J. Product. & Dev., 14(1): 111– 128(2009)

EFFECT OF PLANTING DISTANCES ON THE GROWTH, YIELD, ESSENTIAL OIL PRODUCTIVITY AND CHEMICAL COMPOSITION OF ROSEMARY (*ROSMARINUS OFFICINALIS*, L.) PLANT.

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ABSTRACT

This experiment was carried out in Medicinal and Aromatic Plants Research Station at EL-Kanater EL-Khayria, Horticultural Research Institute, Agricultural Research Center, in two successive seasons; 1998 and1999. The aim of this study was to investigate the effect of planting distances on the growth, yield, essential oil productivity and chemical composition of Rosmarinus officinalis, L. plant. The plants of this experiment were cultivated at a distance of 20, 30, 40, 60 or 80 cm between them in the row and 30 cm between the rows. All the plants of this experiment were fertilized with nitrogen (N) at 150 kg, phosphorus (P_2O_5) at 50 kg and potassium (K_2O) at 30 kg/fad. Nitrogen was added in the form of ammonium nitrate (33.5% N), while phosphorus was applied as calcium superphosphate (15.5% P_2O_5) and potassium as potassium sulfate (48% K_2O). The obtained results can be summarized as follows: Growing rosemary plants at 20 cm apart resulted in the tallest plants, while, increasing the distance from 20 to 80 cm decreased steadily plant height. Cultivation at 80 cm between the plants in the row increased the number of branches, fresh and dry weights of herb as well as leaves/plant. Also, the plants which grew at this distance had the highest oil percentages and oil yield in their fresh herb and leaves per plant. Whereas increasing planting distances from 20 to 80 cm increased photosynthetic pigments (chlorophylls a, b and total, as well as carotenoids), total carbohydrates, nitrogen, phosphorus and potassium percentages in the herb in the two seasons. As a general trend, it is very clear that the highest values of all previous parameters were resulted in cultivation at the widest distance (80 cm between the plants in the row). Whereas the lowest values of all previous characters were produced from cultivation at the narrow distance (20 cm between the plants in the

row). At the same time the opposite trend was found with plant height in the two seasons.

Key words: Distances, *Rosmarinus officinalis*, cultivated, growth, essential oil productivity, photosynthetic pigments.

INTRODUCTION

Rosemary plant is a shrubby evergreen bush up to 2 meters high with silvery green, needle-shaped leaves and pale blue flowers. The whole plant is strongly aromatic. (Lawless, 1992). Rosemary plant belongs to family *Lamiaceae* (Labiatae). It is stimulant, diuretic, antispasmodic, used for treatment many diseases such as cough, whooping, asthma, palpitation, neuralgia and depression. (Messegue, 1979).

Planting distances is one of the factors which worth investigation, as this affect the number of plants per unit area which is reflected on the total yield per faddan. Many researchers reported that, increasing the planting distances between the plants resulted in an increase in the vegetative growth and yield, this conclusion was reported by Shalaby *et al* (1993) on *Melissa officinalis* and Badran and Hafez (2002) on *Nigella sativa*. On the other hand, Zaied *et al.,* (1990) on *Cassia acutifolia* and Khater *et al.,* (1993) on geranium plants, mentioned that there was a significant decrease in plant height with the increasing in plant spacing.

Cultivating the plants with the widest spaces resulted in an increase in essential oil percentage and essential oil yield. This conclusion was reported by Kandeel (1982) on chamomile and Khater *et al.,* (1993) on geranium.

Also increasing planting distances between the plants resulted in an increment in chlorophyll a, b, carotenoids, total carbohydrates and minerals content. These results were reported by El-Shaer (1989) on NPK content in fennel plant and AbdEl-Salam (1992) on NPK content in *Pimpinella anisum.*

This experiment aimed to study the response of rosemary (*Rosmarinus officinalis,* L.) plant to planting distances to improve its growth, yield, essential oil productivity and chemical constituents.

MATERIALS AND METHODS

This study was carried out in two successive seasons of 1998 and 1999 in the Experimental Field of Medicinal and Aromatic Plants Research Section, Horticultural Research Institute, Agricultural Research Center, Ministry of Agriculture, El-Kanater El-Khayria, Egypt. Soil of this field is clay sand which contained 40.74% clay, 25.72% silt, 30.33% fine sand,

3.21% coarse sand, 7.20 pH value, 5.25 ppm Zn, 2.50 ppm B, 0.93 ppm Mo and available N, P, K were 22.4, 109 and 180 ppm, respectively. Rooted cuttings (15-20 cm long) of *Rosmarinus officinalis,* L. plants were used. The cuttings were planted on 28th January in the two seasons of 1998 and 1999.

