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# INFLUENCE OF WATER REGIME TREATMENTS ON GROWTH OF *ROSMARINUS OFFICINALIS* L. PLANT

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**ABSTRACT:** The current research was carried out at the Hort. Dept., Fac. of Agric., Benha Univ., Egypt, throughout the 2019/2020 and 2020/2021 seasons. To investigate the impact of water regime i.e. (100, 70 and 50% of field capacity) on growth of *Rosmarinus officinalis* L. plant in the two seasons. The results revealed that differences treatments of field capacity increased the growth parameters of rosemary plant in the two seasons. The use of field capacity at 100% achieved the highest values on all studied parameters of vegetative growth and some chemical composition, except the total carbohydrates % in both seasons. On contrary, the use of 50% FC scored the best values for total carbohydrates % and essential oil productivity in both seasons. Consequently, it is preferable to treat rosemary plants with FC at 100% in order to achieve the highest levels of vegetative growth parameters. On the other hand, it is possible to treat rosemary plant with 50% FC to obtain the highest essential oil productivity.

**Key words:** *Rosmarinus officinalis,* field capacity, vegetative growth, oil productivity.

## INTRODUCTION

*Rosmarinus officinalis* L. is a Mediterranean evergreen plant that belongs to the Lamiaceae family. It is also of great importance due to the presence of essential oil, which has medical importance and is used in the perfume industry (Miguel *et al*., 2007). It is also characterized by many medicinal properties as it treats stomach pain and spasms and is considered an anthelmintic and has the advantage that its leaves are considered antioxidants in addition to its use in cooking purposes (Singh and Guleria, 2013). The volatile oil in rosemary has a percentage of 1.43 as mentioned by Zaouali *et al.* (2013). The main component of the volatile oil was 1.8-Cineole and its ratio reached to (35.8%). It has medical benefits as an antispasmodic, inflammatory and diabetic, in addition to its use as an antiseptic (Juhas *et al.*, 2009; Abu-Al-Basal, 2010; Beninca *et al.*, 2011). Water is one of the important factors that have an impact on plant growth and then on its productivity. At this time, it is better to use water resources efficiently due to the limited quantities of water, and it represents a challenge for researchers to find and provide water sources to work on increasing plant production, especially in tropical areas that are characterized by hot dry weather and in arid regions with limited water resources. However, Water has a great effect on the growth of plants. It was found that the rosemary plant, if exposed to water stress, growth parameters decreases. On contrary, the productivity of the volatile oil and its components may increase (Leithy *et al.*, 2006). Also, as a result of water stress, the fresh, dry weights of the herb is completely and partially affected, in addition to the volatile oil and its components, and the total content of carbohydrates increases. On the contrary, the protein N, P and K % within the plant decreases (Khalid, 2006). In this

context, the content of chlorophyll is related to and affected by the lack of water, which shows that chlorophyll is related to the percentage of water in the leaves (Munne-Bosch and Alegre, 2000). Despite the studies that have been conducted and related to the different effects of irrigation on plant growth, it has been noted that they did not definitively explain the different effects of irrigation on the different growth stages of rosemary plants (Nicola´s *et al.*, 2008). Therefore, this study was conducted to find out the effect of different water regimes (100, 70 and 50% field capacity) on the vegetative growth, chemical constituents and oil productivity of *Rosmarinus officinalis* L. plant.

## MATERIALS AND METHODS

This study was carried out in the Experiment Farm of the Hort. Dept., Fac. of Agric., Benha University in 2019/2020 and 2020/2021 seasons.

**Plant materials:**

The uniform terminal cuttings of *Rosmarinus officinalis* L. were taken yearly from the mother plants which were kindly obtained from the Experimental Farm of the Moshtohor Faculty research in uniform size and length (25 cm) long with 10-12 pairs of leaves. The cuttings were planted in polyethylene bags in a mixture of clay:sand (1:1 v/v) on November 15$^{th}$ after that seedling were transplanted on March 21$^{st}$ in both seasons.

**Irrigation treatments:**

Plastic pots of 25 cm in diameter were used, perforated from the bottom, were packed with 3860 g of the soil, divided into three treatments (100%, 70% and 50% of field capacity). In 100% of field capacity, the amount of water added was 2316 ml, in 70% and 50% of field capacity the amount of water added were 1621 and 1158 ml, respectively.

