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THE EFFECT OF PLANT DENSITY AND CUTTING HEIGHT ON THE YIELD OF MARJORAM (*ORIGANUM SYRIACUM L.*) *UNDER OPEN FIELD CONDITIONS*

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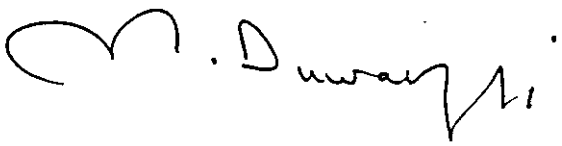
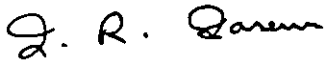
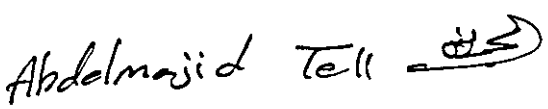
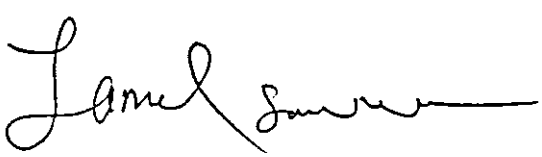
1. Prof. Mahmud Duwaryi (Chairman of committee)	
2. Dr. Jamal.R.Qasem (Co-advisor)	
3. Prof. Abdelmajid Tell (Member of committee)	
4. Dr. Jamal Sawwan (Member of committee)	
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I PROUDLY DEDICATE

THIS THESIS TO:

The memory of my grandfather, his holiness Sheik Younis Abu Al-Rub whose spirit has encouraged me to contribute something to the edifice of science.

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ABSTRACT

THE EFFECT OF PLANT DENSITY AND CUTTING HEIGHT ON THE YIELD OF MARJORAM (*ORIGANUM SYRIACUM L.*) *UNDER OPEN FIELD CONDITIONS*

By

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This research was carried out at Jubeiha Agricultural Research Station during 1994/1995 growing season and aimed to study the effect of plant density (5.3, 3.3, 2.4 and 1.9 plants/m^2) and cutting height (3, 7, 11 and 15 cm) from soil surface on growth and yield of marjoram (*Origanum syriacum* L.) grown under irrigation and field conditions. The experiment was conducted in a two factors factorial arrangement in a randomized complete block design (RCBD) with four replicates.

Increasing plant density from 1.9 to 5.3 plants/m^2 resulted in a significant increase in the total fresh and dry yield, fresh and dry yield of leaves, and number of leaves and total branches per unit area. Total dry yield was 125.3 g/m^2 for 5.3 plants/ m^2 and 43.2 g/m^2 for 1.9 plants/m^2. Effect of cutting height on fresh and dry yield of the plant was only pronounced at the second harvest, at which 7 cm cutting height gave the highest dry yield (29.9 g/m^2) as compared to 17.0 g/m^2, the yield obtained from 15 cm cutting height. No significant differences were found among different cutting treatments at the third harvest.

I. INTRODUCTION

The world is experiencing a marked progress (i.e., quality and quantity) in the cultivation of medicinal and aromatic plants primarily for utilization in medicines as well as in food industries. These plants serve mainly as substitutes to synthetic chemicals, food preservatives and additives, which proved to have adverse effects on human life (1).

Among the aforementioned plants, marjoram (*Origanum syriacum* L.) is an important species of the Labiatae family, originated in the Mediterranean region. The locals call this species by its popular name "Za'tar". It has a prominent position among medicinal and aromatic plants in Jordan, and utilized for several industrial purposes, such as, culinary, pharmaceutical and cosmetics. Furthermore, its dried and fresh leaves are used excessively for human consumption in pies and bread forms (2).

In the last few decades, Jordanians depended heavily on wild marjoram, collected from mountainous areas and other natural habitats. This practice may affect the spread and the natural population of wild plants and may lead to its extinction. However, the rapid movement toward urbanization on the expense of arable land coupled with over grazing plays a role in this regard (3,4).

Recently, the high demand on marjoram, and its economic return drew the attention of some growers to direct their efforts toward its efficient cultivation. This resulted in an increase in local production from 17 tones in 1989 to 176 tones in 1993. Consequently, this action was reflected in the following points:

- Reduction in the imported amount of the fresh marjoram from 150 tones in 1989 to 5.9 tones in 1993, and
- Reduction in the imported amount of dried marjoram from 602 tones in 1992 to 320 tones in 1993.

As a result, and in order to protect Jordanian farmers efforts and products, the Agriculture Marketing Organization issued a law prohibiting its importation starting July 1994 (5).

Until now, there are no statistics concerning the total area cultivated with marjoram, except those concerned with cultivation by the Medicinal and Aromatic Plants Project which has been adopted and supported by Nour Al-Hussein Foundation. The total cultivated area under this project reached 14.65 hectares, with 210 families depending completely on this plant for their daily living. Since 1989 and within the framework of this project, systematic cultivation of marjoram has begun, as its first agricultural product, mainly due to: a) its excellent resistance to plant pathogens and insects which decrease the need for pesticide. b) its ability to withstand adverse environmental conditions, and c) high plant productivity and excellent market prices due to high customer demand (6).

Studies on the suitable cultivation practices and productivity of this species are very limited, in spite of the interest in growing marjoram in Jordan. Thus the objectives of the present research were to:

1- Specify the suitable plant density, in terms of number of plants per unit area.
2- Specify the suitable cutting height and its effect on production.
3- Study the response of marjoram to both planting density and cutting height under irrigation conditions.

4- Study the effect of the two factors on certain growth parameters.

5- Lay the basis for future studies concerning marjoram species, and to provide some needed answers to important questions being raised by local farmers and marjoram producers.

II. LITERATURE REVIEW

Marjoram (*Origanum syriacum* L.) is a perennial herb, grows in rocky soils. Its stems are erect up to 50 cm high, ending in pure white spike-like inflorescence, leaves are petiolated, entire, oval, and dark green (7).

It has been highly regarded as a medicinal plant, used to treat respiratory tract diseases, colds, cough, even toothaches; and for its pleasing odor and flavor, Arabs tend to consume the leaves in many forms in their daily diet (8,9 and 10).

Literature on cultivation of marjoram are very limited. The only existing studies consist of a number of recommendations based on observations and scattered data published by some interested Jordanian organization such as Nour Al-Hussein Foundation, which recommended to plant marjoram at a density of 20000-25000 seedlings per hectare; distance between rows 80-100 cm; and 50 cm between plants in open field. Under plastic-house conditions density of 35000 seedlings per hectare was reported. Cutting height was recommended at 7 cm from soil surface for maximum number of lateral branches (6).

In Palaestine, the Arab Scientific Institute for Research and Technology Transfer (ASIR), recommended to plant marjoram at a density of 70000 seedlings per hectare, with a distance of 35 cm between plants and 40 cm between rows. They reported to cut plants at a height of 15 cm from the soil surface (11).

However, in Egypt, Cairo University published a text book on medicinal and aromatic plants, based on gathered recommendations and observations on planting and cultivation of this group of plants. They prefer to use high planting density for marjoram, the hectare required 62500 seedlings, where the distance between plants and rows is 40 cm . They recommended to cut the plant at a height of 5-10 cm from soil surface to encourage its revegetation (12).

It's worth mentioning another species: *Majorana hortensis* L. called by its Arabic name "Mardagoosh" , belongs to the Labiatae family and is considered very close to Marjoram. This species has acquired lightened awareness in Egypt, where its morphological characteristics have been studied by Sahhar *et al.* (13). They found that plant height gradually increased up to 30 weeks after planting reaching a height of 38.7 to 42.4 cm, after which no significant increase occurred. The highest increase in the number of branches took place at 24-26 weeks after planting and giving 11.6 branches per plant. Fresh and dry weight of both stems and leaves reached their maximum values at 34 weeks, the stems fresh weight per plant was 11.7 g and of leaves 22.3 g, while dry weight of the stems was 4.6 g and 7.9 g for leaves (13).

1- Plant Density

Awad and Kamel (14) studied the effect of planting distance on growth and yield of *Majorana hortensis*. They used 20, 40 and 60 cm between plants in row, and 1 meter between rows.

1.1- Plant height

Awad and Kamel (14) found no significant differences in plant height as a result of planting distance treatment, although taller plants were produced at wider distance. This was explained by more resources available for plants, which led to more vegetative growth and stem elongation.