The experimental area consisted of plots (2.0 X 2.5 m) having 6 rows with a distance of 30 cm between rows. The plants were cultivated at a distance of 20, 30, 40, 60 or 80 cm between them inside the rows.

The plants were fertilized with nitrogen (N) at 150 kg, phosphorus (P_2O_5) at 50 kg and potassium (K_2O) at 30 kg/fad. Nitrogen was added in the form of ammonium nitrate (33.5% N), while phosphorus was applied as calcium superphosphate (15.5% P_2O_5) and potassium as potassium sulphate (48% K_2O).

The layout of this experiment was a randomized complete blocks design including 5 treatments with 3 replicates. The plants were harvested twice/season (first and second cuts) on August 5th and November 28th in both seasons by cutting the herb of the plants at 10 cm above the soil surface. The following parameters were recorded in the first and second cuts in both seasons:

1- Plant height (cm.).
2- Number of branches/ plant.
3- Herb fresh weight (g/ plant).
4- Herb dry weight (g/ plant).
5- Leaves fresh weight (g/ plant).
6- Leaves dry weight (g/ plant).
7- Essential oil percentage in fresh herb.
8- Essential oil percentage in fresh leaves.
9- Oil yield of fresh herb/ plant.
10- Oil yield of fresh leaves/plant. The essential oil percentage in the fresh herb and leaves was determined according to the British Pharmacopoeia (1963).
11- Chlorophylls and carotenoids were determined in fresh leaves according to Saric *et al.,* (1967).
12- Total carbohydrates percentages were determined in the dry herb according to Herbert *et al.,* (1971).
13- N, P, K content. Total nitrogen content in the dry herb was determined by modified micro-Kjeldahl methods according to the procedure described by Pregl (1945) and Piper (1947). Phosphorus content in dry herb was determined according to Troug and Meyer (1939). Potassium content was determined in the dry herb by using Atomic Absorption/ Flame Spectrophotometer AA-646 according to Allen *et al.,* (1997).

The all parameters recorded on the growth, yield and chemical composition were statistically analyzed by using the method described by Steel and Torre (1980).

RESULTS AND DISCUSSION

1. Plant height (cm.):

Data shown in Table 1 indicated that planting distances affected significantly plant height. In both cuts of the two seasons, increasing the distance from 20 to 80 cm decreased steadily plant height.

Table 1. Effect of planting distances (cm) on plant height (cm) of *Rosmarinus officinalis,* L., at 1998 and 1999 seasons.

Planting distances (cm)	1998		1999	
	1st Cut	2nd Cut	1st Cut	2nd Cut
20	70.40	66.83	71.73	72.80
30	66.80	60.53	68.60	65.57
40	60.50	58.57	66.40	63.30
60	57.20	56.53	61.90	62.57
80	50.47	48.67	57.53	56.37
L.S.D at 0.05	**2.85**	**3.67**	**2.64**	**4.43**

In the first season, plant height ranged from 70.40 to 50.47 cm in the first cut and from 66.83 to 48.67 cm in the second one.

In the second season, the averages of plant height ranged from 71.73 to 57.53 cm in the first cut and from 72.80 to 56.37 cm in the second one. These results in the both seasons indicated that increasing the distance between plants decreased the plant height.

These results were in agreement with those of Khater *et al.,* (1993) on geranium plants, mentioned that there was a significant decrease in plant height with the increase in plant spacing.

2. Number of branches/plant:

As shown in Table 2, it is clear that the number of branches / plant increased as the distance between the plants increased.

In the first season, the number of branches / plant ranged from 13.90 to 25.43 and from 18.60 to 30.00 in the first and second cuts, respectively.

In the second season, the averages were 15.30 and 20.70 at 20 cm and increased to 29.40 and 32.47 at 80 cm in the two cuts, respectively. However, there was no significant difference between the plants cultivated at the distances of 30 and 40 cm.

These results were in harmony with those of Clark and Menary (1979) on peppermint who demonstrated that plants growing at density of 40 plants/m^2

Table 2. Effect of planting distances (cm) on number of branches/ plant of *Rosmarinus officinalis,* L., at 1998 and 1999 seasons.