All pots were irrigated with tap water at the previously assigned treatments. In the winter season, plants were irrigated once a week, while in the summer season, they were irrigated every 3 days. The number of irrigation times was calculated in a period of 6 months, 3 months in summer and 3 months in winter, as well as for a period of 12 months, 6 months in summer and 6 months in winter. The number of irrigation times in a 6-month period was 42, and the number of irrigation times in a 12-month period was 84.

**Chemicals fertilization:**

The recommended dose of chemical fertilizers as NPK was added in six equal doses, the first three doses were added during plant growth and until the first cut, and the other three doses were added after that and till the second cut. However, after planting a month, about 100 kg of ammonium sulfate/fed (1.56 g/pot) was added with repeated nitrogen fertilization monthly to obtain a good growing. Also, K fertilizer was added in batches of up to 25 kg per fed (0.39 g/pot) as potassium sulfate. Organic and phosphate fertilizers added 20 $m^3$ decomposed organic fertilizer as well as 300 Kg of calcium super phosphate (3 g/pot), 100 Kg sulfur per fed (1 g/pot). Other agricultural practices were carried out during the growth of the rosemary plant when needed.

**Layout of the experimental:**

The experimental layout was simple factorial experience including 3 treatments. Each treatment was 3 replicated and each replicate consisted of 5 plants and the obtained data was subjected to statistical analysis according to Snedecor and Cochran (1989).

**Treatments:**

1. 100% field capacity.
2. 70% field capacity.
3. 50% field capacity.

**Data recorded:**

The plants were harvested twice / season (first and second cuts) on 15$^{th}$ July and 15$^{th}$ October in both seasons, by cutting the herb of the plants at 10 cm above the soil surface.

**The following data were recorded in both seasons:**

1. Vegetative growth
   - Plant height (cm).
   - Branches number/plant.
   - F.W. (g/plant).
   - D.W. (g/plant).
2. Chemical composition:

In rosemary fresh leaves, chlorophylls (a & b) and carotenoides were estimated according to A.O.A.C. (1990). Also, In the dry leaves, N, P, K % and total carbohydrates were determined according to Horneck and Miller (1998), Sandell (1950), Horneck and Hanson (1998) and Herbert *et al.* (1971), respectively.

3. Essential oil production:

The essential oil for each tasted treatment was extracted by hydro-distillation according to Guenther (1961).

## RESULTS AND DISCUSSION

**Vegetative growth:**

**1. Plant height (cm) and branches number/plant:**

It is clear from Table (1) that deficit irrigation treatments were significantly decreased the plant height and No. of branches of *Rosmarinus officinalis* plants. The tallest plants (30.27, 26.33, 27.00 and 18.33 cm, respectively) were achieved by applying 100% FC in both seasons, while the shortest plants (21.50, 19.67, 23.17 and 16.67 cm in the first and second cuts, respectively) were gained by using treatment of 50% FC at the first and second seasons, respectively. Also, the highest number of branches were recorded from 100% FC in two cuts in both seasons, compared with treatment of 50% FC as recorded the lowest values in both seasons, except the first cut of the first season the highest number of branches were recorded from 50% FC (15.67), compared to 100% FC treatment which gave (14.67) but the increment was insignificant. The results obtained are in line with Hassan *et al.* (2013) on *Rosmarinus officinalis* L., Mohamed *et al.* (2021) on *Viola odorata* and Karimzadeh *et al.* (2018) on *Dracocephalum moldavica.*

These previous results indicate that the lack of water affects the fullness of the plant, which leads to reduced growth and slow development of cells, especially in the stem and leaves. Cell growth is greatly affected by water stress, and thus growth decreases, which is reflected in the effect on the decrease in plant height. From the above, it is clear that the deficit of water affected the rosemary plant, and this was evident in reducing its height and the growth of shoots (Nicola´s *et al.*, 2008). The previous results are in agreement with Leithy *et al.* (2006), Bettaieb *et al.* (2009), Mohamed *et al*. (2021) and Ekren *et al.* (2012).