1.2- Number of branches

Increasing planting distance resulted in an increase in the number of branches produced per plant, since wider distances encouraged branching initiation and development on the plant (14). Moreover, number of branches per plant increased as plants advanced in age, at which in the second year, higher number of branches were obtained compared with the first year crop (13 and 14).

1.3-Fresh weight

Fresh weight per plant increased with planting distance . It was reported yield of 201.9, 278.6 and 338.2 g/ plant at 20, 40 and 60 cm planting distance, respectively. This was explained by more resources available for plants to utilize at wider distance, and to express their full vegetative growth by more production of branches per plant. However, higher yield per plant was obtained in the second rather than the first year of planting (14).

Results of other studies showed that fresh weight per unit area increased as plant number was increased (15 and 16).

1.4- Fresh weight of leaves

Increasing planting distance significantly increased fresh weight of leaves per plant. It was 140.5 g/plant at 60 cm distance and 88.7 g/ plant

at 20 cm (14).

Bisher (15) and khalil (16) stated that fresh and dry weight of leaves of closer planting were greater than wider ones per unit area. This was explained by increase in plants number as planting distance decreased .

1.5- Dry weight

Dry weight per plant increased with planting distance, by up to 36 % at wider compared with closer distance (14). However, dry weight per unit area decreased as plant density was reduced (15 and 16). This however, was found to depend on the time at which cutting was done (14 and 15).

2-Cutting Height

The lack of information on cutting height could be due to less attention given by researchers to these plants, since they were more concerned with other important crops for human consumption. These plants were studied by chemists and pharmacologists from their medicinal point of view, while less, if no attention was given to them by agronomist. Furthermore, they were not planted on a large scale, for any commercial purposes, thus there is a lack of information concerning their methods of planting and cultivation. Nowadays, farmers become more concerned in planting this species, which would raise many inquires concerning this plant.

As mentioned earlier, this study was carried out to investigate the effect of density and cutting height on the growth and productivity of *Origanum syriacum* L. and aimed to give a scientific basis for cultivating and commercially producing one of the widely used medicinal herb.

III. MATERIALS AND METHODS

1- Site of Study

This experiment was conducted at Jubeiha Station, located at University of Jordan Campus, north-west of Amman with longitude 35° 51'E, latitude 32° 01' and 980 m altitude. Climate is Mediterranean; characterized by cold rainy winter and dry hot summer, other relevant weather data are shown in Table 1 (Appendix A). The soil is fine, loamy, and its analysis is shown in Table 2 (Appendix A).

2- Land Preparation

Two plowing operations were done, one by chisel to a depth of 20 to 25 cm then followed by rotary cultivator to mix the manure and leveling soil surface. Prior to planting, farmyard manure was added at a rate of 10 tones/ha, then compound chemical fertilizer (20,20,20 & 1.5 trace element) was side dressed using 1 ton/ha, followed by urea fertilizer (46 % N) at a rate of 100 kg/ha applied at the second and third harvest to enhance revegetation.

3- Plant Cultivation

Four month old marjoram seedlings with an average height of 17.9 cm were obtained from Nour Al Hussien Foundation. Hardening of seedlings before transplanting was accomplished by exposing them to low temperature, and to adapt them to field conditions during winter season.

Transplanting was carried out to the experimental plots on 20th October, 1994. Each plot was 4.5 * 2.2 m and consisted six rows, the outer ones considered as a border lines.

Plants were grown under irrigation using drip irrigation system. However, irrigation intervals and amount of water added were adjusted to maintain optimum moisture availability, and the total amount of water used was 1000 m^3/ha during the whole growing season.

Red spider was controlled by a systemic insecticide (Dicofol) and fungal wilt by (Hymexazol) as a protector, while hand-weeding was practiced when needed and throughout the whole growing season (17).

Three cuttings were done during the whole growing season; the first was on 19th, November, 1994 to enhance lateral growth, while the second and the third harvests were on 30th April and 30th July, 1995, respectively. After the first cut, the soil was piled in a practice called " Radi " around each plant in order to encourage branching at low heights (18).

4- Treatments

Two factors were studied:

4.1- Plant Density

Four planting densities were used, these were **5.3, 3.3, 2.4** and **1.9** plants/m^2 and managed by changing the distance between plants in one row to be: **25, 40, 55**, or **70** cm respectively, while distance between rows was kept constant at **75** cm for all treatments.

4.2- Cutting Height

Plants were cut at a height of **3, 7, 11,** or **15** cm from the soil surface At the date of each harvest.

5- Data Collection

The traits of the plant at harvesting date were studied on five plants labeled randomly from the middle four rows of each plot, and the following measurements were taken:

- Plant height (cm): Length of the highest branch from the soil surface to the top.
- Number of main basal branches per m^2.
- Number of all other harvested branches per m^2.
- Number of leaves per m^2.
- Plant fresh and dried weight/ m^2 (oven dried at 70° C for 24 h).
- Fresh and oven dried leaves weight/ m^2.
- Leaves/branches ratio: The ratio of leaves' weight to the total plant weight (branches & leaves).
- Total yield: Summation of fresh or dried weights of leaves and of the whole plant at the three harvests.

6- Experimental Design and Data Analysis

All possible combinations of the two factors (density & cutting height) were arranged in a factorial experiment and laid out in a randomized

complete block design (RCBD) with four replicates. The layout of experiment is shown in Fig 1 (Appendix A).

All data were subjected to statistical analysis following the general linear model procedure (GLM) of SAS system according to Steel and Torrie (19), and treatments means were compared using the least significant differences (LSD) at P = 0.05.

Analyses of variance of the whole data are shown in Tables 1 to 10 (Appendix B).

VI. RESULTS AND DISCUSSION

In the present study the effect of plant density and cutting height on height, number of basal and total branches, number of leaves, fresh and dry weight of leaves and of the whole plant, and leaves/ branches ratio were determined for marjoram grown under irrigation and open field conditions. Statistical analysis of the data and treatments means arrangement are shown in Tables 1-10.

It was noticed that, there was no interaction between the two factors (density and cutting height), especially at the second and third harvest, which means that each of them acts separately and independently.

A) Plant Height

The effect of plant density and cutting height on marjoram height measured at three harvest dates is shown in Table 1.

A.1- Plant Density

The differences obtained in marjoram height at the first harvest, were not due to the effect of any treatment. This harvest was done to standardized plants height. However, at the second and third harvests, differences in plant height at different density treatments were not significant. These results agreed with those reported by Awad and Kamel through their work with *Majorana hortensis* (14).

Table 1. Effect of density and cutting height on marjoram height (cm) taken at three harvests.

Cutting Height (cm)	Plant Density (plants/m^2)				Mean
	5.3	3.3	2.4	1.9	
First Harvest					
3	18.2	21.7	19.3	20.4	19.9
7	19.0	18.1	21.3	20.4	19.7
11	18.1	18.3	17.6	19.4	18.4
15	19.4	18.5	17.4	18.1	18.3
					Means LSD*
Mean	18.7	19.2	18.9	19.6	0.6
Second Harvest					
3	26.6	24.5	22.0	21.5	23.7
7	28.0	24.9	26.0	30.3	27.3
11	24.4	30.6	26.5	23.3	26.2
15	29.7	24.0	29.8	22.6	26.5
					Means LSD*
Mean	27.2	26.0	26.1	24.4	3.1
Third Harvest					
3	28.6	28.7	29.9	29.9	29.3
7	32.1	35.3	31.2	29.6	32.1
11	33.3	32.1	33.6	29.1	32.0
15	32.6	30.3	32.9	33.2	32.3
Mean	31.7	31.6	31.9	30.5	NS**

* Least significant differences values were calculated at P = 0.05. **NS: not significant

Plants at high densities were taller than those in the other treatments, although differences were not significant. This may be due to mutual shading effect of dense marjoram populations and plants elongated to trap light.

Plants grown under shading conditions usually have an elongated internodes (20), or may exhibit phenotypic plasticity to adapt themselves to such conditions.

A.2- Cutting Height

The differences in plant height at the first harvest were not due to differences between treatments, while the effect of cutting height was better demonstrated in later harvests.

Low cutting height enhanced plants regrowth, at least one of its branches, to a height which is not significantly different from other cutting treatments. This may be due to the fact that apex removal had encouraged the growth of new branches below the cut. These were juvenile and gave more vigorous growth than old branches (21).