Planting distances (cm)	1998		1999	
	1st Cut	2nd Cut	1st Cut	2nd Cut
20	13.90	18.60	15.30	20.70
30	20.00	25.30	22.10	27.40
40	20.30	25.50	22.40	27.90
60	23.27	28.37	27.80	30.70
80	25.43	30.00	29.40	32.47
L.S.D at 0.05	**5.30**	**4.18**	**4.48**	**5.67**

had a single stem form with terminal inflorescence. In contrast, plants growing at a density of 10 plants/m^2 tended to produce many lateral shoots prior to inflorescence formation. Also, Badran and Hafez (2002) on *Nigella sativa* indicated that reducing plant density caused a considerable increase in branches number.

3. Herb fresh weight (g)/ plant:

The data exhibited in Table 3 pointed out that herb fresh weight was increased by increasing the distances between the plants.

In the first season, the mean fresh weight was 206.80 g at 20 cm and 389.90 g at 80 cm in the first cut. The increment was 88.50 %. Whereas, in the second cut it ranged from 187.40 to 340.07 g with an increase of 81.50 %.

In the second season, the fresh weights of the herb were heavier in the first cut than in the second one. The same trend was observed as in the first season. In the first cut, herb fresh weight was greater at the widest distance (405.57 g) compared to the narrowest one (218.37 g), the increment was 85.70 %. In the second cut, a similar effect was observed, i.e. increasing the distance between the plants from 20 to 80 cm led to a significant increase in herb fresh weight. It ranged from 193.47 to 358.60 g with 85.40% increment. This may be due to the increment in number of branches/plant.

Table 3. Effect of planting distances (cm) on herb fresh weight (g/plant) of *Rosmarinus officinalis,* L., at 1998 and 1999 seasons.

Planting distances (cm)	1998		1999	
	1st Cut	2nd Cut	1st Cut	2nd Cut
20	206.80	187.40	218.37	193.47
30	229.70	207.87	263.50	221.03
40	287.67	236.07	299.90	266.03
60	310.50	286.07	324.77	292.03
80	389.90	340.07	405.57	358.60
L.S.D at 0.05	**20.27**	**15.34**	**25.34**	**24.54**

4. Herb dry weight (g/ plant):

From results in Table 4, it may be observed that, increasing the distance between the plants from 20 to 80 cm, increased the herb dry weight with significant differences.

In the first cut of the first season, herb dry weight ranged from 128.20 to 272.93 g when the distances were 20 and 80 cm, respectively. The increment was 112.90 %. The same trend was noticed in the second cut of this season. The lightest dry herb (108.90 g) was those cultivated at the narrowest distance (20 cm), while the heaviest one (227.83 g) was obtained when the distance between the plants was 80 cm, with an increasing of 109.20%.

In the second season, the plants had more dry weight than in the first one. The effect of planting distances on herb dry weight was the same as in the first season, i.e. increasing the distance resulted in an augmentation of herb dry weight.

Table 4. Effect of planting distances (cm) on herb dry weight (g/ plant) of *Rosmarinus officinalis*, L., at 1998 and 1999 seasons.

Planting distances (cm)	1998		1999	
	1st Cut	2nd Cut	1st Cut	2nd Cut
20	128.20	108.90	135.80	118.97
30	149.30	128.93	173.37	143.70
40	189.87	149.90	202.13	177.73
60	211.03	186.23	224.10	200.13
80	272.93	227.83	290.00	251.03
L.S.D at 0.05	**15.21**	**17.23**	**24.22**	**21.35**

From these results it may be concluded that increasing planting distance from 20 to 80 cm led to a gradual increment in the dry weight of the herb of rosemary. This may be due to the wider area available for each plant leading to more absorption of essential elements, water and sunlight consequently more branching and accumulation of dry matter.

These findings coincided with those of Nofal (1976) who showed that the fresh and dry weights of marjoram plants increased by increasing the spacing between hills from 20 to 30 cm. Also, Badran and Hafez (2002) on *Nigella sativa* indicated that reducing plant density caused considerable increase in herb dry weight.

5. Leaves fresh weight (g)/ plant:

As shown in Table 5, the data revealed that as the distance between the plants increased (from 20 to 80 cm) there were significant increments in leaves fresh weight, in both seasons.

In the first season, the leaves fresh weight increased steadily as the distance increased from 20 to 80 cm. In the first cut the mean fresh weight of leaves was 143.17 g/ plant at 20 cm, while at 80 cm it reached 284.27 g/ plant, the increment was 141.10 g/ plant, i.e. 98.55 %. In the second cut, the same trend was observed. The plants had heavier fresh leaves as the planting density decreased. The average fresh weight of leaves ranged from 144.53 to 285.67 g/ plant as the distance increased from 20 to 80 cm, the increment attained 141.14 g/ plant (97.65 %). In the second season, a similar effect of planting distances was noticed on this respect.