**2. Fresh and dry weights (g/plant):**

Table (2) demonstrates that the fresh and dry weights of rosemary were significantly affected by using deficient irrigation treatments. It was observed that the fresh and dry weights/plant decreased with a decrease in the level of field capacity, and the lowest value was achieved by applying 50% FC treatment for both seasons.

However, the highest values of fresh weight at 100% FC were (36.33, 87.17, 26.33 and 60.33 g, respectively), compared to the lowest values with 50% FC (30.83, 56.67, 20.08 and 50.83 g, respectively). Also, the dry weight gave the highest values at 100% FC (17.08, 35.59, 11.85 and 24.89 g, respectively), compared with 50%FC which gave minimum values (12.09, 20.57, 6.38 and 16.49 g, respectively) in both cuts of both seasons. These results are in agreement with those obtained by Bidgoli (2018) on *Rosmarinus officinalis* L. and Farsi *et al*. (2019) on *Origanum majorana* L.

The reason for the results obtained to increase the plant's yield of fresh herb is that the availability of irrigation leads to a high percentage of moisture around the roots, which follows the increase in the number of

**Table 1. Effect of different irrigation treatments on plant height and No. of branches of *Rosmarinus officinalis* L. plant during 2019/2020 and 2020/2021 seasons.**

| Treatments | Plant height (cm) | | No. of branches /plant | |
|---|---|---|---|---|
| | 1st cut | 2nd cut | 1st cut | 2nd cut |
| | | 1st season | | |
| **100% F.C.** | 30.27 | 26.33 | 14.67 | 35.00 |
| **70% F.C.** | 25.67 | 23.83 | 12.67 | 31.00 |
| **50% F.C.** | 21.50 | 19.67 | 15.67 | 26.67 |
| **L.S.D at 0.05** | 3.58 | 2.88 | 2.62 | 6.32 |
| | | 2nd season | | |
| **100% F.C.** | 27.00 | 18.33 | 15.33 | 27.00 |
| **70% F.C.** | 23.83 | 17.00 | 14.33 | 20.33 |
| **50% F.C.** | 23.17 | 16.67 | 12.67 | 18.67 |
| **L.S.D at 0.05** | 3.43 | 3.70 | N. S | 3.70 |

**Table 2. Effect of different irrigation treatments on fresh and dry weights of rosemary plant during 2019/2020 and 2020/2021 seasons.**

| Treatments | Fresh weight (g/plant) | | Dry weight (g/plant) | |
|---|---|---|---|---|
| | 1st cut | 2nd cut | 1st cut | 2nd cut |
| | | 1st season | | |
| **100% F.C.** | 36.33 | 87.17 | 17.08 | 35.59 |
| **70% F.C.** | 30.07 | 63.22 | 12.75 | 23.39 |
| **50% F.C.** | 30.83 | 56.67 | 12.09 | 20.57 |
| **L.S.D at 0.05** | 6.01 | 6.32 | 4.81 | 4.56 |
| | | 2nd season | | |
| **100% F.C.** | 26.33 | 60.33 | 11.85 | 24.89 |
| **70% F.C.** | 24.83 | 59.17 | 9.59 | 21.95 |
| **50% F.C.** | 20.08 | 50.83 | 6.38 | 16.49 |
| **L.S.D at 0.05** | N. S | 6.25 | 4.16 | 3.70 |

roots and therefore the absorption of large quantities of nutrients, which is naturally reflected in the growth and production of a high vegetative biomass (Singh *et al*., 1997). It was also found that under water deficit, the dry weight decreases, which is a result of the decrease in chlorophyll content, as the previous results indicated, and thus the efficiency of photosynthesis decreases, as mentioned by Khalid (2006).

