil. The relative percentage of the main essential oil constituents (cineol, linalool and borneol) was greatly variable in the investigated planting spaces in relation to the planting dates.

Among various metrological data, temperature and day-length were the important factors that contributed to the greatest differences in essential oil percentage through more photosynthesis. Spring cultivation (February & March) produced highest percentage for essential oil in 1stcut, and in 2ndcut autumn cultivation (October and November) during both seasons. These results are very important for optimization the growing conditions for *Rosmarinus officinalis* L. plant under Mansoura conditions.

INTRODUCTION

Rosemary (*Rosmarinus officinalis* L.), belongs to family (*Lamiaceae*), is one of the few medicinal and aromatic plants with a relevant economic value due to its use as fresh condiment or dry spice, used in both cooking and as a medicinal. It is still increasing from year to year, because some of its constituents have high therapeutic effects. Recently much attention has been paid to intensive by growing of this plant and increasing the yields and improving the quality of the crude drug.

Essential oil of rosemary is extracted by steam distillation from the leaves and flowering tips. Rosemary oil has been widely used as cosmetics, soaps, perfumes, as well as in the flavoring and conservation of food products

(Bolens, 1985). Rosemary works as an ingredient in the pharmaceutical industry as digestive, carminative, diaphoretic, antimicrobial, aphrodisiac, antiseptic, inhalants, antispasmodic, astringent, antioxidant and anticancer (which means it increases immunity). In addition, it is used for treatment of coughs, asthma, palpitation, migraines of nervous origin and depression (Lawless, 1992).

The production of medicinal and aromatic plants is affected by many factors such as the agricultural practices, environmental conditions, planting date and distance which were proved to enhance plant growth and development.

Planting date is one of the most important limiting factors that play a great role in plant production. Massoud (1980) on *Saturia hortensies* plant found that the highest values of plant height, plant fresh and dry weight were obtained in case of sowing in the spring (February), while the least respective weight was obtained from plants sown in autumn (November). Piccaglia *et al.* (1993) found that autumn planting of peppermint produced taller plants which flowered earlier, higher essential oil percentage and yield, but had a lower leaf biomass compared with spring planting. On the other hand, they indicated that planting date had no effect on oil composition.

Planting distance is one of the primary factors which worth investigation, as this affect the number of plants per unit area which is reflected on the total yield per feddan. Randhawa *et al.* (1984) planted *Mentha spicata* rhizomes at 30, 45 and 60 cm spacing between rows, and observed that (30 cm) row spacing gave the highest herbage and essential oil yield. Ahmed (1986) on *Achillea millefolium*, tested different planting distances at 30, 40, 50, 60 and 70 cm, he found that the oil percentage in flower heads and the oil yield per plant were increased by increasing the plant spacing, but the oil yield / fed was decreased with increasing the distance. Umesha *et al.* (1990) found that the greatest plant density gave the maximum leaves yield of *Ocimum gratissimum* plant. Shalaby *et al.* (1993) found that when *Melissa officinalis* was cultivated at distance of 40, 60 and 80 cm in row spaced 60 cm apart the wider plant spacing increased individual plant parameters, closer spacing produced greater herb yield. Mohamed (1997) cultivated *Thymus vulgaris* at three spacing (20, 40 and 60 cm apart), and found that plants grown at the distance of 60 cm produced the highest yield of fresh and dry weight of herb per plant, while, plant density of 20 cm produced the highest yield of herbage and oil / fed. Rao *et al.* (1999) on *Rosmarinus officinalis*, reported that the highest yields were obtained with a spacing of 45 cm. Kassem (2002) studied the effect of planting distances (20, 30, 40, 60 and 80 cm) on *Rosmarinus officinalis*, the plant height was decreased steadily when the distance increased and the number of branches, herb fresh and dry weight / plant obtained with 80 cm spacing. The greatest density (20 cm) produced highest yield of fresh and dry herb / fed. Singh (2004) on rosemary studied the effect of plant spacings at (30, 45, and 60 cm), and found that the higher total herbage yield was obtained at closer spacing compared with wider spacing. Olcay Arabaci and Emine Bayram (2004) cultivated *Ocimum basilicum* with various plants densities (20, 40 and 60 cm), and found that the highest green herb yield was obtained from the density of 20 cm compared with wider

spacing. Saglam *et al.* (2004) on *Melissa officinalis*, found that the highest herb yield was obtained from the closer distance compared with wider spacing.

The interaction between planting date and distance affected the different growth parameters. Matter (1997) on black cumin revealed that the early sowing dates with the narrow planting distance gave the best result of plant height, but wide spacing between plants resulted in continuous number of branches, fresh and dry weight / plant. Kotb *et al.* (1998) on *Nigella sativa* showed that the seed yield per plot increased by decreasing plant distances at the early sowing date. They found that the highest volatile oil percentage, content / plant and feddan were produced when the seeds were early sown with increasing planting distances. Meawad *et al.* (2000) on *Hyoscyamus muticus* found that the numbers of branches, fresh and dry weight of leaves were increased as planting density decreased at sowing date of February.

Among various meteorological factors, temperature and day-length were found to be the most critical factors influencing optimum planting date of medicinal and aromatic plants. The length of various developmental phases in the plants growth period showed highly significant inverse relationships with the prevailing mean temperatures and day-length for the respective growth phases. Length of the growing season influenced yields in a significant and positive manner with the duration of reproductive phase exerting maximum influence followed by that from elongation to bud initiation.

The main object of this work was to investigate the influence of planting date and distance on the growth, essential oil productivity of *Rosmarinus officinalis* L. plant.

MATERIALS AND METHODS

This experiment was carried out during two successive seasons of 2004/05 and 2005/ 06 at the Experiment Station of Medicinal and Aromatic Plants, Fac. Agric., Mansoura Univ. The research aimed to investigate the influence of planting date and distance on the growth, essential oil content and composition of *Rosmarinus officinalis* L. plant.

Rosemary (*Rosmarinus officinalis* L.) plants were cultivated using cuttings of 20 cm length and planted in the nursery. Planting was done at four different dates, spring cultivation (1st February & 1st March), and autumn cultivation (1st October & 1st November) in the first and second seasons. The experiment area was divided into plots; the plot area was 5 m^2 (2.5 × 2.0 m) contained four rows at 60 cm apart. The plants were cultivated at distance of 40, 50 and 60 cm between them. Each treatment of four planting dates was combined with each treatment of three spacings to form 12 interaction treatments. Factorial experiment design in randomized complete blocks design with three replicates was followed, according to Steel and Torrie (1980).