Table 5. Effect of planting distances (cm) on leaves fresh weight (g)/ plant of *Rosmarinus officinalis,* L., at 1998 and 1999 seasons.

Planting distances (cm)	1998		1999	
	1st Cut	2nd Cut	1st Cut	2nd Cut
20	143.17	144.53	148.00	149.00
30	162.77	163.17	167.97	167.20
40	203.70	204.50	210.80	210.27
60	231.60	232.53	241.70	236.20
80	284.27	285.67	270.60	290.07
L.S.D at 0.05	**13.47**	**11.44**	**13.36**	**12.24**

6. Leaves dry weight (g)/ plant:

As shown in Table 6, the data on leaves dry weight increased significantly as the planting distances increased, in both seasons.

In the first season, the dry weight of the leaves/ plant, in the first cut, was 74.47 g at 20 cm, and reached 170.53 g at 80 cm. The increment was 128.99 %. In the second cut, the average values were 69.53 g at 20 cm and 162.83 g at 80 cm. The increase in this cut was 93.30 g/ plant (134.19 %).

Table 6. Effect of planting distances (cm) on leaves dry weight (g)/ plant of *Rosmarinus officinalis,* L., at 1998 and 1999 seasons.

Planting distances (cm)	1998		1999	
	1st Cut	2nd Cut	1st Cut	2nd Cut
20	74.47	69.53	77.27	76.70
30	89.50	84.80	93.70	91.97
40	114.07	109.40	121.00	119.43
60	134.33	128.13	142.60	138.20
80	170.53	162.83	166.43	174.03
L.S.D at 0.05	**11.27**	**10.24**	**12.22**	**11.16**

In the second season, the plants in the first cut had heavier dry weight of leaves (166.43 g) at 80 cm than at 20 cm (77.27 g). The increment was 89.16 g/ plant (115.39 %). In the second cut, the dry weight of leaves ranged from 76.70 to 174.03 g/ plant as the planting distance increased from 20 to 80 cm. The increase reached 97.33 g (126.90 %).

From these results it may be concluded that the plants had heavier fresh and dry weights of leaves when they were grown at wider distances. Planting *Rosmarinus officinalis* at 80 cm resulted in greater leaves dry weight. They were more than double compared with 20 cm. This may be due to the increment in the number of branches / plant bearing more leaves

These results were in agreement with those of El-Gamassy *et al.* (1973) on sweet marjoram plant, concluded that the wide distance increased the fresh and dry weights of leaves per individual plant. Also, El-Sharkawy (1976) on marjoram plant, found that the mean weights of leaves produced from the plants were heavier with the wide spacing than the narrow one.

***7. Essential oil percentage in fresh herb*:**

The oil percentages in fresh herb are shown in Table 7. It can be noticed, generally, that increasing the planting distances between the plants resulted in an increment in oil percentage in fresh herb. The plants grown at 80 cm had, in both cuts in the first season, the highest oil percentages (0.26 and 0.27 % in the first and second cuts, respectively). However, planting rosemary plants at 20 cm led to the least oil percentage in both cuts (0.20 and 0.18% in the first and second cuts, respectively). There was an exception in the second cut of the first season i.e., increasing the distance from 30 cm to 40 cm decreased oil percentage in the fresh herb.

Table 7. Effect of planting distances (cm) on essential oil percentage in fresh herb of *Rosmarinus officinalis,* L., at 1998 and 1999 seasons.

Planting distances (cm)	1998		1999	
	1st Cut	2nd Cut	1st Cut	2nd Cut
20	0.20	0.18	0.18	0.19
30	0.21	0.21	0.21	0.22
40	0.22	0.20	0.20	0.21
60	0.24	0.25	0.25	0.27
80	0.26	0.27	0.27	0.28
L.S.D at 0.05	**0.03**	**0.05**	**0.04**	**0.05**

In the second season, a similar trend was observed. In the first cut, the plants cultivated at 80 cm contained more oil percentage (0.27 %) than those grown at 20 cm (0.18 %). In the second cut, the highest oil percentage (0.28

%) was determined in the fresh herb of the plants grown at 80 cm apart. While, the least oil percentage (0.19 %) was found in the fresh herb of the plants cultivated at 20 cm.

The high percentages of essential oil in the fresh herb of the plants grown at wide distances (80 and 60 cm) may be due to the favorable conditions for growth leading to more metabolisms of primary and secondary products of rosemary plant.