**Chemical compositions:**

**1. N, P and K (%):**

Table (3) declares that the decreasing of irrigation level from 100 to 50% FC was decreased N, P and K % in both cuttings of two seasons. In this respect, the highest values were recorded by applying100% FC treatment, for N% were (2.103, 2.397, 2.197 and 2.250%, respectively), for P % were (0.234, 0.251, 0.246 and 0.279%, respectively) and for K % were (2.170, 2.327, 1.967 and 2.197%, respectively). However, the lowest values of N, P and K %, achieved by the lowest irrigation level (50% FC), for N % recorded (1.357, 1,590, 1.577 and 1.867%, respectively), for P % recorded (0.132, 0.162, 0.152 and 0.200%, respectively) and K% recorded (1.720, 1.673, 1.413 and 1.677%, respectively). These results are in line with Hassan *et al.* (2013) and El-Leithy *et al.* (2018).

It is clear that the previous results affected by deficient irrigation, the negative

**Table 3. Effect of different irrigation treatments on N, P and K% of *Rosmarinus officinalis* L. plant during 2019/2020 and 2020/2021 seasons.**

| Treatments | N (%) | | P (%) | | K (%) | |
|---|---|---|---|---|---|---|
| | 1st cut | 2nd cut | 1st cut | 2nd cut | 1st cut | 2nd cut |
| | | | 1st season | | | |
| **100% F.C.** | 2.103 | 2.397 | 0.234 | 0.251 | 2.170 | 2.327 |
| **70% F.C.** | 1.660 | 1.770 | 0.207 | 0.228 | 2.047 | 2.190 |
| **50% F.C.** | 1.357 | 1.590 | 0.132 | 0.162 | 1.720 | 1.673 |
| **L.S.D at 0.05** | 0.16 | 0.27 | 0.072 | 0.002 | 0.12 | 0.61 |
| | | | 2nd season | | | |
| **100% F.C.** | 2.197 | 2.520 | 0.246 | 0.279 | 1.967 | 2.197 |
| **70% F.C.** | 1.833 | 2.117 | 0.185 | 0.213 | 1.803 | 1.933 |
| **50% F.C.** | 1.577 | 1.867 | 0.152 | 0.200 | 1.413 | 1.677 |
| **L.S.D at 0.05** | 0.24 | 0.29 | 0.002 | 0.002 | 0.23 | 0.41 |

impact of which was reflected on the total nitrogen, phosphorous and potassium content of rosemary plant, resulted from the decrease in vegetative growth due to the decrease of absorption nutrients (Pascale *et al.*, 2001). These results obtained in our study on the low of irrigation and its association with decreased growth due to the low content of nutrients, and it was found that high irrigation level could compensate for nutrient deficiency and agree with Silber *et al.* (2003).

## 2. Total carbohydrates (%):

It is obvious from Table (4) that the highest percentage of total carbohydrates was significantly increased by deficit irrigation and was recorded at (50% FC) treatment in two cuttings in both seasons. However, at 100% FC recorded the lowest values which were (12.373, 16.457, 15.09 and 17.61%, respectively), compared with 50% FC treatment which recorded the highest values (21.947, 23.633, 19.85 and 24.77%, respectively) in two cuttings in both seasons.

The aforementioned results are in conformity with those reported by Mohammadzadeh and Pirzad (2020) on (*Lavandula officinalis* L.), rosemary (*Rosmarinus officinalis* L.) and thyme (*Thymus vulgaris* L.).

**Table 4. Effect of different irrigation treatments on total carbohydrates (%) of *Rosmarinus officinalis* L. plant during 2019/2020 and 2020/2021 seasons.**

| Treatments | 1st cut | 2nd cut |
|---|---|---|
| | 1st season | |
| **100% F.C.** | 12.373 | 16.457 |
| **70% F.C.** | 18.790 | 20.483 |
| **50% F.C.** | 21.947 | 23.633 |
| **L.S.D at 0.05** | 3.94 | 3.43 |
| | 2nd season | |
| **100% F.C.** | 15.09 | 17.61 |
| **70% F.C.** | 18.09 | 20.15 |
| **50% F.C.** | 19.85 | 24.77 |
| **L.S.D at 0.05** | 1.916 | 3.019 |

## 3. Chlorophylls a and b:

Table (5) indicates that chlorophylls a and b contents of rosemary significantly decreased by using irrigation level from 100 to 50% FC. The highest values in this respect (0.808, 0.893,0.751 and 0.963 mg $g^{-1}$ F.W, respectively) for chlorophyll a and (0.565, 0.760, 0.580 and 0.791 mg $g^{-1}$ FW, respectively) were recorded for chlorophyll b at the highest irrigation level (100% FC) in both cuts in two seasons in the same table, respectively.

