

EFFECT OF WATER DEFICIT ON THE GROWTH, YIELD AND ESSENTIAL OIL CONTENT OF LEMONGRASS *IN VIVO*.

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ABSTRACT: *Two field experiments were carried out on Cymbopogon citratus, during two years of 2015 and 2016 at Al Khtatbah, Sadat Center, Minufiya Governorate, Egypt. The aim of this research work was to study the effect of drip irrigation regimes (24, 12, 8 and 4 liters/plant/week) on yield and essential oil content of lemongrass. All growth and yield characters were significantly affected by the deficit of irrigation water. The plant height, number of tillers, fresh and dry weights / plant, fresh and dry yield per hectare) as well as nutrient content in the dry herb, essential oil percentage and oil yield of lemongrass decreased as affected by water deficit in all cuts of the two experimental seasons. However, the highest irrigation regime (24 liters/plant/week) provided the best results in this respect. On the other hand, the best quality of the essential oil (concentration of citral) was obtained at the lower regime (8 liters /plant/week).*

Key words: *Water stress, Cymbopogon citratus, essential oil, secondary product, NPK%.*

INTRODUCTION

Cymbopogon citratus, Family: Poaceae (Gramineae) commonly, known as lemongrass is considered as one of the most important plants that has an attractive economic value due to its medicinal and biochemical properties (Abdou *et al.* 2014 and Hamed *et al.* 2017), this importance due to its essential oil content, which contains citral as a main component (Rehman *et al.* 2016).

Furthermore, the essential oil has a great value for pharmaceutical industries, it is used as antibacterial, antifungal (Bayala *et al.*, 2014), antiprotozoal, anticancer, anti-inflammatory, antiseptic (Bayala *et al.*, 2018; Maruoka *et al.*, 2018), decreased total cholesterol and low-density lipoprotein and act as strong antioxidant (Somparn *et al.*, 2018), perfumes and cosmetic industries (Chen 2018).

Besides, notable for its lemon flavor and fragrance, it is widely used in cooking as a major source of lemon flavoring in the food additives (Ferreira *et al.*, 2017), eco-friendly pesticides (Mao *et al.*, 2018), Fresh herb is also containing small amounts of vitamins such as vitamin-A and C; βionones are used in the synthesis of Vitamin-A (Venugopal 2010). Also have rich source of minerals like potassium, zinc, calcium, iron, manganese, copper, and magnesium (Abdel-kader *et al.*, 2014). Biomass crop may have applications for biofuel production, and as a non-edible plant oil source for biodiesel production (Binu *et al.*, 2013 & Alagumalai 2015).

Water supply shortages becomes a critical constraint on water future use in Egypt, It is well known that water resources in Egypt are limited to the share of Egypt in the flow of the Nile River by 55.5 million m³ , the deep

groundwater in the deserts (mostly non-renewable) and a small amount of rainfall in the northern coastal area and Sinai (Eissa *et al.*, 2018), Ethiopia Dam shapes a great future problem for Egypt water availability from Nile River (Shalan *et al.* 2018), Increases in dam and irrigation development in upstream parts of the basin is poised to conflict with agricultural expansion and population growth in Egypt (Molle *et al.*, 2018).

Whereas, the human population is approximately 95 million with an increasing rate reaches to 2.4% per year, (Central Agency for Public Mobilization and Statistics, 2017).

Water stress in plants may lead to physiological disorders, such as a reduction in photosynthesis and transpiration, translocation, ion uptake, carbohydrates, nutrient metabolism and hormones as argued by (Moradi 2014). So it can be defined as the absence of adequate moisture necessary for normal plant growth and to complete the life cycle (Zhu, 2002).

Water stress reduce growth and yield due to reduction in photosynthesis and plant biomass (Bahreininejad *et al.*, 2013) up to photosynthesis was limited by low CO₂ availability due to reduced stomatal and mesophyll conductance (Elansary *et al.*, 2016), Whereas drought stress is associated with stomatal closure and thereby with decreased CO₂ fixation (EL-Attar & Ashour, 2016).

This study aimed to investigate the possible effect of water stress on the vegetative growth, essential oil content, and chemical content of lemongrass.