***8. Essential oil percentage in fresh leaves*:**

As shown in Table (8) the planting density affected adversely the oil percentage in fresh leaves of rosemary. The narrow spacing (20 cm) led to the formation of the least oil percentage in the fresh leaves, while the wide planting (80 cm) caused the synthesis of the highest percentages of essential oil in the fresh leaves, in both seasons.

Table 8. Effect of planting distances (cm) on essential oil percentage in fresh leaves of *Rosmarinus officinalis,* L., at 1998 and 1999 seasons.

Planting distances (cm)	1998		1999	
	1st Cut	2nd Cut	1st Cut	2nd Cut
20	0.25	0.22	0.24	0.23
30	0.26	0.24	0.28	0.25
40	0.27	0.26	0.29	0.27
60	0.29	0.28	0.30	0.29
80	0.31	0.30	0.33	0.31
L.S.D at 0.05	**0.04**	**0.06**	**0.05**	**0.06**

In the first season, the oil percentages ranged, in the first cut, from 0.25 to 0.31 %. There was a steady increment in the oil percentage as the distances increased. In the second cut, the same trend was observed. The averages of oil percentage were between 0.22 and 0.30 % for the plants grown at 20 and 80 cm respectively. In the second season, a similar trend same as that of the first one was observed, i.e., increasing the distances between the plants led to an increment in the oil percentage. These results were in agreement with those obtained by Kandeel (1982) on chamomile, indicated that the oil percentage was high with wide spacing compared to that obtained with the narrowest one.

Also, Galambosi *et al.*(1998) indicated that the highest oil percentage (2.4 %) of mint was obtained with 30 cm spacing between the plants in a row and 50 cm between the rows. Khater *et al.* (1993) on geranium showed that the wide spacing gave an increment in the percentage of volatile oil.

9. Essential oil yield of fresh herb (ml/ plant):

Oil yield/ plant were significantly influenced by planting density as it can be noticed in Table 9. In both seasons the widest spacing resulted in the highest oil yield/ plant. In the first season, the plants at the first cut produced oil ranging from 0.414 ml/ plant at 20 cm spacing to 1.014 ml/ plant for 80 cm spacing. The increment was 144.9 %. In the second cut the plants grown at 80 cm gave the greatest oil yield/ plant (0.918 ml), whereas those cultivated at 20 cm produced the least oil yield (0.337 ml/ plant). The increase was 172.4%. In the second season, a similar trend was observed. There was a steady increase in oil yield owing to the augmentation of planting distances. The increment in oil yield/ plant as a result of wider spacing may be attributed to the heavier fresh weight of the plants as well as the higher oil percentage in the herb.

Table 9. Effect of planting distances (cm) on essential oil yield of fresh herb (ml)/ plant of *Rosmarinus officinalis,* L., at 1998 and 1999 seasons.

Planting distances (cm)	1998		1999	
	1st Cut	2nd Cut	1st Cut	2nd Cut
20	0.414	0.337	0.393	0.368
30	0.482	0.437	0.553	0.486
40	0.633	0.472	0.600	0.559
60	0.745	0.715	0.812	0.788
80	1.014	0.918	1.095	1.004
L.S.D at 0.05	**0.001**	**0.001**	**0.001**	**0.001**

10. Essential oil yield of fresh leaves (ml/ plant)

Data exhibited in Table 10 show that leaves oil yield (ml) / plant increased as the distances increased in both seasons. In the first cut of the first season, the highest oil yield/ plant (0.881 ml) was produced by the plants cultivated at 80 cm apart. While, the least oil yield (0.358 ml) was formed by the plants grown at 20 cm. There was a gradual increase in the oil yield of fresh leaves (ml)/ plant as the distance increased from 20 to 80 cm. In the second cut, a similar trend was observed, i.e., the highest oil yield (0.857 ml/ plant) was obtained with planting at 80 cm, while at 20 cm the yield was 0.318 ml/ plant. A steady increment occurred by increasing the planting distance from 20 to 80 cm. The differences between all treatments were significant.

In the second season, same as in the first one, the widest distance (80 cm) led to the highest oil yield of fresh leaves (ml/ plant). The lowest yield resulted from the narrowest planting distance (20 cm). The values ranged, in the first cut, from 0.355 to 0.893 ml/ plant for 20 and 80 cm, respectively. In

Table 10. Effect of planting distances (cm) on essential oil yield of fresh leaves (ml)/plant of *Rosmarinus officinalis,* L. at 1998 and 1999 seasons.