**Table 5. Effect of different irrigation treatments on chlorophyll a and b (mg/g F.W.) of *Rosmarinus officinalis* L. plant during 2019/2020 and 2020/2021 seasons.**

| Treatments | Chlorophyll a (mg/g F.W.) | | Chlorophyll b (mg/g F.W.) | |
|---|---|---|---|---|
| | 1st cut | 2nd cut | 1st cut | 2nd cut |
| | | 1st season | | |
| **100% F.C.** | 0.808 | 0.893 | 0.565 | 0.760 |
| **70% F.C.** | 0.785 | 0.815 | 0.539 | 0.712 |
| **50% F.C.** | 0.730 | 0.766 | 0.513 | 0.657 |
| **L.S.D at 0.05** | 0.072 | 0.10 | 0.002 | 0.14 |
| | | 2nd season | | |
| **100% F.C.** | 0.751 | 0.963 | 0.580 | 0.791 |
| **70% F.C.** | 0.648 | 0.778 | 0.538 | 0.699 |
| **50% F.C.** | 0.592 | 0.723 | 0.470 | 0.608 |
| **L.S.D at 0.05** | 0.16 | 0.12 | 0.14 | 0.14 |

**Oil productivity:**

**1. Essential oil percentage:**

Table (6) reveals that volatile oil percentage was increased by deficit irrigation level was obtained by irrigation the treatment of rosemary plant at 50% FC was scored the highest percentage (0.147, 0.213, 0.167 and 0.223%, respectively) in two cuttings in both seasons. However, the treatment of 100% FC achieved the lowest values (0.103, 0.163, 0.107 and 0.127% in both cuts, in two seasons, respectively) in this concern. These results are in line with by Bidgoli (2018) and Raffo *et al.* (2020) on rosemary plant.

The possible reason for these results is that due to the low of water, the density of the oil glands increases due to the lack of leaf area, which follows the accumulation of large quantities of volatile oil (Simon *et al*., 1992). In this context, Khalid (2006) and Ekren *et al.* (2012) they stated that the different water treatments affected of oil productivity.

**2. Essential oil compositions:**

Data presented in Table (7) and Figs. (1-3) indicate that the irrigation levels improved volatile oil compositions of rosemary plant. The volatile oil constituents of rosemary included 11 compounds were identified, i.e. (α- pinene, Camphene, β-pinene, limonene, 1,8 cineol, camphor, α- terpineol, borneol, bornyl acetate, Eugenol and β caryophyllene).

However, the main component was 1,8 cineole ranged from (15.15 to 15.78%), followed by α- pinene ranged from (9.91 to

**Table 6. Effect of different irrigation treatments on Essential oil percentage of *Rosmarinus officinalis* L. plant during 2019/2020 and 2020/2021 seasons.**

| Treatments | 1st cut | 2nd cut |
|---|---|---|
| | 1st season | |
| **100% F.C.** | 0.103 | 0.163 |
| **70% F.C.** | 0.110 | 0.190 |
| **50% F.C.** | 0.147 | 0.213 |
| **L.S.D at 0.05 %** | 0.072 | 0.072 |
| | 2nd season | |
| **100% F.C.** | 0.107 | 0.127 |
| **70% F.C.** | 0.130 | 0.187 |
| **50% F.C.** | 0.167 | 0.223 |
| **L.S.D at 0.05 %** | 0.002 | 0.002 |