MATERIALS AND METHODS

This investigation was carried out at a private Farm located (30° 21' 544799N, 30° 49' 15.3899E) in Al khatatabah, Sadat City, Minufiya Governorate, Egypt during two successive seasons of 2015 and 2016 on

Cymbopogon citratus plants for study the effect of water regime under drip irrigation on vegetative growth, essential oil content, quality and chemical composition of on *Cymbopogon citratus* plants, the all data were taken at the laboratory of medicinal and aromatic plants, Plant Biotechnology Department Genetic Engineering and Biotechnology Research Institute (GEBRI), Sadat City University, Egypt.

The lemongrass transplants were transplanted in the prepared nursery on 15th November in both seasons in experimental farm of (GEBRI). The soil was prepared and divided into plots of 1.5×2.5. Each plot contained two rows and eight plants at a distance of 50 cm apart. The homogenous transplants were cultivated in the experimental farm on the first of March during the two experimental seasons.

1- **Treatments:** the water regime-treatments were 24, 12, 8 and 4 liters/plant/week in both seasons of the experiment, starting from the first of May to the first of November.

2- **Statistical analysis:** all plants received the required agricultural practices. The plants were cut two times, the first cut was on 15th July and the second was on 15th October during the two seasons. Plants were cut at height of 15cm above the soil surface. The following experiments were planned in a complete randomized design with three replicates, the data analyzed by analysis of variance (ANOVA), using COSTAT Statistical software (computer program).

3-**The experimental soil and fertilizers properties:**

a. the experimental soil: was sandy in texture its chemical properties estimated according to (Webster & Lark, 2018) and presented in Table (1).

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Table (1): The mechanical and chemical analysis of the experimental soil were as following:-

| First: mechanical analysis | | | |
|-----------------------------------|--------|--------------------|-----------|
| - Sand % | 97.00 | - Clay % | 1.50 |
| - Silt % | 1.50 | - Soil texture | sandy |
| Second: chemical analysis | | | |
| PH: | 7.19 | Total N | 24.00 ppm |
| EC dsm ⁻¹ | 1.09 | Total P | 8.8 ppm |
| Organic matter: | 0.20% | Total K | 28.8 ppm |
| Cations: (mg/L) | | Anions: (mg/L) | |
| Ca ⁺⁺ : | 60.00 | CO ₃ : | 0.0 |
| Mg ⁺⁺ : | 41.5 | HCO ₃ : | 305.00 |
| Na ⁺ : | 80.1 | Cl: | 140.00 |
| TDS mg/L: | 330.00 | SO ₄ : | 50.500 |

Where, TDS: Total Dissolved Solids.
E.C: Electrical Conductivity.

b. Compost: the compost used at 30 m³/hectare in organic fertilizers, the physical and chemical characteristics of the Compost produced by Quesna Company, presented Table (2).

c. Chemical fertilizers: The recommended dose of mineral fertilization according to Ministry of Agriculture was used as follows:

- Ammonium sulphate (20.5%N) at 700 kg/hectare.
- Calcium super phosphate (15.5% P₂O₅) was added at 240 kg/hectare, when the soil prepared.
- Potassium sulphate (48% K₂O) was added at 120kg/hectare with nitrogen fertilizer at 2 equal doses. The first addition was done after 45 days of transplanting and the second was after the first cut.

4-Chemical analysis:-

Nitrogen, phosphorus, potassium content in the dried herb of lemongrass

were determined by Kiel Dahl method (Cottenie *et al.* 1982).

5- Essential oil content:

a- The oil percentage:

The essential oil obtained performed as described by (Venzon *et al.*, 2018), collected plant material (whole plants), the leaves were transected in lengths of approximately 2 cm, then was washed thoroughly with distilled clean water and crushed into smaller pieces. The plant material was transferred to storage in a glass beaker. Thereafter, boiled in distilled water (100 g of plant material in 1000 mL of water) for 2 h and the hydro distillation extraction method was performed using the Clevenger apparatus and aliquots of the essential oil were placed in micro tubes. The extract was stored at -80 °C until use. The essential oil was obtained by hydro-distillation expressed as ml 100 g⁻¹ fresh herb.