All agriculture practices were followed as normal. The plants were harvested twice during each growing season at height of 20 cm from soil

surface. Spring cultivation (February and March), the 1st cut was done in the first week of September and October, the 2nd cut was done in the first week of January and February in both seasons, respectively. Autumn cultivation (October and November) the 1st cut was done in the first week of May and June, the 2nd cut was done in the first week of September and October in both seasons, respectively. The first harvest was after 7 months from planting while the second one was done 4 months after the first harvest as recommended by (Kandeel, 2001).

The following data were recorded:

1- **Plant height (cm):** Height of the plant was measured starting from the soil level to the top of the plant.

2- **Number of branches / plant.**

3- **Herb fresh and dry weight (g/ plant):** Plants were chosen randomly from each treatment and cut and their fresh weight were recorded. Plant samples were dried at room temperature and dry weight were recorded when its weight remained constant.

4- **Essential oil content:** Nine samples using (100g) fresh leaves from each replicate in both seasons were determined the oil percentage (%) by hydro-distillation in Clevenger apparatus according to methods described by the Egyptian Pharmacopoeia (1984). The oil content (ml / plant) was calculated by multiplying oil percentage by plant fresh weight.

5- **Essential oil composition:** Twelve oil samples at second season were analyzed using Gas Liquid Chromatography technique (G.L.C), at the Central laboratory, Fac. Agric. Ain-Shams Univ. The relative retention time (RT) of each peak was compared with authentic sample to identify the unknown samples. The quantitative estimation for each component was based on the peak area measurement by triangulation (Guenther and Joseph, 1978).

6- **Dried leaves yield (ton/fed):** It was calculated by multiplying the dry weight of leaves per plant by number of plants per Feddan.

7- **Essential oil yield (liter/fed):** It was calculated by multiplying essential oil percentage per plant by the number of plants per feddan.

8- **Metrological data:** Metrological measurements during the course of the study were recorded with respect to temperature and day-length starting from planting date until the end of the experiment.

Statistical analysis:

Collected data were subjected to the statistical analysis according to the analysis of variance (Anova). The treatment means were compared using the least significant difference (L.S.D) procedure as mentioned by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

1- Plant height

Data in Table (1) show that the planting date significant affected plant height, in both cuts during the two seasons. The tallest plants produced from spring cultivation (February) and the shortest plants resulted from autumn cultivation (November). These results are in agreement with those obtained by Massoud (1980) on *Saturia hortensies* plant and Meawad *et al.* (2000) on Egyptian henbane (*Hyoscyamus muticus* L.). They found that sowing in spring (February) gave the best result with regard to plant height.

Table (1): Effect of planting dates, distances and their interaction on plant height (cm) and number of branches / plant of *Rosmarinus officinalis* L. plant in two cuts at the two seasons of 2004 / 2005 and 2005 / 2006

Treatments		Plant height (cm)				Number of branches / plant			
		1st season		2nd season		1st season		2nd season	
		1st cut	2nd cut	1st cut	2nd cut	1st cut	2nd cut	1st cut	2nd cut
Planting date									
February		58.6	47.4	56.4	51.8	86.0	127.4	173.2	167.1
March		58.3	41.1	47.7	47.0	83.8	103.8	166.2	151.1
October		56.9	39.3	45.2	42.7	65.3	101.3	83.8	103.8
November		44.5	31.1	38.4	37.5	62.7	52.3	78.8	85.7
L.S.D at 5 %		1.91	2.17	1.95	2.47	4.20	2.17	5.27	4.23
Planting distance									
40		57.0	42.0	51.5	49.6	64.5	82.8	103.1	106.1
50		54.5	40.0	46.3	44.6	73.3	93.0	123.8	122.4
60		52.3	37.2	43.1	44.6	85.4	112.9	149.6	152.3
L.S.D at 5 %		1.58	1.79	1.61	2.04	3.47	1.79	4.53	3.49
Interaction									
Feb.	40	60.5	50.1	60.6	56.8	77.3	122.0	138.7	120.0
	50	58.5	47.9	56.0	51.1	81.0	127.0	166.7	140.0
	60	56.7	44.2	52.7	47.6	99.3	143.3	193.3	193.3
Mar.	40	60.4	43.0	52.3	54.6	76.3	89.3	138.7	120.0
	50	58.1	41.4	46.5	45.5	82.7	93.7	166.7	140.0
	60	56.3	39.0	44.3	40.8	92.3	128.7	193.3	193.3
Oct.	40	58.6	40.8	51.1	45.9	58.3	86.3	61.3	86.3
	50	57.6	39.9	43.7	44.5	64.0	97.0	83.3	105.0
	60	54.4	37.3	40.8	37.9	76.3	120.7	106.7	120.0
Nov.	40	48.4	34.1	41.8	41.0	46.0	43.3	59.0	71.7
	50	43.7	31.0	38.9	37.3	65.7	54.3	78.3	89.7
	60	41.3	28.3	34.5	34.1	73.7	59.3	98.3	95.7
L.S.D at 5 %		1.86	2.12	1.89	2.41	4.10	2.12	4.13	5.14

The planting distances significant affected the plant height. The tallest plants were produced from the closer planting space (40 cm) and the shortest plants resulted from the wider planting distances (60 cm). The distance from 40 to 60 cm decreased steadily plant height. This might be due to the rapid differentiation of cells in wide spacing than in narrow ones. These results

agreed with those obtained by Kothari and Singh (1995) on *Mentha gracilis*, Kassem (2002) on *Rosmarinus officinalis* and Yuonis *et al.* (2004) on *Ammi visnaga*. They found that the plant height significantly decreased by increasing plant space.

Data in the same Table reveal that the interaction between the planting dates and planting distances significantly affected the plant height. The best result was obtained at early planting date (February) and at 40 cm planting distance compared with the other treatments. These results are in agreement with those obtained by Matter (1997) on black cumin, which revealed that narrow planting distance at November planting date gave the best result with regard to plant height.