**Table 7. GLC analysis of the essential oil of rosemary plants in the second cut of the second season (2020/2021).**

| Peak No. | Components | Area % | | |
|---|---|---|---|---|
| | | F.C. at 100% | F.C. at 70% | F.C. at 50% |
| 1 | α- pinene | 9.91 | 11.58 | 14.87 |
| 2 | Camphene | 5.59 | 6.30 | 7.61 |
| 3 | β- pinene | 3.28 | 3.85 | 4.95 |
| 4 | Limonene | 3.76 | 4.39 | 5.83 |
| 5 | 1,8 cineole | 15.15 | 15.76 | 15.78 |
| 6 | Camphor | 13.99 | 12.79 | 12.07 |
| 7 | α- terpineol | 2.05 | 1.99 | 1.97 |
| 8 | Borneol | 3.61 | 3.59 | 5.52 |
| 9 | Bornyl acetate | 9.41 | 10.04 | 5.92 |
| 10 | Eugenol | 5.83 | 5.74 | 3.81 |
| 11 | β-caryophyllene | 1.52 | 1.25 | 1.98 |
| Unknown | | 25.9 | 22.72 | 19.69 |
| Total | | 100.00 | 100.00 | 100.00 |

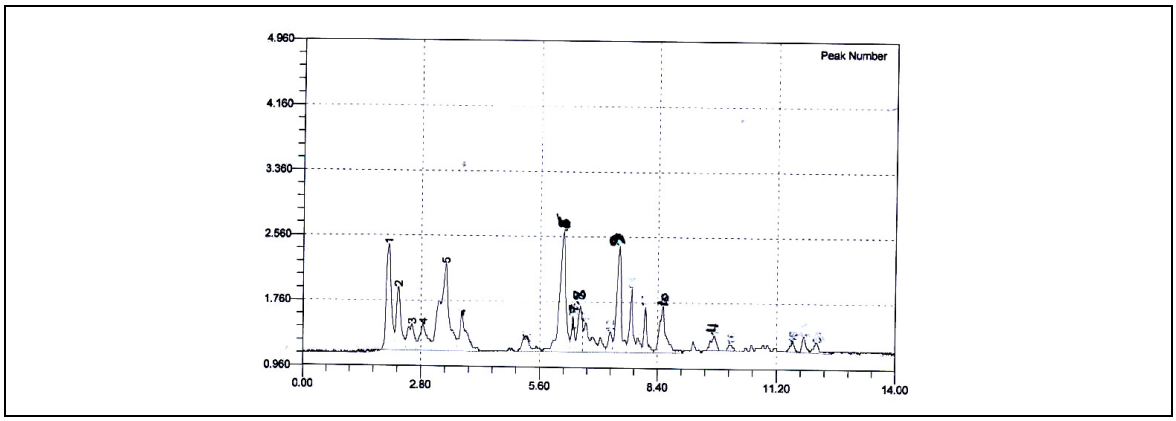


**Fig. 1. Effect of irrigation treatment at (100% F.C.) on essential oil compositions in the second cut of the second season.**

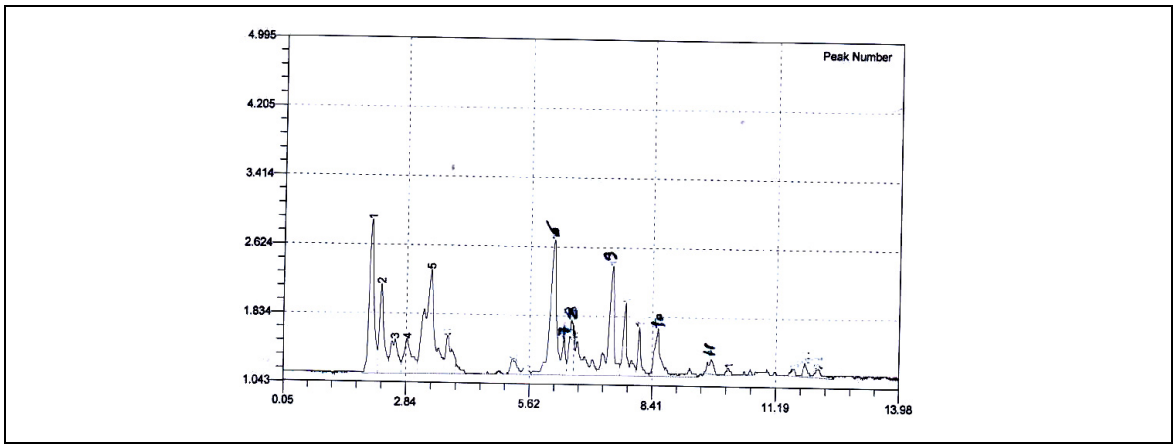


**Fig. 2. Effect of irrigation treatment at (70% F.C.) on essential oil compositions in the second cut of the second season.**