It is worth mentioning, that these measurements were done only on the longest branch which is considered as an indicator on plant height.

B) Number of Basal Branches

The effect of plant density and cutting height on number of basal branches (originated at or under soil surface) per m^2 is shown in Table 2.

B.1- Plant Density

Seedlings produced through vegetative propagation showed an average of two to three branches per seedling at planting time. Thus, these planted at higher densities showed significantly higher number of basal branches than lower densities, this was for all harvests.

The highest number of basal branches was produced, at the first harvest, at 5.3 plants/m^2 and by cutting the plant at 7 cm height from soil surface.

An increase in basal branches number per m^2 up to 80.6% was obtained at the second compared with the first harvest.

Plant density of 5.3 plants/m^2 gave significantly higher number of basal branches compared with density of 3.3 plants/m^2, and the difference was 38.7% , which in turn gave significantly higher number of basal branches (up to 27.5%) than 2.4 density. Where 1.9 plant density show no significant differences from the 2.4 density. Under all cutting treatments 5.3 plants/m^2 was the highest.

Similar trend was obtained at the third harvest, at which 5.3 plants/ m^2 gave significantly higher number of basal branches (84.5 branch/m^2) than

Table 2. Effect of density and cutting height on number of basal branches /m^2 of marjoram at three harvests.

Cutting Height (cm)	Plant Density (plants/m^2)				Mean
	5.3	3.3	2.4	1.9	
First Harvest					
3	11.9	9.2	6.7	7.1	8.7
7	13.3	7.5	4.8	3.8	7.6
11	12.0	10.0	4.8	3.8	7.5
15	12.0	7.2	5.4	5.2	7.3
					Interaction
Mean	12.3	8.5	5.4	5.0	LSD 2.2
Second Harvest					
3	63.5	31.6	25.7	17.6	34.6
7	62.1	32.6	23.3	25.8	36.0
11	58.6	42.0	27.8	21.2	37.4
15	69.6	49.1	36.0	25.9	45.2
					Means LSD
Mean	63.5	38.9	28.2	22.9	7.4
Third Harvest					
3	87.2	48.0	39.1	25.2	49.9
7	74.6	50.0	35.2	32.4	48.1
11	80.3	50.3	39.7	30.5	50.2
15	95.7	54.0	44.9	36.3	57.7
					Means LSD
Mean	84.5	50.6	39.8	31.1	9.8

* Least significant differences values were calculated at P = 0.05.

other densities. This increase was 40.1% over 3.3 plants/m^2 , 52.9 % over 2.4 plants/m^2 and 63.2 % over 1.9 plants/m^2.

B.2- Cutting Height

The differences in number of basal branches obtained between treatments at the first harvest, were mainly due to variation in propagated seedlings.

The highest cutting (15 cm) gave significantly higher number of basal branches than other cutting treatments at the second harvest, and was 45.2 branch/m^2. While at the third harvest, there were no significant differences in basal branch number.

In general, the highest number of basal branch was produced at the highest density (5.3 plants/m^2) and cutting height of 15 cm from the soil surface rather than 3 cm, although differences were not significant.

Number of basal branches was not affected by cutting treatments, that may due to nature of marjoram, and its ability to develop certain number of basal branches without being affected by cutting.

C) Number of Total Branches

The effect of plant density and cutting height on the number of total branches per m^2 is shown in Table 3. Total number of branches refers to all branches cut at harvest time including basal branches.

C.1-Plant Density

The number of total branches per m^2 at the first harvest, was the same as shown in Table 2, indicating that at early growth stages all branches were basal. However, at the second harvest, plants had enough time for growth and development which was reflected as an increase in the number of total branches, and this increase was up to 93.2%.

The highest density (5.3 plants/m^2) gave the highest mean number of total branches and was 182.9 branch/ m^2, while differences between 3.3 and 2.4 plants/ m^2 were not significant, but both were significantly higher than the lowest density (1.9 plants/m^2).

Reduction in total branch number in response to plant density was noticed at the third harvest, at which 5.3 plants/ m^2 gave significantly higher mean number of total branches than 3.3 plants/ m^2 and up to 30.4%, and this gave 21.6 % more of total branches than 2.4 plants/m^2. However, the lowest density (1.9 plants/m^2) gave the lowest number of total branches.

C.2- Cutting Height

The effect of first cutting height treatment on number of branches was

Table 3. Effect of density and cutting height on total number of branches per m^2 of marjoram at three harvests.

Cutting Height (cm)	Plant Density (plants/m^2)				Mean
	5.3	3.3	2.4	1.9	
First Harvest					
3	11.9	9.2	6.7	7.1	8.7
7	13.3	7.5	4.8	3.8	7.6
11	12.0	10.0	4.8	3.8	7.5
15	12.0	7.2	5.4	5.2	7.3
					Interaction
Mean	12.3	8.5	5.4	5.0	LSD 2.2
Second Harvest					
3	208.8	89.8	95.8	51.2	111.4
7	148.2	116.8	111.3	95.6	127.0
11	171.2	145.5	73.1	61.5	112.8
15	167.2	83.5	87.6	42.5	95.2
					Means LSD
Mean	182.9	108.9	92.0	62.7	25.8
Third Harvest					
3	219.2	126.1	141.6	73.8	140.2
7	237.9	181.2	144.4	99.5	165.8
11	310.4	198.3	147.1	110.1	191.5
15	343.7	267.8	173.2	123.7	227.1
					Means LSD
Mean	277.8	193.4	151.6	101.8	38.4

* Least significant differences values were calculated at P = 0.05.

better demonstrated when the second cutting measurements were taken. The moderate cutting height (7 cm) gave significantly higher number of branches than 15 cm, and this increase was 25%, while no significant were found differences between 3, 7 and 11 cm cutting height.

Although there was no clear trend at this harvest, the lower cutting height (especially 7 cm) gave higher number of branches, and subsequently a higher yield.

Different trend was obtained at the third harvest. Number of harvested branches increased with cutting height, and higher number was obtained at 15 cm height (227.1 branch/ m^2) than at 3 and 7 cm, but both were not significantly different.

Results of the third harvest showed that at higher cutting, more number of branches were produced. This may be explained by that the height of cut determine the number of buds available for regrowth. The height of remaining stubble also determine number of leaves (photosynthetic parts) and stored carbohydrates left in the plants. On both accounts, a high cut will enhance regrowth (22). The lower number of branches obtained at higher cutting (15 cm) at the second harvest, may be due to that it is not subjected to cut effect (lower apex removal) as did lower cutting (3 cm).

D) Total Number of Leaves

The effect of plant density and cutting height on the total number of leaves produced per m^2 is shown in Table 4.

D.1-Plant Density

Significant interaction between the two factors was detected at the first harvest. The highest number of leaves per m^2 was produced at 5.3 plants/m^2 and by cutting plants at 7 cm from soil surface.

Similar trend was obtained at the second harvest, at which the highest density(5.3 plants/m^2) gave the highest number of leaves, which was 3051.7 leaves/m^2.

Number of leaves per m^2 was reduced at the third harvest compared with the second harvest which may be due to aging effect, since plant were at pre-flowering stage which resulted in a reduction in vegetative growth, and consequently in the number of leaves produced (20). However, the highest density (5.3 plants/m^2) gave higher number of leaves than 3.3 plants/m^2 and by 33%, 2.4 plants/m^2 by 49.5% and 1.9 plants/m^2 by 66.4%.

D.2- Cutting Height

Number of leaves increased with reduction in cutting height at the first harvest,, this might be due to the high number of leaves removed through cutting.

Table 4. Effect of density and cutting height on total number of leaves per m^2 of marjoram at three harvests.

Cutting Height (cm)	Plant Density (plants/m^2)				Mean
	5.3	3.3	2.4	1.9	
First Harvest					
3	181.3	143.3	72.1	63.3	115.0
7	130.6	85.0	53.3	43.8	78.2
11	104.0	73.3	49.7	49.5	69.1
15	80.0	43.3	29.1	23.8	44.2
					Interaction
Mean	123.9	86.3	51.4	45.1	LSD 14.6
Second Harvest					
3	3051.7	1276	1400.5	806.4	1633.7
7	2731.2	1619.0	1359.7	1326.1	1759.0
11	1921.6	155.7	898.4	645.3	1255.3
15	1907.2	845.0	982.5	339.5	1018.4
					Means LSD
Mean	2402.8	1324.0	1160.3	779.3	332.6
Third Harvest					
3	1262.4	695.3	801.1	454.4	803.3
7	1668.3	1119.0	740.7	580.0	1026.9
11	1822.6	1168.0	817.1	552.0	1089.6
15	1724.0	1350.0	905.3	590.0	1142.2
					Means LSD
Mean	1619.0	1082.9	816.0	544.1	253.8

* Least significant differences values were calculated at P = 0.05.