2- Number of branches / plant

The data in Table (1) reveal that the planting dates affected the number of branches per plant, in both cuts during the two seasons. The highest values were resulted from plants cultivated in spring (February), while the lowest values were shown in autumn (November). These results are in accordance with those of Meawad *et al.* (2000) on *Hyoscyamus muticus* plant, which showed that sowing date at February gave the highest number of branches.

The same Table reveals that the number of branches/plant was increased significantly by increasing the plant distance. The greatest values were recorded from the plants grown at wider planting distance, while, the smallest values came from the closer planting distances. These results agreed with those obtained by Badran and Hafez (2002) on *Nigella sativa*, Kassem (2002) on *Rosmarinus officinalis* and Khater *et al.* (2002) on damsisa. They found that the number of branches / plant increased by increasing the plant distances.

Data presented in Table (1) indicate that, the number of branches was affected with the interaction between the planting date and distance. The highest number of branches / plant was obtained from the interaction between wider planting distance (60 cm) and planting date at February compared to the other interaction treatments. These results are in agreement with those obtained by Meawad *et al.* (2000) on *Hyoscyamus muticus*, since they found that the number of branches was increased as planting density decreased at sowing date (February).

3- Herb fresh and dry weights (g / plant)

From the data in Table (2), it is clear that the plant fresh and dry weights were significantly affected by sowing dates. The highest values were obtained from the spring cultivation (February), while the lowest values came from the autumn cultivation (November). These results are similar to those of Massoud (1980) on *Saturia hortensies* L., who found that the highest fresh and dry weight of the plants were obtained in the spring planting (February), while the lightest fresh and dry weight were obtained from plants sown in autumn (November).

On the other hand, the data in Table (2) show that the planting distance significant affected the plant fresh and dry weight, in both cuts of the two

seasons. The heaviest fresh and dry weight / plant resulted from the wider planting distance (60 cm) and lightest fresh and dry weight / plant produced from the narrow planting distance (40 cm). These results are in accordance and very similar to those reported by Putievsky (1983) on *Salvia sclarea*, Mohamed (1997) on *Thymus vulgaris*, Galambosi *et al.* (1998) on Hungarian peppermint, Kassem (2002) on *Rosmarinus officinalis* and Yuonis *et al.* (2004) on *Ammi visnaga*. They found that the plants grown at the wider planting spaces produced highest fresh and dry weight / plant.

It appeared from data in Table (2) that the plant fresh and dry weights were affected by the interaction between planting date and distance. The planting date of February with the wider planting distance (60 cm) gave the maximum herb fresh and dry weight / plant, while the lowest values were obtained from the closer planting distance (40 cm) at November planting date. These results are in accordance to those found by Meawad *et al.* (2000) on *Hyoscyamus muticus* L., that fresh and dry weights / plant were increased at February with wider planting space.

Table (2): Effect of planting dates, distances and their interaction on herb fresh and dry weights (g / plant) of *Rosmarinus officinalis* L. plant in two cuts at the two seasons of 2004/2005 and 2005/2006.

Treatments		Herb fresh weight (g / plant)				Herb dry weight (g / plant)			
		1st season		2nd season		1st season		2nd season	
		1st cut	2nd cut	1st cut	2nd cut	1st cut	2nd cut	1st cut	2nd cut
Planting date									
February		414.5	530.4	673.6	720.0	162.7	188.7	300.8	277.7
March		356.2	262.0	431.8	564.6	145.9	82.2	178.7	209.2
October		311.4	226.2	373.6	439.9	130.7	81.2	119.5	161.5
November		149.2	121.5	269.5	368.6	64.0	44.7	94.9	120.2
L.S.D at 5 %		11.77	16.65	13.60	12.93	7.83	10.20	7.85	8.69
Planting distance									
40		261.1	232.1	345.0	400.0	105.3	79.9	140.6	153.8
50		302.6	268.6	422.6	495.9	122.8	94.0	171.0	178.2
60		359.7	354.3	519.9	656.5	149.3	123.6	208.9	226.1
L .S.D at 5 %		9.68	13.73	11.22	10.67	6.46	8.42	6.48	7.17
Interaction									
Feb.	40	385.9	434.1	573.1	567.7	153.4	157.5	141.0	154.0
	50	403.9	486.1	622.6	665.0	155.8	173.1	182.0	186.0
	60	452.6	666.9	785.2	857.3	182.8	225.9	213.3	284.2
Mar.	40	291.4	291.4	350.2	401.4	112.7	61.6	141.0	154.0
	50	355.2	355.2	433.8	503.9	142.1	76.2	182.0	186.0
	60	421.7	421.7	511.5	788.5	178.5	108.8	213.3	284.2
Oct.	40	252.8	170.5	294.4	322.6	106.3	61.2	103.6	129.4
	50	314.8	203.3	306.0	445.3	133.3	75.2	105.1	165.7
	60	366.8	304.8	424.8	551.9	152.0	107.2	149.6	189.5
Nov.	40	113.1	105.2	162.4	308.1	49.0	36.6	62.0	106.9
	50	137.1	108.1	287.9	369.3	59.2	41.2	99.2	119.8
	60	197.6	147.9	358.2	428.2	83.9	52.6	123.5	134.0
L.S.D at 5 %		11.48	16.24	12.61	13.27	7.64	9.95	7.66	8.47

4- Essential oil content:

Results in Table (3) show that the essential oil percentage (%) and content (ml / plant) were affected by the planting dates at the two cuts during both seasons. Planting date at February and March produced highest essential oil percentage and content per plant in 1st cut and also, the planting date at October and November produced highest essential oil percentage and content per plant in 2nd cut for harvesting's date at September and October for both seasons, respectively. The essential oil content of *Rosmarinus officinalis* plants reached its maximum value in summer. These results are in agreement with those obtained by Singh and Grag (1976) on *Mentha arvensis* and Khalil (1979) on *Achillea millefolium*.

Table (3): Effect of planting dates, distances and their interaction on essential oil (%) and content (ml / plant) of *Rosmarinus officinalis*, L. plant in two cuts at the two seasons of 2004 / 2005 and 2005 / 2006.