Table (2): Physical and chemical properties of used compost:

| Properties | Statement |
|----------------------------------|-----------|
| Volume of 1 kg (m ³) | 1.2 |
| Moisture content (%) | 21.1% |
| Organic Matter (%) | 35.8% |
| Organic Carbon (%) | 12.6% |
| Total N (%) | 1.4% |
| C:N ratio | 9:1 |
| Total P (%) | 0.88% |
| Total K (%) | 1.11% |
| Total Ca (%) | 4.6% |
| Total Mg (%) | 0.2% |
| Fe (%) | 0.55% |
| Mn (ppm) | 100 |
| Zn (ppm) | 100 |
| EC | 4.88 |
| PH | 7.9 |

The volatile oil percentage was determined in the fresh herb obtained from each replicate in all cuts during the two experimental seasons, by using the water described by (British Pharmacopeia 1963).

b. Gas Chromatography and Mass Spectrometry (GC-MS) analysis of essential oil:

The essential oil obtained from the second cut in the second season was analyzed using GC-MS apparatus at GC/MS LAB of National Research Center (NRC), Giza, Egypt.

RESULTS AND DISCUSSION

1. Growth parameters:

1.1 Plant height:

The recorded Data in Table (3) clearly indicate that all studied growth and yield characters were significantly affected by the irrigation regime. The Plant height

was significantly reduced under water stress conditions in both seasons and this effect was more pronounced with increasing the severity of water stress in two experimental seasons by decreasing of water amount from 24 liters/plant/week to 4liters/plant/week, plant height (cm) showed significant reduction.

The irrigated plants 24liters /plant/ week significantly resulted in the tallest plants in each cutting in two growing seasons in comparison to the irrigation 12, 8 and 4 liters/plant/week. Meanwhile the treatment of watering 4 liters/ plant/week produced the shortest plants in both seasons. the plant height in the first cutting in the second season was (116.8), (98.5), (79.4) and (56.4) whereas, it was (158.6), (148.8), (129.7) and (88.3) cm in the second cutting experimental season for the treatments irrigation 24, 12, 8 and 4 liters/plant/week respectively.

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Table (3): Effect of water regime on plant height and the number of tillers per plant.

| Treatment of Water regime liters/plant/week | Plant height in cm | | | | Number of tillers per plant | | | |
|---|------------------------|---------------------|------------------------|---------------------|-----------------------------|---------------------|------------------------|---------------------|
| | 1 st season | | 2 nd season | | 1 st season | | 2 nd season | |
| | 1 st cut | 2 nd cut | 1 st cut | 2 nd cut | 1 st cut | 2 nd cut | 1 st cut | 2 nd cut |
| 24 | 111.8 | 151.2 | 116.8 | 158.6 | 23.4 | 46.1 | 23.8 | 56.1 |
| 12 | 101.5 | 133.8 | 98.5 | 148.8 | 20.8 | 40.7 | 20.9 | 46.7 |
| 8 | 80.9 | 125.6 | 79.4 | 129.7 | 14.6 | 35.7 | 14.3 | 39.3 |
| 4 | 57.7 | 114.7 | 56.4 | 88.3 | 11 | 27.5 | 11.1 | 32.4 |
| LSD (5%) | 0.22 | 1.61 | 2.23 | 1.81 | 0.21 | 0.6 | 0.5 | 0.99 |

These results could explained Such reduction in plant height in response to drought may be due to blocking up of xylem and phloem vessels thus slowness any translocation through (Lovisollo and Schuber 1998) in addition (Ben-zioni *et al.*, 1967) reported that the incorporation of amino acids into protein is inhibited by longer water stress.

Similar results were obtained by (Chakraborty *et al.*, 2010), (Abdel-kader *et al.*, 2014) and (Singh *et al.*, 2016) on lemongrass. Also (Khalil *et al.*, 2013), (Hendawy *et al.*, 2013) and (El-mekawy *et al.*, 2013) reported that reduced water uptake results in decrease in tissue water content.