Lower cutting heights (3 and 7 cm) resulted in higher number of leaves produced at the second harvest, and was significantly higher than 11 and 15 cm cutting heights.

Number of leaves at the third harvest, showed similar trend to that of total number of branches (Table 3), where number of leaves increased with cutting height. However, cutting marjoram at 15 cm gave significantly higher number of leaves than 3 cm by 29.7 %. It is clear that number of leaves produced is strongly related to the height and number of branches and leaves left on the plants.

E) Leaves Fresh Yield

Leaves are the main edible part of marjoram plant, used excessively for human consumption, thus their weight is a good indicator on plant productivity. The effect of plant density and cutting height on fresh yield of leaves is shown in Table 5.

Marjoram seedlings were left for a month after planting to be established then harvested. Results of the first harvest showed reduction in marjoram fresh weight per m^2 with reduced density and increasing cutting height. The highest fresh yield produced was at the highest plant density (5.3 plants/m^2). In addition, this density produced maximum fresh weight at 3 cm cutting heights, while the lowest density (1.9 plants/m^2) gave the lowest fresh weight. This was more pronounced at 15 cm cutting height.

E.1- Plant Density

E.1-1 Second Harvest

Significant differences were obtained between different plant densities, at which the highest density (5.3 plants/ m^2) gave significantly higher leaves fresh yield (136.4 g/m^2) than other densities. This increase was 43.7 % over 3.3 plants/m^2, 55.6 % over 2.4 plants/m^2 and 68.2 % over 1.9 plants/m^2. However, there were no significant differences between 3.3 and 2.4 plant density, or between 2.4 and 1.9 plants/m^2.

Table 5. Effect of density and cutting height on leaves fresh yield of marjoram (g/m^2) at three harvests.

Cutting Height (cm)	Plant Density (plants/m^2)				Mean
	5.3	3.3	2.4	1.9	
First Harvest					
3	6.8	3.0	3.0	2.3	3.8
7	6.2	3.0	2.1	2.0	3.3
11	4.0	2.7	1.9	1.8	2.6
15	4.4	2.1	1.4	1.1	2.3
					Interaction
Mean	5.3	2.7	2.1	1.8	LSD 0.6
Second Harvest					
3	166.3	73.2	69.4	39.7	87.2
7	173.7	83.1	68.2	75.7	100.2
11	104.7	104.1	45.1	30.3	71.1
15	100.8	48.0	59.8	27.7	59.1
					Means LSD
Mean	136.4	77.1	60.6	43.4	24.7
Third Harvest					
3	111.9	64.9	67.4	40.4	71.1
7	164.9	97.1	67.6	55.1	96.2
11	161.2	109.7	68.1	49.0	97.0
15	145.7	101.4	72.0	46.2	91.3
					Means LSD
Mean	145.9	93.3	68.8	47.7	28.3
Total Leaves Fresh Yield					
3	284.9	141.1	139.8	82.5	162.1
7	344.8	183.2	137.9	132.8	199.7
11	269.9	216.6	115.2	81.1	170.7
15	250.9	151.6	133.2	75.0	152.7
					Means LSD
Mean	287.6	173.1	131.5	92.8	44.6

* Least significant differences values were calculated at P = 0.05.

E.1-2 Third Harvest

The highest fresh yield of leaves was obtained where the highest plant density (5.3 plants/m^2) was used. This trend complied with the previous results of the first and second harvests.

Although, there was an increase in fresh weight of leaves at the third harvest and at all plant densities, but this was not as high as that obtained at the second harvest, which may be due to plant's tendency toward flowering on the expense of their vegetative growth.

E.1-3 Total Leaves Fresh Yield

Results show that, as the number of plants per unit area was decreased, the fresh yield of leaves was subsequently decreased, this was true to certain extent.

Fresh yield of leaves at 5.3 plant density was 287.6 g/m^2. It was higher than 3.3 plants/m^2 by 39.8 %, 2.4 plants/m^2 by 54.3 % and 1.9 plants/ m^2 by 67.7%.

E.2- Cutting Height

Removal of higher proportion of the plant, at the first harvest resulted in an increase in the number of leaves (Table 4). This was led to an increase in leaves fresh weight as cutting the plant at lower height. In general, highest yield was obtained at 3 cm cutting height treatment and at all densities.

E.2-1 Second Harvest

The influence of the first cut on leaves fresh yield was pronounced when the second harvest measurements were taken. The highest yield was

obtained at the moderate cutting treatment (7 cm), which was significantly higher than 11 cm by 29 % and 15 cm by 41 %, but not significantly different from 3 cm treatment.

E.2-2 Third Harvest

No significant differences for leaves fresh yield were found between different cutting treatments. Lower cutting (3 cm) height gave the lowest yield of leaves at this stage. low cutting may have exhausted the plant, even that, and by repeat cutting at the same height, this will substitute weakness of the growth by removing higher mass from the plants. However, this show no significant differences between lower cutting (3 cm) and other cutting treatments.

E.2-3 Total Leaves Fresh Yield

Considering the fresh yield of leaves throughout the growing season, higher yield was also obtained at 7 cm cutting height (199.7 g/m^2), compared with other treatments. This moderate cutting height was significantly better than 15 cm treatment, but show no significant differences from other cutting heights (3 and 11 cm), which gave higher number of leaves (Table 4).

F) Plant Fresh Yield

The effect of plant density and cutting height on fresh weight of marjoram is shown in Table 6.

Marjoram fresh yield was reduced with reduction in plant density and increasing cutting height at the first harvest. The lowest fresh yield was produced at 1.9 plants/m^2, and 15 cm cutting height.

F.1- Plant Density

F.1-1 Second Harvest

Fresh yield significantly decreased as plant density was decreased. However, 5.3 plants/m^2 gave the highest yield and was 192.8 g/m^2, and significantly higher than 3.3 plants/m^2 by 45.3 %, 2.4 plants/m^2 by 56.3 and 1.9 plants/m^2 by 68.3 %.

No significant differences were found when 3.3 and 2.4 plants/m^2 were used, and also between the lowest two densities (2.4 and 1.9 plants/m^2).

F.1-2 Third Harvest

Similar trend for the effect of density on fresh yield was obtained at this harvest, The highest density (5.3 plants/m^2) gave significantly the highest fresh weight than other densities, and was 219.0 g/m^2. The increase was

Table 6. Effect of density and cutting height on marjoram fresh yield (g/m^2) at three harvests.

Cutting Height (cm)	Plant Density (plants/m^2)				Mean
	5.3	3.3	2.4	1.9	
First Harvest					
3	8.0	3.9	3.7	3.1	4.7
7	7.2	3.6	2.7	2.3	4.0
11	4.8	3.3	2.3	2.2	3.2
15	5.4	2.8	1.7	1.4	2.8
					Interaction
Mean	6.4	3.4	2.6 c	2.2 c	LSD 0.8
Second Harvest					
3	264.7	103.1	99.8	59.2	127.2
7	248.6	115.3	96.2	111.6	142.9
11	136.3	144.0	59.9	39.0	94.8
15	139.6	59.72	81.0	35.0	78.8
					Means LSD
Mean	192.8	105.5	84.2	61.2	37.3
Third Harvest					
3	165.1	83.7	96.1	61.0	101.5
7	224.6	155.9	97.9	83.1	140.4
11	253.4	165.1	107.9	69.6	149.0
15	232.8	146.5	114.1	81.4	143.7
					Means LSD
Mean	219.0	137.8	104.0	73.8	47.8
Total Fresh Yield					
3	419.9	191.2	199.6	123.3	233.5
7	480.5	274.9	196.7	197.0	287.3
11	394.6	312.5	170.1	110.9	247.0
15	377.7	209.0	196.8	117.9	225.3
					Means LSD
Mean	418.2	246.9	190.8	137.3	70.2

* Least significant differences values were calculated at P = 0.05.