Treatments		Essential oil percentage (%)				Essential oil content (ml / plant)			
		1st season		2nd season		1st season		2nd season	
		1st cut	2nd cut	1st cut	2nd cut	1st cut	2nd cut	1st cut	2nd cut
Planting date									
February		0.33	0.27	0.34	0.28	1.20	0.99	1.68	1.48
March		0.30	0.23	0.33	0.23	0.87	0.58	1.10	1.15
October		0.27	0.32	0.28	0.33	0.65	0.46	0.75	1.05
November		0.24	0.33	0.26	0.34	0.28	0.33	0.54	0.98
L.S.D at 5 %		0.04	0.04	0.04	0.04	0.08	0.09	0.08	0.05
Planting distance									
40		0.25	0.25	0.28	0.27	0.45	0.43	0.73	0.87
50		0.30	0.28	0.31	0.29	0.62	0.56	0.99	1.12
60		0.32	0.33	0.33	0.33	0.80	0.89	1.31	1.67
L.S.D at 5 %		0.04	0.04	0.04	0.03	0.07	0.09	0.08	0.08
Interaction									
Feb.	40	0.30	0.23	0.33	0.26	0.70	0.69	1.38	1.04
	50	0.33	0.27	0.35	0.27	0.84	0.94	1.68	1.33
	60	0.36	0.30	0.37	0.30	1.09	1.38	2.15	2.07
Mar.	40	0.27	0.20	0.30	0.20	0.52	0.32	0.71	0.62
	50	0.30	0.23	0.33	0.23	0.68	0.51	1.12	0.91
	60	0.33	0.27	0.35	0.26	0.92	0.68	1.37	1.49
Oct.	40	0.23	0.27	0.26	0.30	0.42	0.37	0.60	0.79
	50	0.27	0.33	0.27	0.33	0.62	0.55	0.64	1.18
	60	0.30	0.36	0.30	0.36	0.83	0.86	1.00	1.52
Nov.	40	0.21	0.30	0.23	0.30	0.19	0.26	0.27	0.88
	50	0.23	0.30	0.26	0.33	0.24	0.27	0.58	1.00
	60	0.27	0.37	0.30	0.37	0.41	0.47	0.83	1.22
L.S.D at 5 %		0.06	0.06	0.05	0.05	0.05	0.05	0.05	0.05

In the same Table, results clear that the essential oil productivity influenced by planting distance. The highest values resulted from the wider planting distance (60 cm) and the lowest values produced from the closer planting distance (40 cm).These results are in agreement with those obtained by Khater *et al.* (1993) on geranium, Piccaglia *et al.* (1997) on *Salvia officinalis*, Kassem (2002) on *Rosmarinus* officinalis and Badi *et al.*, (2004) on

Thymus vulgaris. They noticed that wider space between plants led to highest accumulation in the essential oil productivity.

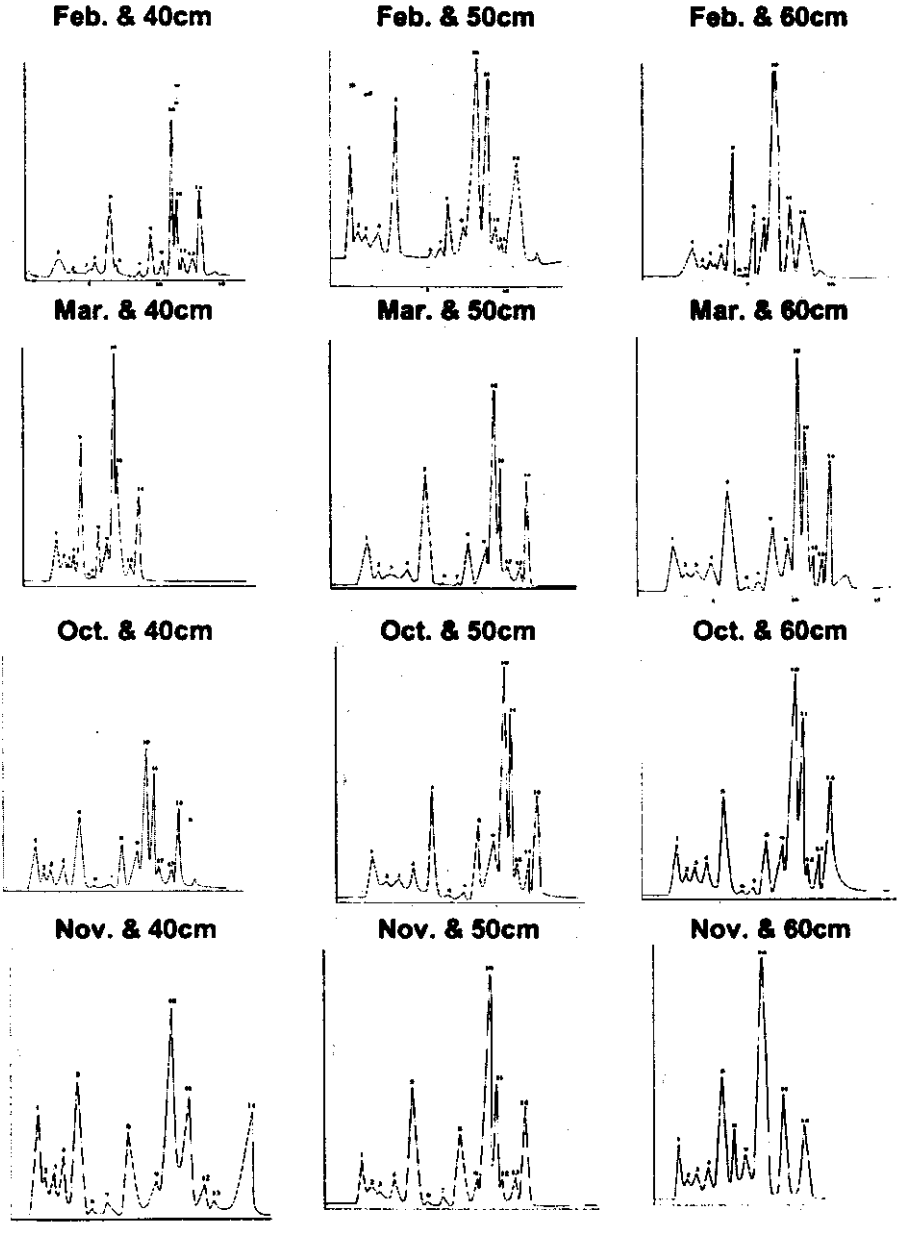
Concerning the interaction, data in Table (3) reveal that the early sowing date with wider planting distance produced the highest essential oil percentage and content per plant in the 1st cut for both seasons, respectively. The plants cultivated later in October and November gave highest oil percentage in 2nd cut for the both seasons, respectively. These results with coincide with those obtained by Kotb *et al.* (1998) who showed that the highest essential oil productivity of *Nigella sativa* was produced when the seeds were early sown and increasing planting distances.