Therefor under drought stress conditions, cell elongation in plants is inhibited by reduced turgor pressure (El-Mekawy *et al.*, 2013). Likewise drought stress also trims down the photo-assimilation metabolites required for cell division as consequence impaired mitosis (Farooq *et al.*, 2009), cell elongation and expansion result in reduced plant height and growth (Eiasu *et al.*, 2009) on *Pelargonium capitatum* plant, (Gerami *et al.*, 2016) on *Origanum vulgare L* found that water stress negatively affected plant growth.

1.2 Number of tillers/plant:

The data in Table (4) clearly indicate that, the mean number of tillers/plant was markedly increased as a result of increasing of water supply in the two cutting of each experimental season. The treatment of irrigation 24 L/P/W significantly gave more tillers per plant than those of watering 12, 8 and 4 L/P/W in both seasons. The lowest values in this concern were produced by watering lemongrass plants 4 L/P/W. For example, the mean number of tillers/plant in the second cutting of the first season were (46.1), (40.7), (35.7) and (27.5) for treatments of irrigation 24, 12, 8 and 4 L/P/W, respectively.

These results reflect the importance role of the adequate water supply for lemongrass plants in enhancing tillering. This may be due to that drought reduced cycling dependent Kinase (Taiz & Zeiger 2006) activity results in slower cell division as well as inhibition of growth (Schuppler *et al.*, 1998; Farooq *et al.*, 2009). This supported by the results of (Rahmani *et al.*, 2011) on *Calendula officinalis* and (El-Mekawy, 2013) on *Achillea santouolina*.

Similar results were obtained by (Singh *et al.*, 2016) and (Abdel-kader *et al.*, 2014) on lemongrass.

Table (4): Effect of water regime on the fresh and dry weight of herb.

| Treatment of Water regime liters/plant /week | Herb fresh weight (g / plant) | | | | Herb dry weight (g / plant) | | | | Herb fresh yield (ton /hectare) | | | |
|--|-------------------------------|---------------------|------------------------|---------------------|-----------------------------|---------------------|------------------------|---------------------|---------------------------------|---------------------|------------------------|---------------------|
| | 1 st season | | 2 nd season | | 1 st season | | 2 nd season | | 1 st season | | 2 nd season | |
| | 1 st cut | 2 nd cut | 1 st cut | 2 nd cut | 1 st cut | 2 nd cut | 1 st cut | 2 nd cut | 1 st cut | 2 nd cut | 1 st cut | 2 nd cut |
| 24 | 652.3 | 1557 | 705.5 | 1440 | 163.1 | 429 | 178.4 | 360 | 26.09 | 62.27 | 28.22 | 57.60 |
| 12 | 443.2 | 1381 | 450.8 | 1016 | 110.8 | 352.9 | 112.7 | 258.1 | 17.73 | 55.24 | 18.03 | 40.62 |
| 8 | 201.9 | 1136 | 202.8 | 841.1 | 50.49 | 288.9 | 51.54 | 206.8 | 8.08 | 45.44 | 8.11 | 33.64 |
| 4 | 167.2 | 829.9 | 169.5 | 724.4 | 41.83 | 234.7 | 42.41 | 182.1 | 6.69 | 33.20 | 6.78 | 0.00 |
| LSD (5%) | 5.69 | 11.11 | 14.55 | 17.16 | 1.43 | 21.43 | 5.44 | 4.15 | 0.23 | 0.44 | 0.58 | 0.69 |

1.3 The fresh weight of herb:

It is evident from the data in Table (4) that, increasing amount of water revealed significant increases in total fresh weight of herb/plant in both seasons. Where, the highest means were recorded with plants received the highest water quantity.

The superiority of the plants that received the highest rate of irrigation quantities in producing the heaviest total plant fresh weight and reached its maximum values in the case of watering 24 L/P/W in the two cutting through two experimental season. Meanwhile, the irrigated plants 12 and 8 L/P/W respectively gave significantly lower fresh weight compared to the watered at 24 L/P/W in both seasons.

On the other hand, the irrigated plants 4 L/P/W significantly resulted in the lowest fresh weight of herb/plant compared to the other treatments. For example the mean fresh weight of herb/plant in the second cutting during the second season were (1440), (1015.56), (841.11) and (724.44) gm/plant for the treatment of watering 24, 12, 8 and 4 L/P/W, respectively.