37.1% over 3.3 plants/m^2, 52.5 % over 2.4 plants/m^2 and 66.3% over 1.9 plants/m^2.

F.1-3 Total Fresh Yield

Marjoram fresh yield produced at all harvests is an important indicator required by growers to judge the economic value of its cultivation.

Reference to data presented in Table 6, significant differences in total yield were found under different planting densities. The highest fresh yield was obtained at the highest density (5.3 plants/m^2), it gave 40.9% more than 3.3 plant density, which in turn gave significantly higher yield than 1.9 plants/m^2 by 44.4%.

The increase in yield may be due to the increase in plant density which was reflected as an increase in the number of basal branches, total branches, leaves number and yield (Tables 2, 3, 4 and 5). Consequently the total yield per unit area was increased; especially in absence of competition between plants for water and nutrients. These results agreed with those reported by other workers (15 and 16).

Comparing marjoram fresh yield at three harvest dates, there was an increase in fresh yield with age. At first harvest, plants established their root systems, showed small vegetative growth, and thus very low yield was obtained.

At five months after the first harvest, plants were well established, produced good canopy, and thus an increase in yield was obtained. Three months after the second harvest, another flush of leaves was produced but this increment was not as much as the previous harvest, since plants were at flowering stage and most of the reserved food was directed toward the

production of flowers on the expense of vegetative growth (20), and this was the case at all planting densities.

F.2- Cutting Height

Results revealed that plant fresh yield was significantly decreased as the cutting height from the soil surface was increased at the first harvest. This may be due to that cutting plants at 3 cm above the soil surface, relatively removed higher proportion of vegetative parts compared with other cutting treatments (7, 11 and 15 cm).

F.2-1 Second Harvest

It was clearly shown that 3 and 7 cm cutting height weren't significantly different. Both gave higher fresh yield of marjoram than 15 cm, while cutting at 7 cm height was significantly better than 11 cm. The highest yield at the second harvest was obtained when plants were cut at 7 cm and was 142.9 g/m^2, which may be explained by the fact that number of total branches and leaves number and fresh yield were the highest at this cutting treatment (Tables 3, 4 and 5).

This moderate cutting treatment was better than others, especially at this stage since it allows better regrowth compared with the sever cutting treatment (3 cm). It was also better than higher cutting treatments (11 and 15 cm) in terms of number of total branches and leaves produced which finally lead to higher fresh yield.

F.2-2 Third Harvest

No significant differences were obtained between different cutting treatments. However, the very low cutting height (3 cm) gave the lowest

yield as a result of exhausted plants, and was negatively reflected on plants revegetation. On the other hand, moderate and high cutting heights maintained the plants and enhanced their regrowth in a way that all of them became not significantly different.

F.2-3 Total Fresh Weight

Although there were no significant differences between different cutting height treatments at this parameters, the 7 cm cutting height gave the highest yield (287.3 g/m^2) followed by 11 cm (247.0 g/m^2). Although, 15 cm cutting height had more stubble left behind and more buds available for regrowth, but 3 cm cutting treatment gave higher yield may because of the higher mass of plants removed.

Effect of cutting was more clear at second harvest, where the plant at first harvest showed only two to three branches not fully developed and seemed to be more affected by the first cut. In addition, cutting treatments had no effect on number of basal branches grown and produced as discussed before. However, after the second cut treatment lower cutting height effectively enhanced marjoram regrowth and yielded more than higher cutting treatment.

G) Fresh Leaf/Branch Ratio

This growth parameter could give a preliminary indication about the quality of the product. The effect of plant density and cutting height on leaf/branch ratio is shown in Table 7.

G.1- Plant Density

Density had no effect on the quality of yield at the second and third harvest as well as total yield. The main effect was at the first harvest at which 5.3 plants/m^2 gave the best quality at all cutting treatments.

In general, we can conclude that plant density have no effect on fresh leaf/branch ratio.

G.2- Cutting Height

Comparing the effect of cutting height treatments, on the leaf/branch ratio at three harvest dates, no symmetric trend was observed.

The best quality of marjoram was at 7 cm cutting height at the first and third harvest dates, while at the second harvest, 11 and 15 cm treatments gave the best quality.

Considering the total yield obtained, no significant differences were found between different cutting height treatments and at all densities.

Table 7. Effect of density and cutting height on marjoram fresh leaf/ branch ratio at three harvests.

Cutting Height (cm)	Plant Density (plants/m^2)				Mean
	5.3	3.3	2.4	1.9	
First Harvest					
3	84.5	76.6	80.0	75.5	79.2
7	85.3	82.2	79.7	85.5	83.2
11	82.1	82.1	82.5	83.6	82.6
15	81.8	77.8	81.4	80.0	80.3
					Interaction
Mean	83.5	79.7	80.9	81.2	LSD 2.4
Second Harvest					
3	69.0	71.5	71.0	72.1	70.9
7	70.4	72.9	73.0	68.7	71.3
11	77.4	73.7	76.6	78.5	76.6
15	72.8	80.8	74.9	79.5	77.0
					Means LSD
Mean	72.4	74.7	73.9	74.7	2.8
Third Harvest					
3	71.0	76.5	71.7	70.9	72.5
7	72.8	62.7	69.5	70.0	68.7
11	63.5	68.5	63.8	70.1	66.6
15	65.3	68.7	62.2	57.5	63.5
					Means LSD
Mean	68.2	69.1	66.8	67.2	5.2
Total Leaf/Branch Ratio					
3	69.6	74.5	71.1	70.2	71.4
7	71.5	67.0	71.4	68.2	69.5
11	68.9	70.2	68.4	73.0	70.1
15	67.6	71.9	67.4	64.3	67.8
Mean	69.4	70.9	69.6	68.9	NS **

* Least significant differences values were calculated at P = 0.05. **NS: no significant differences.

H) Leaves Dry Yield

The effect of density and cutting height on marjoram dry weight of leaves is presented in Table 8.

Leaves dry yield was reduced, at the first harvest, with a reduction in plant density and increasing cutting height. The highest yield was obtained at 5.3 plants/m^2 and at 3 cm cutting height.

H.1- Plant Density

H.1-1 Second Harvest

Dry yield of leaves was reduced as the number of plants per unit area was decreased. However, the highest yield of leaves was obtained at 5.3 plants/m^2 and was 30.2 g/m^2, which was significantly higher than 3.3 plants/m^2 by 44%, 2.4 plants/m^2 by 56.3 % and 1.9 plants/m^2 by 68 %. The lowest yield obtained was at 1.9 plants/m^2 and 15 cm cutting height.

H.1-2 Third Harvest

Similar trend was obtained at this harvest, at which 5.3 plants/m^2 significantly gave higher yield than 3.3 plants/m^2 by 31.8 %, 2.4 plants/m^2 by 48.3 % and 1.9 plants/m^2 by 65.6 %.

Densities of 3.3 and 2.4 plants/m^2 were significantly superior than 1.9 density, which gave the lowest yield of dried leaves (17.3 g/m^2).

Table 8. Effect of plant density and cutting height on leaves dry weight (g/m^2) of marjoram at three harvests.

Cutting Height (cm)	Plant Density (plants/m^2)				Mean
	5.3	3.3	2.4	1.9	
First Harvest					
3	2.8	1.4	1.3	1.2	1.7
7	3.1	1.3	0.8	0.9	1.5
11	1.9	1.3	1.1	0.9	1.3
15	2.2	0.8	0.6	0.4	1.0
					Interaction
Mean	2.5	1.2	1.0	0.8	LSD 0.4
Second Harvest					
3	35.2	16.2	14.3	8.5	18.6
7	37.7	18.0	14.8	15.9	21.6
11	25.3	22.0	10.8	7.3	16.3
15	22.5	11.3	13.1	6.5	13.3
					Means LSD
Mean	30.2	16.9	13.2	9.5	4.7
Third Harvest					
3	40.9	23.8	25.5	16.3	26.6
7	57.3	40.9	24.5	20.5	35.8
11	49.2	35.5	26.7	16.7	32.0
15	53.8	36.8	27.1	15.8	33.4
					Means LSD
Mean	50.3	34.3	26.0	17.3	8.3
Total Leaves Dry Weight					
3	79.0	41.5	41.1	25.9	46.9
7	98.1	60.3	40.0	37.2	58.9
11	76.4	58.8	38.5	62.4	59.0
15	78.4	48.9	40.8	22.7	47.7
					Means LSD
Mean	83.0	52.4	40.1	37.0	17.0

* Least significant differences values were calculated at P = 0.05.