5- Essential oil components

Data in Table (4) and illustrated in Figure (1) reveal that the essential oil compositions of rosemary were 14 components, such as camphene (6.60 to 12.97 %), α-pinene (0.17 to 1.94 %), β-pinene (0.02 to 2.15 %), myrcene (0.78 to 2.87 %), α-terpinene (10.40 to 27.13 %), limonene (0.01 to 0.98 %), caryophellene (0.04 to 0.84 %), p-cymene (3.07 to 9.92 %), camphore (1.13 to 5.37 %), cineol (21.16 to 39.82 %), linalool (6.47 to 19.97 %), citronellol (0.12 to1.64 %), thymol (0.51 to 4.46 %) and borneol (8.72 to 18.10 %). The identified compounds formed from 93.17 to 99.36 % of the essential oil depending on planting dates and distances on *Rosmarinus officinalis*, L. oil. The major compounds (cineol, linalool and borneol) of the essential oil formed from 42.60 to 61.58 %. This result was in accordance with previous reports by Al-Masry *et al.* (1991) since they mentioned that the major components of *Rosmarinus officinalis* oil were cineol 28 %, borneol 32 % and other two compounds were camphene and camphore, Taufek *et al.* (2004) characterized thirty compounds were representing 98.2 % of the essential oil with 1,8-cineol (29.5 %), and camphor (11.5 %) as the major components, and EL- Boraie *et al.* (2006) indentified 17 components in essential oil of *Rosmarinus officinalis* L. plants..

Table (4): Effect of planting dates and distances on essential oil components (%)of *Rosmarinus officinalis*, L. plant.

Treatments / Components	Spring						Autumn					
	February			March			October			November		
	40 cm	50 cm	60 cm	40 cm	50 cm	60 cm	40 cm	50 cm	60 cm	40 cm	50 cm	60 cm
Camphene	11.30	11.14	6.60	12.97	9.71	8.24	12.73	7.94	7.94	12.96	12.03	8.16
α-pinene	0.27	0.17	0.20	0.77	0.48	0.33	1.94	0.54	1.02	0.48	1.55	0.63
β-pinene	0.55	0.43	0.44	0.02	0.77	1.85	2.15	1.59	1.69	1.28	1.36	1.63
Myrecene	2.72	0.84	1.23	2.87	1.84	2.15	2.30	1.88	1.78	2.05	2.11	1.71
α-terpinene	23.32	22.21	19.13	22.36	21.33	16.97	17.13	15.84	10.40	22.24	19.52	18.86
Limonene	0.47	0.20	0.06	0.01	0.15	0.21	0.25	0.34	0.07	0.19	0.98	------
Caryophellene	0.11	0.04	0.04	0.22	0.08	0.27	0.11	0.16	0.47	0.84	0.14	------
P-Cymene	7.78	3.07	7.15	9.92	5.86	3.18	7.43	8.58	5.14	6.36	5.48	5.33
Camphore	1.74	1.13	2.89	1.28	1.96	4.34	4.57	5.37	4.25	2.30	1.95	2.83
Cineol	25.49	24.34	39.82	23.16	29.41	31.96	21.16	23.09	33.07	23.01	30.37	38.06
Linalool	6.47	19.97	11.14	6.94	9.62	11.76	7.35	13.49	14.17	8.03	10.54	11.30
Citronellol	0.12	1.64	------	1.57	0.45	1.42	0.90	1.50	1.13	1.36	1.27	------
Thymol	0.92	0.65	------	------	2.12	0.96	3.82	3.30	4.46	0.51	1.75	------
Borneol	18.10	10.96	10.35	15.99	14.55	13.81	14.38	13.47	11.87	11.56	9.02	8.72
Known	99.36	96.79	99.05	98.08	98.33	95.47	96.22	97.09	97.46	93.17	98.07	97.23



1- camphen 2- α-pinene 3- β-pinene 4- myrcene 5- α-terpinene 6- limonene 7- caryophellene 8- p-cymene 9- camphore 10- cineol 11- linalool 12- citronellol 13- thymol 14- borneol

Figure (1): Effect of planting dates and distances on the percentage of essential oil components of *Rosmarinus officinalis* L. plants in first cut at the second season 2006

6- Dried leaves yield (ton / fed)

It is obvious from Table (5) and illustrated in Figure (2), that the interaction between planting dates and distances significantly affected the yield of dry leaves per feddan. The highest effect was recorded in the second season at all studies planting dates and distances. In this connection, the best interaction for increasing the leaves yield from spring cultivation (February & March) and autumn cultivation (October & November) resulted in the maximum value of dried leaves yield at closer planting space (40 cm), compared with the other planting distances at the two cuts in both growing seasons.

Table (5): Effect of planting date, distance and their interaction on yield of dried leaves (ton / fed) and essential oil (litter/ fed) of *Rosmarinus officinalis*, L. plant at the two cuts during the two seasons of 2004/2005 and 2005/2006.

Treatments		Leaves yield (ton / fed)				Essential oil yield (litter / fed)			
		1st season		2nd season		1st season		2nd season	
		1st cut	2nd cut	1st cut	2nd cut	1st cut	2nd cut	1st cut	2nd cut
Feb.	40	1.52	1.80	2.75	2.27	1.12	1.15	2.55	1.73
	50	1.24	1.62	2.54	2.19	1.16	1.25	2.30	1.77
	60	1.14	1.56	2.28	2.09	1.21	1.53	2.38	2.30
Mar.	40	1.21	0.78	1.69	1.80	1.89	0.53	1.18	1.03
	50	1.16	0.75	1.66	1.73	1.91	0.68	1.49	1.21
	60	1.05	0.70	1.45	1.72	1.02	0.76	1.52	1.66
Oct.	40	1.08	0.75	1.26	1.53	0.70	0.62	0.85	1.31
	50	1.07	0.73	1.07	1.50	0.83	0.73	1.00	1.57
	60	1.01	0.69	1.05	1.31	0.92	0.96	1.11	1.69
Nov.	40	0.57	0.47	0.73	1.56	0.32	0.36	0.45	1.33
	50	0.54	0.45	0.70	1.31	0.32	0.43	0.77	1.36
	60	0.52	0.42	0.68	1.09	0.46	0.52	0.92	1.46