Planting distances (cm)	1998		1999	
	1st Cut	2nd Cut	1st Cut	2nd Cut
20	0.358	0.318	0.355	0.343
30	0.423	0.392	0.470	0.418
40	0.550	0.532	0.611	0.568
60	0.672	0.651	0.725	0.685
80	0.881	0.857	0.893	0.899
L.S.D at 0.05	**0.002**	**0.001**	**0.001**	**0.001**

the second cut, the averages were 0.343 and 0.899 ml/ plant for the distances 20 and 80 cm, respectively.

11. Photosynthetic pigments:

As shown in Table 11, it can be observed that increasing planting distances, in both seasons, increased steadily photosynthetic pigments content.

Concerning to chlorophyll (a) content, it was highest in the plants grown at 80 cm. The values were 0.48 and 0.42 mg/ g fresh leaves for the plants of the first and second seasons, respectively. However, the least chlorophyll (a) content was determined in the leaves of the plants cultivated at 20 cm apart. The figures recorded were 0.25 and 0.20 mg/ g in the first and second seasons, respectively.

Regarding chlorophyll (b) content, it can be noticed that increasing the distance between the plants led to an increment in its content. Planting at 20 cm resulted in the least amount (0.19 and 0.20 mg/g) in both seasons, respectively. However, cultivation at 80 cm increased chlorophyll (b) content to its maximum (0.37 and 0.31 mg/ g) in both seasons, respectively.

The total chlorophylls (a + b) content increased steadily as the distance of planting increased, i.e. the least values (0.44 and 0.40 mg / g) were determined in fresh leaves of the plants grown at 20 cm, while the greatest content (0.85 and 0.73 mg/ g) was detected in the plants cultivated at 80 cm, in both seasons, respectively.

Concerning to carotenoids content, there was a continuous increase in carotenoids content with the increase in planting distances. The least amount in both seasons (0.12 and 0.13 mg/ g) was found in the fresh leaves of the plants grown at 20 cm, whereas the highest values (0.30 and 0.32 mg/ g) were determined in the plants cultivated at 80 cm, in both seasons, respectively.

Table 11. Effect of planting distances (cm) on photosynthetic pigments (mg/ g) in fresh leaves of *Rosmarinus officinalis,* L., in the first cut at 1998 and 1999 seasons.

Planting distances (cm)	Chlorophyll						Carotenoids	
	a		b		a+b			
	1998	1999	1998	1999	1998	1999	1998	1999
20	0.25	0.20	0.19	0.20	0.44	0.40	0.12	0.13
30	0.38	0.24	0.28	0.24	0.66	0.48	0.19	0.20
40	0.40	0.28	0.31	0.28	0.71	0.56	0.26	0.27
60	0.45	0.35	0.33	0.30	0.78	0.65	0.28	0.30
80	0.48	0.42	0.37	0.31	0.85	0.73	0.30	0.32
L.S.D at 0.05	**0.09**	**0.10**	**0.08**	**0.07**	**0.08**	**0.10**	**0.05**	**0.90**

These increments in photosynthetic pigments, caused by increasing planting distances, may be attributed to more growing area for the plants, i.e. more available water, sun light and minerals leading to more synthesis of these pigments. These results were in agreement with those found by Radwan (1988) on *Tagetes erecta,* showed that the carotenoids percentage and content per plant were increased by increasing the spacing between plants, Abd El-Salam (1992) on *Pimpinella anisum*, reported that the chlorophylls (a, b and total chlorophylls) as well as carotenoids were increased by increasing the spacing between plants from 20 to 80 cm.

12. Total carbohydrates percentage in the herb:

Data shown in Table 12 revealed that total carbohydrates content in herb of rosemary increased steadily, in both seasons as the distance between the plants increased. In the first season, the percentage of total carbohydrates in the herb ranged from 30.64 to 51.01 % in the first cut for the plants cultivated at 20 and 80 cm, respectively. In the second cut, of the same season, the values were 30.86 % in the herb of the plants grown at 20 cm and 55.30 % in the plants cultivated at 80 cm. In the second season, the greatest total carbohydrates content was determined in the plants grown at 80 cm. The values were 50.43 and 52.79 % in the first and second cuts, respectively. However, the least total carbohydrates percentage was found in the plants cultivated at 20 cm. The recorded values were 31.19 and 32.41 % in the first and second cuts, respectively.

These increases in total carbohydrates content in the herb of rosemary plant as the density of cultivation decreased may be due to the increase in photosynthetic pigments content as already mentioned, as well as the more available water, sunlight and minerals, consequently more production of carbohydrates. These results were in agreement with those found by El-Shaer (1989) on fennel, concluded that increasing the spacing

between plants from 15 to 25 cm increased significantly the total sugars percentage and Abd Elsalam (1992) on *Pimpinella anisum,* found that increasing the spacing between plants from 20 to 80 cm increased the total carbohydrates content in the herb.