H.1-3 Total Leaves Dry Yield

Total yield of leaves for the whole growing season showed similar response to that of fresh and dry yield of marjoram. It was decreased with reduction in plant density.

Significant differences were found only at the highest density means (5.3 plants/m^2), which was higher than 3.3 plants/m^2 by 36.8 %, 2.4 plants/m^2 by 51.7% and 1.9 plants/m^2 By 55.4%.

H.2- Cutting Height

H.2-1 Second Harvest

The effect of cutting height was better demonstrated at this harvest. Cutting at 7 cm gave significantly higher yield of leaves than cutting at 11 cm by 25.5% and at 15 cm by 38.4 %. While no significant differences were found between 3 and 7 cm cutting height. This increment in leaves dry yield resulted from the increase in number of leaves and total branches harvested at 7 cm cutting height (Tables 3 and 4).

H.2-2 Third Harvest

The only significant differences were observed between means of 3 and 7 cm cutting heights, at which moderate cutting gave the highest yield , and was 35.8 g/m^2. These results confirm the idea that sever cutting treatment (3 cm) affected the plant and reduced it's potential to recover, while moderate cutting (7 cm) enhanced plant regrowth.

2-3 Total Leaves Dry Yield

Total dry yield of marjoram leaves produced at different cutting height treatment averaged 46.9 g/m^2 for 3 cm, 58.9 g/m^2 for 7 cm, 59.0 g/m^2 for 11 cm and 47.7 g/m^2 for 15 cm cutting treatments (Table 8). No significant differences were found between total leaves dry yield obtained during the first year.

As a total the highest dry yield of leaves produced was at 7 cm cutting height (58.9 g/m^2) and 11 cm (59.0 g/m^2) (Table 9).

I) Plant Dry Yield

Dry yield is the best indicator can reflect the effect of any treatments on plant yield.

Data presented in Table 9 illustrated the effect of plant density and cutting height on marjoram dry yield.

Dry yield of marjoram, at the first harvest, was increased significantly as decreasing cutting height and increasing plant density . Cutting plant at lower height (3 cm) with using 5.3 plants/m^2 produced the higher dry yield.

I.1- Plant Density

I.1-2 Second Harvest

Significant reduction in plant dry yield was obtained with reduced plant density. The highest yield was obtained at the highest plant density (5.3 plants/m^2) and was 41.4 g/m^2. This density gave more dry yield than 3.3 plants/m^2 by 45.6 %, 2.4 plants/m^2 by 52.9 % and 1.9 plants/m^2 by 68.6 %.

I.1-2 Third Harvest

Results of the effect of plant density on marjoram dry yield was similar to that of the previous harvests. Significant reduction in dry yield was obtained with reduction in density at all cutting height treatments. Average yield was 85.1 g/m^2 for 5.3 plants/m^2, 55.1 g/m^2 for 3.3 plants/m^2, 43.2 g/m^2 for 2.4 plants/m^2 and 29.2 g/m^2 for 1.9 plants/m^2.

At 5.3 plants/m^2 yield produced was more than 3.3 plants/m^2 by 35 %, 2.4 plants/m^2 by 49.2% and 1.9 plants/m^2 by 65.7%.

Table 9. Effect of density and cutting on marjoram dry yield (g/m^2) at three harvests.

Cutting Height (cm)	Plant Density (plants/m^2)				Mean
	5.3	3.3	2.4	1.9	
First Harvest					
3	3.4	2.0	1.6	1.4	2.1
7	3.8	1.7	1.0	1.0	1.9
11	2.5	1.7	1.2	1.1	1.7
15	2.7	1.1	0.8	0.5	1.3
					Interaction
Mean	3.1	1.6	1.2	1.0	LSD 0.4
Second Harvest					
3	51.7	22.4	20.6	12.3	26.7
7	52.8	23.9	20.2	22.5	29.9
11	31.8	29.9	20.5	9.3	22.9
15	29.3	13.7	17.0	8.0	17.0
					Means LSD
Mean	41.4	22.5	19.5	13.0	7.1
Third Harvest					
3	65.3	34.7	39.0	26.3	41.3
7	85.3	66.4	39.1	33.6	56.1
11	93.7	62.5	45.3	27.4	57.2
15	96.0	56.8	49.5	29.5	57.9
					Means LSD
Mean	85.1	55.1	43.2	29.2	17.4
Total Dry Yield					
3	120.5	59.2	61.1	40.1	70.2
7	124.4	92.0	60.4	57.2	83.5
11	128.1	94.1	67.0	37.9	81.8
15	128.1	71.7	67.3	37.7	76.2
					Means LSD
Mean	125.3	79.3	64.0	43.2	22.3

* Least significant differences values were calculated at P = 0.05.

I.1-3 Total Dry Yield

Total yield throughout the growing season was affected by planting density. The highest density (5.3 plants/m^2) was the best during the first year. It gave significantly higher dry yield than 3.3 plants/m^2 by 36.7 %, 2.4 plants/m^2 by 48.9% and 1.9 plants/ m^2 by 65.5 %.

These results represent the effect of plant density on marjoram dry yield at the first year, where the plants were not crowded and competition for nutrient and water was not severe. These finding were in agreement with those reported by other workers (15 and 16).

I.2- Cutting Height

I.2-1 Second Harvest

cutting marjoram at 3 or 7 cm height produced the highest dry yield and was significantly higher than that given at 15 cm treatment. Differences between 11 and 15 cm cutting height treatments were not significant.

The moderate cutting height enhanced plant growth after the first cut , that may be due to, sufficient photosynthetic active parts left for plant regrowth (20). Thus it gave higher number of leaves and total branches (Tables 3 and 4), and consequently higher yield.

Removal of small mass (15 cm cutting height treatment, and average plant height was 17.9 cm) from the two or three branches found on plant at first harvest, failed to enhance marjoram regrowth.

I.2-2 Third Harvest

Results presented in Table 9 were consistent with previous results of plant and leaves fresh and dry yield (Tables 5,6 and 8), no significant differences were found between different cutting height treatments.

Severe cutting (3 cm) produced the lowest number of leaves and branches, and that reflected on the dry yield, the lower cutting height weakened plants revegetation while repeat cutting at the same height overcome the weakness by removing a proportion from the growing parts nearly equal to the other cutting heights.

I.2-3 Total Dry Yield

Total dry yield of marjoram produced under different cutting height treatments averaged 70.2 g/m^2 for 3 cm, 83.5 g/m^2 for 7 cm. 81.8 g/m^2 for 11 cm and 76.2 g/m^2 for 15 cm cutting treatments (Table 9). No significant difference were existed among averages of the total yield obtained throughout growing season.

This finding, and by connecting with results obtained at third harvest, there was no effect of different cutting treatments on dry yield, except at second harvest.

J) Dry Leaf/ Branch Ratio

Effect of plant density and cutting height on dry leaf/branch ratio is shown in Table 10.

J.1-Plant Density

At the first harvest 5.3 plants/m^2 and cutting marjoram at lower height gave significantly higher leaf/branch ratio.

No significant differences were found between different densities at the second and third harvest, as well as total yield.

In general, increasing plant population had no effect on dry leaf/branch ratio.

J.2-Cutting Height

Cutting marjoram at 3 and 7 cm heights gave the best leaf/branch ratio, while 15 cm height gave the lowest ratio at the third harvest.

However, at second harvest, 15 cm cutting height gave significantly higher ratio than 3 or 7 cm, it was 79.8 %.

Considering total leaf/branch ratio , no significant differences were found between different treatments, and the ratio was 66.8 % for 3 cm, 62.6% for 7 cm, 55.7 % for 11 cm and 69.0% for 15 cm cutting height (Table 10).

Table 10. Effect of plant density and cutting height on marjoram dry leaf/ branch ratio at three harvesting dates.