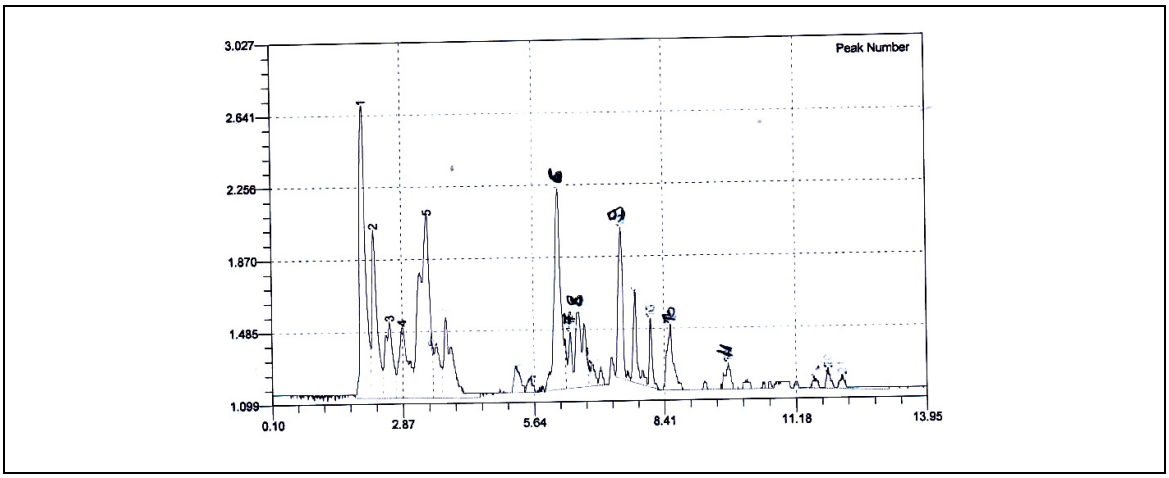


**Fig. 3. Effect of irrigation treatment at (50% F.C.) on essential oil compositions in the second cut of the second season.**

14.87%) from treatment 100% FC to 50% FC, respectively. In addition to unknown components with values from (25.9% at 100% FC to 19.69% at 50% FC).

In general, it is clear from the previous results that the field capacity at (100% FC) was better in the case of vegetative growth parameters and total N, P and K %, while the field capacity at (50% FC) achieved the best value for total carbohydrates % and oil productivity, followed by field capacity at (70% FC).

Abstractly, this gives us an explanation that the oil productivity, the final product was not affected by the increase in the field capacity at (100%FC) and this is a good economic indication for this study.

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## تأثير المقننات المائية على نمو نبات حصالبان

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تم إجراء البحث الحالي في قسم البساتين، كلية الزراعة، جامعة بنها، مصر خلال موسمي (٢٠١٩/٢٠٢٠ و٢٠٢٠/٢٠٢١). لدراسة تأثير السعة الحقلية (٥٠، ٧٠، ١٠٠٪ سعة حقلية) على نمو نبات الحصالبان (إكليل الجبل) في كلا الموسمين. أظهرت النتائج أن معاملات الفروق في السعة الحقلية أدت إلى زيادة معدلات نمو نبات إكليل الجبل في كلا الموسمين. حقق استخدام السعة الحقلية بنسبة ١٠٠٪ أعلى القيم في جميع معاملات النمو الخضري وصبغات البناء الضوئي المدروسة باستثناء نسبة الكربوهيدرات الكلية في كلا الموسمين. على العكس من ذلك، فإن استخدام السعة الحقلية بنسبة ٥٠٪ سجل أفضل القيم لإجمالي الكربوهيدرات ٪ وإنتاجية الزيت في كلا الموسمين. وبالتالي، يفضل معالجة نباتات إكليل الجبل بإستخدام ١٠٠ ٪ سعة حقلية لتحقيق أعلى مستوي انتاج للنمو الخضري اما في حالة الحصول علي أعلي نسبة من الزيت يفضل المعاملة بنسبة ٥٠٪ سعة حقلية.