The interaction between planting date (February) and narrow planting distance (40 cm) gave the superiority value of leaves yield / fed, compared with the other planting dates and planting distances. Variation in dried leaves yield due to planting dates may be attributed to the variation in green matter and dry herb yields and might have been compensated by increased number of plants per unit area, resulting in significantly higher leaves yield / fed. The highest dried leaves yield under February planting may be due to the fact that the plants had longer period of growth with favorable temperature. These results are in agreement with those obtained by Kotb *et al.* (1998) on *Nigella sativa* L. and Matter (1997) on black cumin, which showed that the seed yield per plot increased by decreasing plant distances at the early sowing date.

7- Essential oil yield (liter / fed)

Data from Table (5) and Figure (3) show the interaction treatments affected the essential oil yield / fed. The highest effect was recorded in the second season at all studies of planting dates and distances. Planting date at February and March produced highest oil yield for harvesting's date at September and October (2004 & 2005), in 1st cut for both seasons, respectively. Also, the planting date at October and November produced highest essential oil yield for harvesting's date at September and October (2005 & 2006), in 2nd cut for both seasons, respectively.

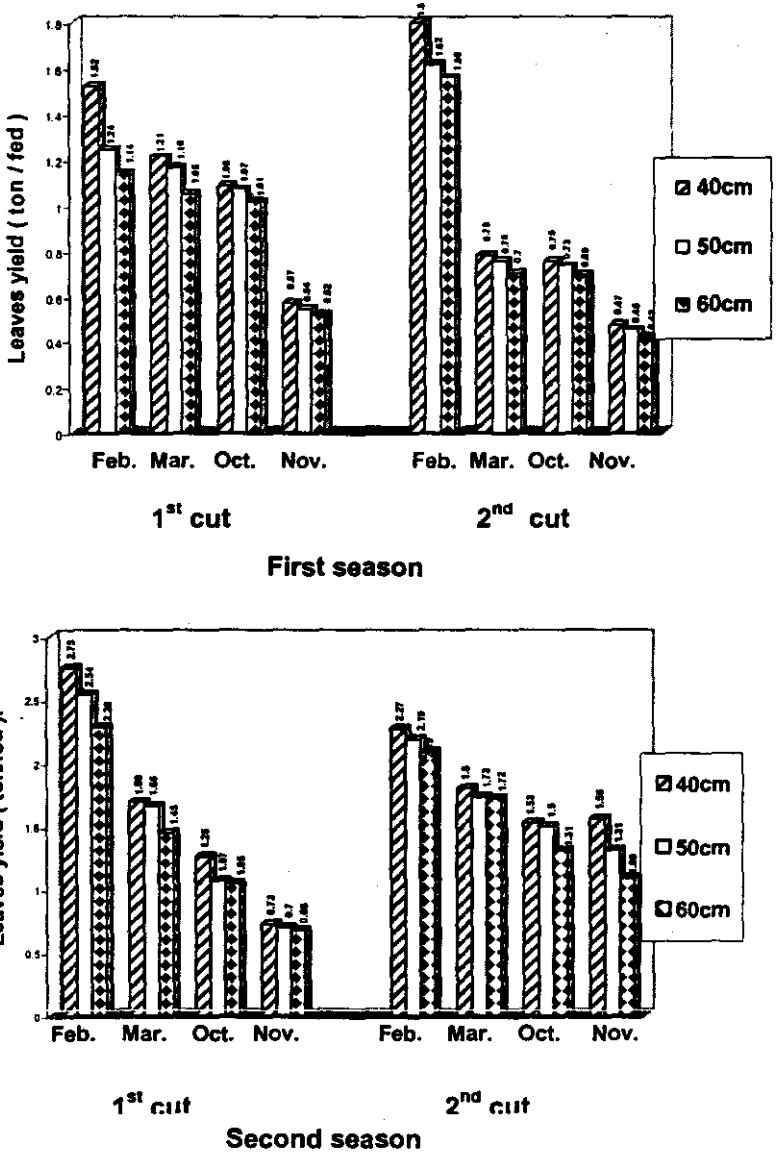


Fig. (2): Effect of planting dates and distances interaction on dried leaves yield (ton / fed) of *Rosmarinus officinalis* L. plant at the two cuts during both seasons