Cutting Height (cm)	Plant Density (plants/m^2)				Mean
	5.3	3.3	2.4	1.9	
First Harvest					
3	81.5	71.3	80.5	80.8	78.5
7	81.1	78.9	77.6	80.6	79.5
11	76.3	77.1	76.6	78.6	77.1
15	77.3	76.1	72.5	75.7	75.4
					Interaction
Mean	79.0	75.8	76.8	78.9	LSD 4.0
Second Harvest					
3	69.9	73.0	70.9	72.9	71.7
7	72.1	75.9	74.2	71.3	73.4
11	80.1	74.6	65.1	78.5	74.6
15	76.9	83.1	77.5	81.7	79.8
					Means LSD
Mean	74.7	76.6	71.9	76.1	5.5
Third Harvest					
3	65.7	69.4	67.6	66.2	67.2
7	66.9	60.9	64.1	63.9	63.9
11	39.2	60.3	59.5	62.5	55.4
15	59.0	64.9	54.8	54.1	58.2
					Means LSD
Mean	57.7	63.9	61.5	61.7	6.7
Total Leaf/Branch Ratio					
3	68.7	67.9	64.0	66.7	66.8
7	67.8	53.3	64.2	65.2	62.6
11	60.8	63.8	66.8	71.2	65.7
15	67.3	64.3	66.6	77.8	69.0
Mean	66.1	62.4	65.4	70.2	NS **

* Least significant differences values were calculated at P = 0.05. ** NS: no significant differences

V. SUMMARY AND CONCLUSION

Marjoram (*Origanum syriacum* L.) is a perennial herb, grows wild in hilly regions, and under cultivation it can be harvested repeatedly. It has extensive domestic uses besides its uses as herbal remedies by infusions.

Effect of four plant densities (5.3, 3.3, 2.4 and 1.9 plants/m^2) and four cutting heights (3, 7, 11 and 15 cm from soil surface) on plant height, number of basal and total branches, number of leaves, fresh and dry weight of leaves and of the whole plant were investigated for marjoram grown in the field under irrigation conditions.

The following conclusions can be drawn from the study:

1. There was no interaction between cutting height and plant density, at the second and third harvest, indicating that the two factors act independently from each other.
2. Higher plant densities produced higher dry yield, and resulted in significant increase in number of leaves and total branches produced per unit area. The highest plant density (5.3 plants/m^2) gave significantly highest total dry yield during the growing season, which amounted 125.3 g/m^2. This was 36.7 % higher than that of 3.3 plants/m^2, 48.9 % than 2.4 plants/m^2 and by 65.5 % when 1.9 plants/m^2 were used.
3. At the second harvest, differences in fresh and dry yield were detected as a result of cutting height treatments. The moderate cutting height (7 cm) gave 29.9 g/m^2 dry yield, it was significantly superior over the highest cutting height (15 cm) which gave 17.0 g/m^2 and this increase was 43.0%
4. Number of total branches and leaves continue to be affected by cutting height treatments at the third harvest. The sever cutting (3 cm) resulted in

the lowest number of leaves and total branches, which indicate that cutting height consequently determine the number of buds available for regrowth.

5. Leaf to branch ratio was not affected by any of the treatments studied in the experiment, considering the total yield.
6. The results in this experiment represent only the first year of the perennial herb, which is an establishment phase. The trend may be changed in the following years, since plants will attain higher size and competition effects may occur, therefore it is recommended that this study should be continued for further investigation.

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APPENDIX A

Table 1. Average precipitation and mean temperature data of air and soil at a depth of 20 cm at Jubehia Station during 1994/ 1995 growing season.

Month	Precipitat--ion (mm)	Min. air temp C°	Max. air temp C°	Min. soil temp C°	Max. soil temp C°
October	16.1	16.2	26.3	19.7	22.1
November	196	7.1	13.4	–	–
December	170	2.8	9.5	4.6	5.1
January	13.3	3.6	11.1	6.2	6.5
February	89.7	3.9	12.2	6.4	6.9
March	32	5.8	15.4	8.9	10.0
April	15.5	7.9	19.1	12.4	14.0
June	0	18.0	29.3	24.2	26.5
July	0	13.5	33.0	25.3	27.8

* measurements were taken from Weather Station at Jubehia location.

Table 2. Soil analysis in Jubehia Agriculture Research Station at planting times during 1994/1995 growing season.

Character	Value
PH	7.4
EC(mmhos/cm)	0.95
CaCo3 (%)	18.9
P(ppm)	63.68
K(ppm)	696.9
O.M	3.12
Sand (%)	16.4
Silt (%)	30.9
Clay (%)	52.7

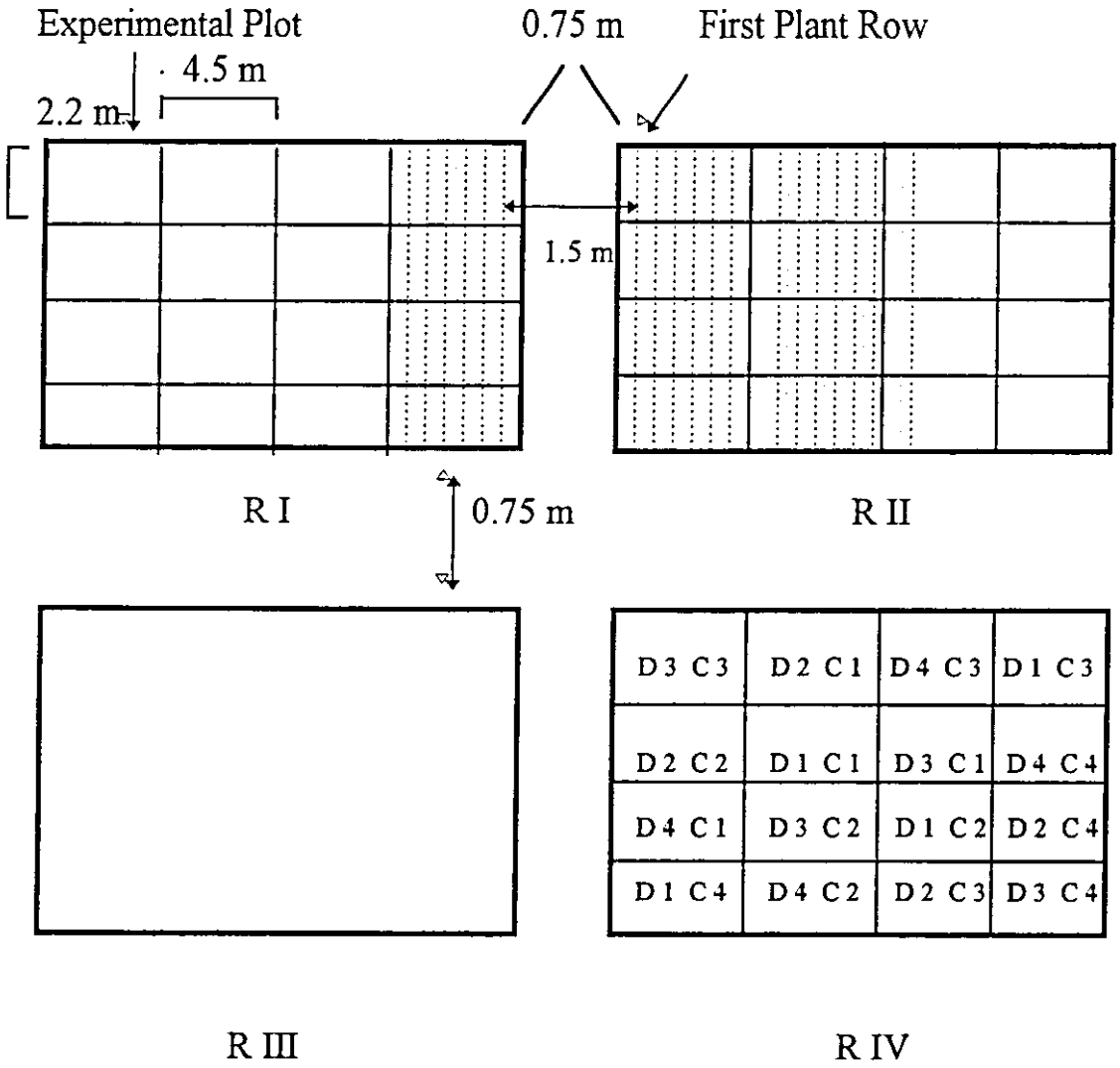

Fig 1. Layout of experiment at Jubehia Station during 1994/1995 growing season. D: Plant Density Treatment 1, 2, 3 & 4 refers to 5.3, 3.3, 2.4 & 1,9 plant/ m^2 , respectively, C: cutting height treatment 1, 2, 3 & 4 refers to 3, 7, 11 & 15 cm, respectively.