Table 12. Effect of planting distances (cm) on total carbohydrates percentage in herb of *Rosmarinus officinalis,* L., at 1998 and 1999 seasons.

Planting distances (cm)	1998		1999	
	1st Cut	2nd Cut	1st Cut	2nd Cut
20	30.64	30.86	31.19	32.41
30	33.74	34.01	36.18	36.80
40	40.53	40.14	38.28	39.90
60	44.24	49.80	39.14	43.20
80	51.01	55.30	50.43	52.79
L.S.D at 0.05	**10.07**	**12.12**	**10.10**	**11.70**

13. Nitrogen percentage:

Data in Table 13, show that in both seasons the percentage of nitrogen increased as the distance between the plants increased.

In the first season, the plants in the first cut had 1.72 % N when they were grown at 20 cm apart. This percentage increased gradually to 1.92, 2.14 and 2.51 % as the spacing between the plants was 30, 40 and 60 cm, respectively. The highest N percentage (3.10 %) was determined in the plants cultivated at 80 cm. In the second cut of the first season, the same trend was observed, as in the first cut. There was a steady augmentation in N percentage with the increase in planting distance.

Table 13. Effect of planting distances (cm) on nitrogen percentage in herb of *Rosmarinus officinalis,* L., at 1998 and 1999 seasons.

Planting distances (cm)	1998		1999	
	1st Cut	2nd Cut	1st Cut	2nd Cut
20	1.72	1.67	1.21	1.36
30	1.92	1.81	1.43	1.65
40	2.14	1.87	1.67	1.96
60	2.51	2.19	2.17	2.15
80	3.10	2.40	2.37	2.49
L.S.D at 0.05	**0.98**	**0.95**	**0.97**	**0.85**

In the second season, planting rosemary at 20 cm apart resulted in the least N percentage (1.21 %) in the first cut. There was a linear increment in N percentage with the increase in planting distances. The values were 1.43, 1.67

and 2.17 % for the distances 30, 40 and 60 cm, respectively. The maximum N percentage (2.37%) was found in the herb of the plants grown at 80 cm.

In the second cut of the second season, the same trend was found as in the first cut.

14. Phosphorus percentage

Data in Table 14 show that there was a steady increment in P percentage with the increase in planting distances from 20 to 80 cm in both seasons.

In the first season, the plants in the first cut had 0.29 % P when they were cultivated at 20 cm. This value increased gradually to 0.33, 0.39 and 0.41 % with the distances 30, 40 and 60 cm, respectively. The maximum P percentage (0.42 %) was determined in the herb of the plants grown at 80 cm.

In the second cut, of the same season, the same trend was found. In the second season, the plants in the first cut contained the least P percentage (0.26 %) when they were grown at 20 cm. There was a linear increment with increasing the distances between the plants. The values were 0.31, 0.37 and 0.38 % for the plants at 30, 40 and 60 cm apart, respectively. The highest percentage of P (0.39%) was determined in the herb of the plants cultivated at 80 cm.

Table 14. Effect of planting distances (cm) on phosphorus percentage in herb of *Rosmarinus officinalis,* L., at 1998 and 1999 seasons.

Planting distances (cm)	1998		1999	
	1st Cut	2nd Cut	1st Cut	2nd Cut
20	0.29	0.21	0.26	0.29
30	0.33	0.32	0.31	0.35
40	0.39	0.35	0.37	0.37
60	0.41	0.36	0.38	0.51
80	0.42	0.40	0.39	0.52
L.S.D at 0.05	**0.06**	**0.09**	**0.07**	**0.10**

In the second cut of the same season, the widest planting distance resulted in the greatest P percentage in the herb (0.52%). However, the narrowest spacing (20 cm) led to the least P percentage (0.29 %). The other distances 30, 40 and 60 cm led to the percentages 0.35, 0.37 and 0.51 %, respectively.

15. Potassium percentage

The data in Table (15) show that there was an increment in potassium percentage as the distance between the plants increased, in both seasons.

In the first season, the herb in the first cut contained 1.95 % K when the plants were cultivated at 20 cm. It increased steadily to 2.10, 2.30 and 2.96 % at the distances 30, 40 and 60 cm, respectively. The highest K percentage (3.17 %) was determined in the herb of the plants grown at 80 cm.