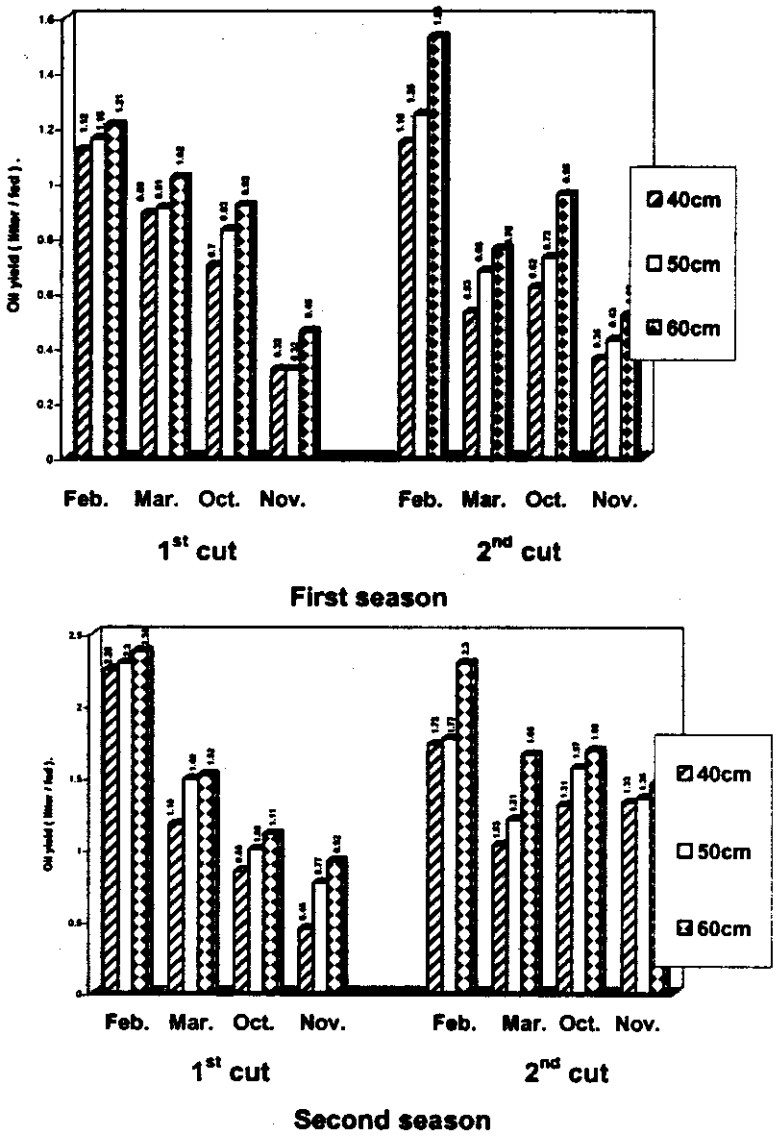


Fig. (3): Effect of planting dates and distances interaction on essential oil yield (litter / fed) of *Rosmarinus officinalis* L. plant at the two cuts during both seasons

8- Effect of Meterological conditions

Table (6) and Figure (4) show the phonological data pertaining to the growth, yield and essential oil productivity obtained from different planting dates. The differential performance of rosemary examined in relation to fluctuations in various climatic factors, temperature and day-length were only variable which exerted considerable influence on growth and development of rosemary in the present studies. It is clear that the main effect on oil percentage was due to the heat units while it was less affected by the day-length since the differences of the photoperiodic conditions between each four successive planting dates was small. The essential oil content in the leaves varied with climatic and ecological conditions. It was also, obvious that the combination of relatively average of day degrees, ranged between (13.6 to 30.0 °C) and relatively average day-length, ranged between (10.3 to 14.3 hrs) led to the highest essential oil percentage among different planting dates. Supporting the last view that spring cultivation (Feb. and Mar.) harvested in 1st cut, and autumn cultivation (Oct. and Nov.) harvested in 2nd cut during September & October at both seasons respectively.The average of daily degrees was about (27.4 & 25.8 °C) at Sept. and Oct. (2004), (30.0 & 27.1 °C) at Sept. and Oct. (2005) and (28.5 & 26.7 °C) at Sept. and Oct. (2006). The increase of essential oil yield during such cutting times can be attributed relatively to the high temperature (27°C) which affected positively on photosynthesis rate.

Table (6): Meterological data of average temperature (°C) and day-length (hrs) of different planting dates of *Rosmarinus officinalis* L. plant in two cuts at the both seasons of 2004 / 2005 and 2005 / 2006

Planting date	Average of daily temperature (°C)				Average of day-length (hrs)			
	1st season (2004/ 2005)		2nd season (2005/ 2006)		1st season (2004/ 2005)		2nd season (2005/ 2006)	
	1st cut	2nd cut	1st cut	2nd cut	1st cut	2nd cut	1st cut	2nd cut
February	27.4	15.5	30.0	15.6	13.2	10.3	13.2	10.3
March	25.8	14.9	27.1	13.6	12.0	11.3	12.0	11.3
October	19.4	30.0	20.0	28.5	13.4	13.2	13.4	13.2
November	23.1	27.1	22.3	26.7	14.3	12.0	14.3	12.0

These results are in accordance with those obtained by Hotin (1968) since they reported that a rise in the temperature to 23-25 °C increased the oil content in mint, basil, celery, sage and lavender infloursences, Murray *et al.* (1972) reported that the environmental factors such as temperature affect the efficiency of certain enzymes responsible for the conversion of one compound to another. They added that these factors resulted differences in the mint essential oil composition and the relative percentage of the constituents. Mansour (1975) reported that plant height of rosella (*Hibiscus sabdariffa*) plants was increased with temperature from 17 °C to 25 °C, Ghosh and Chatterjee (1976) showed that temperature and day-length had greater effects on essential oil and azulene content of *Matricaria chamomilla*. Singh and Grag (1976) found that leaf essential oil content was higher in summer grown plants.

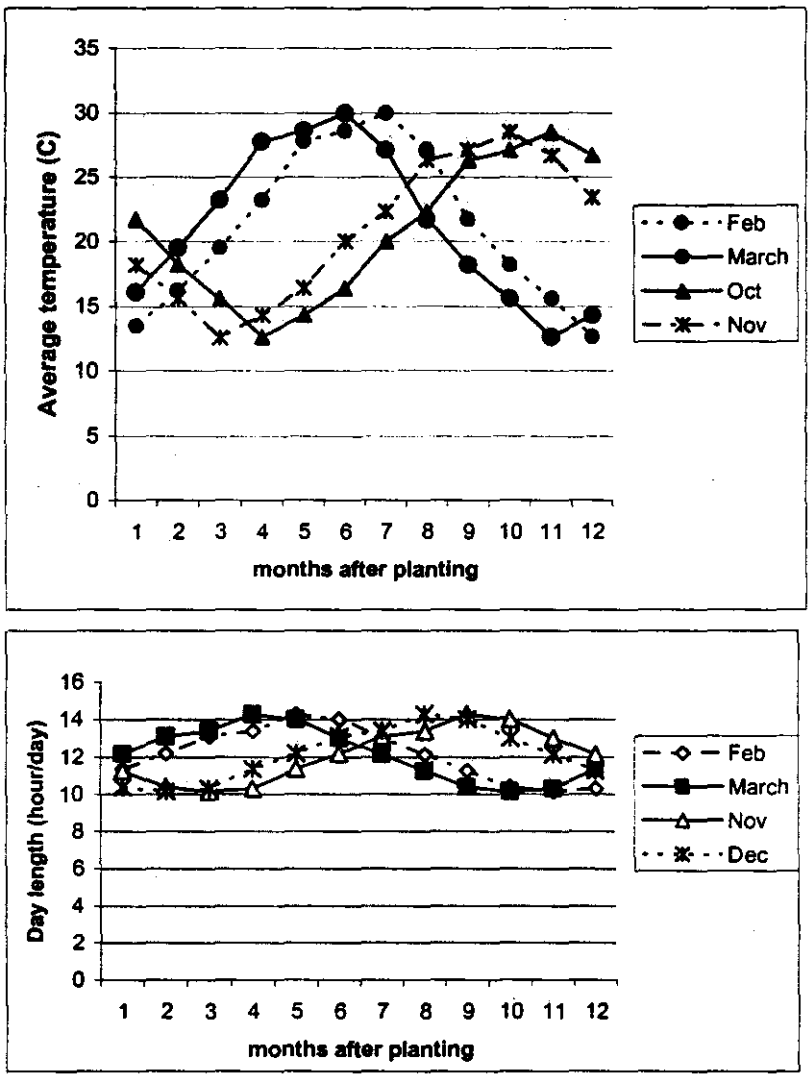


Fig. (4): Average monthly temperature and day length for spring and autumn cultivation during the second growing seasons (2005/2006) of *Rosmarinus officinalis* L. plant