APPENDIX B

Table 1. Analysis of variance for plant height of marjoram as affected by plant density and cutting height at three harvest dates

Source of Variation	D.F	Mean Square		
		First Harvest	Second Harvest	Third Harvest
Replicate	3	0.5	115.6 **	82.8
Plant density A	3	2.4 *	21.3	6.5
Cutting height B	3	11.3**	39.4 *	32.7
Interaction A*B	9	6.8	41.0	14.2
Error	45	0.7	19.2	24.5
Total	63			

.* = P ≤ 0.05 ** = P ≤ 0.001

Table 2. Analysis of variance for number of basal branches of marjoram as affected by plant density and cutting height at three harvest dates

Source of Variation	D.F	Mean Square		
		First Harvest	Second Harvest	Third Harvest
Replicate	3	6.8	135.6	407.7
Plant density A	3	183.3 **	5233.9 **	8757.0 **
Cutting height B	3	6.2 *	357.1*	293.3
Interaction A*B	9	4.9 *	62.4	70.4
Error	45	2.5	107.3	188.2
Total	63			

.* = P ≤ 0.05 ** = P ≤ 0.001

Table 3. Analysis of variance for number of total branches of marjoram as affected by plant density and cutting height at three harvest dates.

Source of Variation	D.F	Mean Square		
		First Harvest	Second Harvest	Third Harvest
Replicate	3	6.8	2399.4	9832.6 *
Plant density A	3	183.3 **	41914.9 **	88868.6 **
Cutting height B	3	6.2 *	2701.3	22063.6 **
Interaction A*B	9	4.9 *	1698.4	2715.2
Error	45	2.5	1316.6	2915.2
Total	63			

. .* = P ≤ 0.05 ** = P ≤ 0.001

Table 4. Analysis of variance for number of leaves of marjoram as affected by plant density and cutting height at three harvest dates.

Source of Variation	D.F	Mean Square		
		First Harvest	Second Harvest	Third Harvest
Replicate	3	201.9	764250.5	203209.1
Plant density A	3	212446.9 **	7749016.1 **	3364201.1 **
Cutting height B	3	13832.1 **	1861228.4 **	355772.6 *
Interaction A*B	9	1020.9 *	307499.3	75605.3
Error	45	105.5	218187.3	127006.9
Total	63			

.* = P ≤ 0.05 ** = P ≤ 0.001

Table 5. Analysis of variance for fresh and total yield of marjoram as affected by plant density and cutting height at three harvest dates.

Source of Variation	D.F	Mean square			
		First Harvest	Second Harvest	Third Harvest	Total yield
Replicate	3	0.3	9433.2 *	5941.6	22111.4
Plant density A	3	56.5 **	52901 **	62725.9 **	237284.3 **
Cutting height B	3	11.1 **	13751.2 **	7548.7	12087.7
Interaction A*B	9	1.2 *	4500.7	1448.3	5348.7
Error	45	0.3	2798.8	4507.3	9706.6
Total	63				

* = $P \leq 0.05$ ** = $P \leq 0.001$

Table 6. Analysis of variance for leaves fresh and total yield of marjoram as affected by plant density and cutting height at three harvest dates.

Source of Variation	D.F	Mean square			
		First Harvest	Second Harvest	Third Harvest	Total yield
Replicate	3	0.3	3222.9 *	3121.7	9626.8
Plant density A	3	41.4 **	26124.5 **	28673.2 **	113434.7 **
Cutting height B	3	7.3 **	3203.8 **	2347.7	6601.0
Interaction A*B	9	1.1 *	1837.3	568.1	2669.2
Error	45	0.2	1204.5	1579.1	3927.9
Total	63				

* = $P \leq 0.05$ ** = $P \leq 0.001$

Table 7. Analysis of variance for fresh leaves/branches ratio and total yield of marjoram as affected by plant density and cutting height at three harvest dates.

Source of Variation	D.F	Mean square			
		First Harvest	Second Harvest	Third Harvest	Total yield
Replicate	3	2.2	154.6 **	53.9	24.4
Plant density A	3	39.1 **	19.0	17.5	11.6
Cutting height B	3	58.0 **	174.9 **	233.6 **	35.4
Interaction A*B	9	23.6 **	26.2	72.9	28.1
Error	45	2.6	15.1	52.6	28.9
Total	63				

.* = P ≤ 0.05 ** = P ≤ 0.001

Table 8. Analysis of variance for dry and total yield of marjoram as affected by plant density and cutting height at three harvest dates.

Source of Variation	D.F	Mean square			
		First Harvest	Second Harvest	Third Harvest	Total yield
Replicate	3	0.07	529.3 **	811.8	1066.5
Plant density A	3	15.0 **	2375.4 **	9041.4 **	19428.6 **
Cutting height B	3	2.0 **	488.9 *	1002.4	575.1
Interaction A*B	9	0.4 *	168.2	240.3	334.2
Error	45	0.07	98.8	597.2	983.0
Total	63				

.* = P ≤ 0.05 ** = P ≤ 0.001

Table 9. Analysis of variance for leaves dry and total yieldof marjoram as affected by plant density and cutting height at three harvest dates.

Source of Variation	D.F	Mean square			
		First Harvest	Second Harvest	Third Harvest	Total yield
Replicate	3	0.1	165.8 *	198.1	422.1
Plant density A	3	9.5 **	1294.3 **	3159.1 **	7051.6 **
Cutting height B	3	1.3 **	194.5 **	239.7	727.3
Interaction A*B	9	0.3 *	63.8	66.1	432.3
Error	45	0.7	43.7	136.8	568.3
Total	63				

.* = P ≤ 0.05 ** = P ≤ 0.001

Table 10. Analysis of variance for dry leaves/branches ratio and total yield of marjoram as affected by plant density and cutting height at three harvest dates.

Source of Variation	D.F	Mean square			
		First Harvest	Second Harvest	Third Harvest	Total yield
Replicate	3	6.5	258.3 *	120.8	87.7
Plant density A	3	40.3 **	70.9	104.9	169.1
Cutting height B	3	51.4 **	195.7 *	460.9 **	111.8
Interaction A*B	9	28.3 **	57.9	166.8	77.6
Error	45	7.6	58.8	89.9	179.2
Total	63				

.* = P ≤ 0.05 ** = P ≤ 0.001

الملخص

تاثير الكثافة النباتية و ارتفاع مستوى القص على الأنتاج في الزعتر البلدي تحت ظروف الزراعة المكشوفة

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و

المشرف المشارك: لدكتور جمال راغب قاسم

لقد أجري هذا البحث في محطة الجبيهة للبحوث الزراعية للموسم الزراعي ١٩٩٥\٩٤. بهدف دراسة تأثير كثافات الزراعة (٥,٣، ٣,٣، ٢,٤ و ١,٩ نبات/م^{٢})، و ارتفاع القص (٣، ٧، ١١ و ١٥ سم) عن سطح التربة على نمو وانتاج نبات الزعتر (*Origanum syriacum* L.) المزروع في الأراضي المروية المكشوفة، وقد تم استخدام تصميم القطاعات العشوائية الكاملة لأربع مكررات باستخدام التوزيع العاملي وبوجود العاملين المتساوين في الأهمية.

أظهرت نتائج الدراسة أن زيادة الكثافة النباتية من١,٩الى ٥,٣ نبات/م^{٢} قد أدت الى زيادة معنوية في الوزن الطازج و الجاف للنبات، ومن حيث وزن الأوراق الطازجة والجافة، و كذلك في عدد الأوراق والمجموع الكلي للأفرع. كان الأنتاج الجاف الكلى ١٢٥,٣ غم/م^{٢} للكثافة النباتية ٥,٣ نبات/م^{٢}، بينما كان الأنتاج ٤٣,٢غم/م^{٢} للكثافة النباتية ١,٩ نبات/م^{٢}. لقد وجد أن التأثير الرئيسي لارتفاع القص على الوزن الجاف و الطازج للنبات كان في القطفة الثانية فقط، حيث أعطت القصة التي تمت على ارتفاع ٧ سم من سطح الأرض أعلى انتاج و الذي بلغ ٢٩,٩غم/م^{٢}، بالمقارنة مع ١٧,٠غم/م^{٢} انتاج أرتفاع القص على ١٥ سم، بينما لم يلاحظ أي فروقات معنوية بين مختلف معاملات القص على انتاج الزعتر في القطفة الثالثة.