In the second cut of this season the same trend was found. In the second season, in the first cut, the narrowest distance (20 cm) resulted in the least K percentage in the herb (2.53 %). The values ranged from 2.61 to 2.91 % for the distances 30 and 60 cm, respectively. The maximum K percentage (3.65 %) was determined in the herb of the plants grown at 80 cm apart. In the second cut of the second season, the same trend was found.

From the results of the effect of planting distances on elements content in the herb of rosemary, it may be concluded that increasing the cultivation distance led to an increase in the uptake of N, P and K by the plants. This may be due to the increasing area surrounding each plant, resulting in more growth and spread of roots, less competition between the plants, consequently more availability of these elements to the plants. These results were in agreement with those found by El-Gamassy and Sadek (1981) on caraway indicated that N, P and K content/ plant increased as the planting distances were increased. El-Shaer (1989) on fennel found that the concentrations of N, P and K in the leaves were increased by increasing the spacing between the plants. Abd El-Salam (1992) on *Pimpinella anisum* indicated that the concentrations of N, P and K in the plants were increased by increasing the spacing between the plants.

Table 15. Effect of planting distances (cm) on potassium percentage in herb of *Rosmarinus officinalis,* L., at 1998 and 1999 seasons.

Planting distances (cm)	1998		1999	
	1st Cut	2nd Cut	1st Cut	2nd Cut
20	1.95	2.17	2.53	2.54
30	2.10	2.34	2.61	2.57
40	2.30	2.62	2.81	2.63
60	2.96	2.83	2.91	2.73
80	3.17	3.43	3.65	2.97
L.S.D at 0.05	**0.95**	**0.91**	**0.90**	**0.29**

Conclusively, the highest values of all recorded parameters were produced from cultivation of the plants at the widest distance (80 cm between the plants in the row). Whereas the lowest values of all recorded characters were obtained from cultivation at the narrow distance (20 cm between the plants in the row). The opposite was found with plant height in the two seasons.

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تأثير مسافات الزراعة على النمو والمحصول وإنتاجية الزيت الطيار والتركيب الكيماوي في نبات الحصا لبان

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هذه التجربة نفذت في مزرعة قسم بحوث النباتات الطبية والعطرية بالقناطر الخيرية، معهد بحوث البساتين- مركز البحوث الزراعية، في عامين متتالين ١٩٩٨-١٩٩٩. وذلك بهدف دراسة تأثير مسافات الزراعة على النمو والمحصول وإنتاجية الزيت الطيار والتركيب الكيماوي في نبات الحصا لبان.

زرعت نباتات التجربة على مسافات ٢٠، ٣٠، ٤٠، ٦٠، ٨٠ سم، من بعضها في سطور تبعد عن بعضها ٣٠سم. و سمدت النباتات بالسماد الكيماوي NPK بمعدل ١٥٠ كجم N من سماد نترات الأمونيوم (٣٣.٥%ن)، ٥٠ كجم P من سماد سوبر فوسفات الكالسيوم الأحادي (١٥,٥ % فو٢أ٥)، ٣٠ كجم K من سماد سلفات البوتاسيوم (٤٨% بو٢أ)/فدان. و كانت أهم النتائج التي تم التوصل إليها كالآتي: الزراعة الكثيفة على مسافة ٢٠ بين النباتات أدت إلى الحصول على أكبر ارتفاع للنبات، بينما زيادة مسافات الزراعة من ٢٠سم حتى ٨٠سم أدت إلى نقص مستمر في ارتفاع النبات في حين أن الزراعة على مسافة ٨٠سم بين النباتات في السطر أدت إلى الزيادة في عدد الأفرع/نبات والوزن الطازج والجاف للأوراق والعشب/نبات وكذلك أعلى نسب مئوية للزيت العطري وأكبر محصول من الزيت العطري في الأوراق والعشب الطازج/نبات كذلك زيادة مسافات الزراعة من ٢٠ الى ٨٠ سم أدت الى الزيادة في محتوى النبات من الكلوروفيلات (أ، ب، الكلية) والكاروتينات والكربوهيدرات الكلية والنيتروجين والفوسفور والبوتاسيوم في كلا الموسمين فمن الواضح جداً أن أعلى القيم من جميع الصفات السابقة نتجت من الزراعة على المسافات الواسعة (٨٠ سم بين النباتات في السطر) بينما أقل القيم من جميع الصفات السابقة نتجت من الزراعة على المسافة الضيقة (٢٠ سم بين النباتات داخل السطر الواحد) بينما وجد العكس بالنسبة لصفة ارتفاع النبات في كلا الموسمين.