Bagchi *et al.* (1997) on *Artemisia annua* found that the autumn was the optimum sowing time in order to obtain good herbage and achene yields, Guerrero and Johnson (2000) reported that temperature and day-length were important factors that contributed to the differences in oil yield and composition on *Origanum majorna* plant.

The experiments on photoperiod presented in Table (6) and Figure (4) show that light had positive effect on growth parameters and essential oil biosynthesis. The positive results recorded herein on branches number / plant, a large leaf mass / plant, considerable plant height and essential oil yield was superior at maturity stage at 1st cut in spring and 2nd cut in autumn. They can be due to extremely long day's during these periods which in turn resulted in high solar radiation and high atmospheric temperature at the early planting date.

This finding is in harmony with Mansour (1975) who found that plant height was taller fewer than 16 hrs and 24 hrs less than 8 hrs day-lengths. Fykse (1983) reported that plant dry weight was increased with increasing light level of *Achillea millefolium*. Nandi and Chatterjee (1986) mentioned that long-day photoperiodic treatments on mint species had a beneficial effect on the essential oil production. Zhang *et al.*(1996) reported that *Achillea millefolium* "summer pastels" is a qualitative long-day plant with a critical photoperiod between 12 and 16 hrs at 18 °C. They found that plants grown under 8 hrs remained vegetative. Bagchi *et al.* (1997) on *Artemisia annua* found that a photoperiod of 11-13 hrs / day promoted rapid growth, and an average photoperiod of 13.2 hrs / day induced flowering. Farooqi *et al.* (1999) mentioned that mint species grew better under long-day conditions.

Hence, the present study indicates that the growth, oil productivity may vary from planting date to another, and even from harvesting date to another. Such variation is ascribed by environmental conditions through consecutive planting and growing of the plants which was undertaken to find optimum time of planting, harvesting under Mansoura climatic conditions.

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تأثير مواعيد ومسافات الزراعة على النمو وإنتاج الزيت الطيار فى نبات حصالبان

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**معهد بحوث النباتات الطبية– مركز البحوث الزراعية– الجيزة

أجريت هذه الدراسة على نبات حصالبان (إكليل الجبل) فى مزرعة النباتات الطبية والعطرية– بكلية الزراعة– جامعة المنصورة خلال موسمين زراعيين ناجحين (٢٠٠٤ / ٢٠٠٥) ، (٢٠٠٥ / ٢٠٠٦) وتهدف الى دراسة تأثير موعد ومسافة الزراعة على النمو وإنتاج الزيت الطيار.

تم زراعة نباتات حصالبان بواسطة العقل فى ٤ مواعيد زراعة ، فى الربيع (١فبراير، ١مارس) وفى الخريف (١أكتوبر، ١نوفمبر) وذلك على٣ مسافات زراعة (٤٠– ٥٠– ٦٠ سم بين النباتات) فى موسمين زراعيين متتاليين. تم الحصول على عدد ٢ حشة لكل موعد زراعة. الاولى بعد ٧ أشهر من الزراعة والثانية بعد ٤ أشهر من الاولى.

كانت النتائج المتحصل عليها كالتالى:

١– أعطت زراعة الربيع فى فبراير فروق معنوية من حيث طول النباتات ومحصول الأوراق الجافة (كجم/ فدان) وأيضا محصول الزيت الطيار (لتر/ فدان) والنسبة المئوية للمكونات الرئيسية للزيت (سينول ، برنيول ، لينالول). مقارنة بمواعيد الزراعة الأخرى.

٢– أعطت مسافة الزراعة الضيقة (٤٠ سم) أطول النباتات وأكبر وزن للمحصول الكلى للأوراق والزيت. بينما أدت مسافة الزراعة الواسعة (٦٠ سم) إلى زيادة عدد الأفرع والوزن الطازج والجاف للعشب وأيضا أنتجت أعلى نسبة مئوية للزيت الطيار والنسبة المئوية للمكونات الرئيسية (سينول ، برنيول ، لينالول).

٣ – أظهرت معظم معاملات التفاعل فروق معنوية فى كل الصفات المدروسة. وأعطت الزراعة المبكرة فى أول فبراير مع مسافة الزراعة الضيقة (٤٠ سم) أحسن النتائج بالنسبة لإرتفاع النبات ومحصول الأوراق الجاف وأيضا محصول الزيت الطيار. بينما أنتجت مسافة الزراعة الواسعة (٦٠ سم) فى نفس ميعاد الزراعة أكبر عدد من الأفرع وأكبر وزن طازج وجاف للعشب وأيضا النسبة المئوية للزيت الطيار.

٤– تعتبر درجة الحرارة وطول النهار من أهم الظواهر المناخية التى تؤدى إلى حدوث فروق معنوية فى صفات النمو والنسبة المئوية للزيت الطيار من خلال عملية البناء الضوئى. أنتجت الحشة الأولى فى زراعة الربيع (فبراير، مارس) وأيضا الحشة الثانية فى زراعة الخريف (أكتوبر، نوفمبر) أعلى نسبة مئوية للزيت الطيار حيث تزامن ميعاد الجمع فى شهر سبتمبر وأكتوبر خلال موسمى الزراعة تعرض النباتات خلالهم لإرتفاع درجة الحرارة مع طول النهار. تعتبرهذه النتائج ذات أهمية كبيرة لدراسة ظروف النمو الأمثل لنبات حصالبان تحت ظروف المنصورة.