The increment in the obtained fresh weight of herb/plant as a result of reducing water regime could be attributed to the increment in both plant

height and number of tillers/plant (Table 4) The pronounced effect of increased irrigation on plant height, number of branches may be attributed to the availability of sufficient moisture around the root concentrated and thus a greater proliferation of root biomass resulting in the higher absorption of nutrients (Tatrai *et al.*, 2016) and water leading to production of higher vegetative biomass (Singh *et al.*, 2016), It was found that increasing levels of water stress reduce growth and yield due to reduction in photosynthesis and plant biomass (Bahreininejad *et al.*, 2013). Under increasing water stress levels photosynthesis was limited by low CO₂ availability due to reduced stomatal and mesophyll conductance (Elansary *et al.*, 2016).

Drought stress is associated with stomatal closure and thereby with decreased CO₂ fixation (EL-Attar & Ashour, 2016).

Similar results were obtained by (Singh *et al.* 2016) on *Cymbopogon flexuosos* S.), (Abdel-kader *et al.*, 2014) on lemongrass and (El-Mekawy, 2013) on *Achillea santolina*, who reported that the fresh weight of herb/plant were markedly increased as a result of increasing water regime.

1.4 The dry weight of herb:

The reported data in Table (4) indicate that, the dry weight of herb increased with increase of amount of water in two growing seasons. The highest irrigation treatment 24 L/P/W significantly gave heavier dry weight of herb during the two growing seasons. Whereas, the irrigated plants with 8 L/P/W significantly resulted in higher dry weight of herb per plant and per Fadden than those obtained by the treatment of irrigation 4 L/P/W which gave the lowest values in this respect in the two experimental seasons.

2. The essential oil content:

2.1 Essential oil percentage in the fresh herb:

The reported data in Table (5) clearly illustrate that the essential oil concentration in the fresh herb of *Cymbopogon citratus* plants relatively showed a slight increment with reducing applied water quantities in each cutting during the two experimental seasons. The highest value of essential oil percentage was found in the fresh herb of the irrigation plants at 8 L/P/W.

Meanwhile the treatment of 24 L/P/W resulted in lower oil percentage than of irrigation at 4 L/P/W. Otherwise, obtained herb from the treatment of 24 L/P/W had the lowest values in this respect. For example, the essential oil percentage in the fresh herb of second cutting during the season of 2016 were (0.33%), (0.37%), (0.42%) and (0.40%) for treatment of irrigation at 24, 12, 8, and 4 liters/ plant/ week respectively.

These results reflect that, the essential oil concentration was in inverse ratio with the herb yield, and could be explained through the dilution effect in oil concentration as result of increasing in the produced herb yield with reducing amount of water as shown in Table (4).

Drought stress increases the secondary products percentage of more

medicinal and aromatic plants(Koyro& Huchzermeyer, 2018), because in case of stress, more metabolites are produce in the plants and substances prevent from oxidization in the cells (Van Oosten *et al.*, 2017), but secondary products content reduce under drought stress, because the interaction between the amount of the secondary products percentage (Nakamura *et al.*, 2003) and mass production is consider important as two components of the secondary products content (Yadav *et al.*, 2014) and by exerting stress, increases the secondary products percentage, but mass production decreases by the drought stress which led to a higher density of the oil glands due to the reduction in leaf area results in an elevated amount of oil accumulation (Nakamura *et al.*, 2003), therefore secondary products content reduces (Hendawy *et al.*, 2013; Hani *et al.*, 2015). On the other side Water deficit stress induces a decrease in glandular trichome density and size as well. trichomes and pathway gene expression in plants grown under (mild and moderate) water stress conditions (Yadav *et al.*, 2014).

Such result could be supported by the finding of (Abdel-kader *et al.* 2014) who mentioned that essential oils are the product of the respiratory catabolic processes, which increase under the dry conditions of the growing site.

2.2 The essential oil yield per plant (cc):

It is evident from the data in Table (4) that the essential oil yield /plant as well as per Fadden significantly increased with increasing of water quantity in each cutting through the two growing seasons. The treatment irrigation of 24 L/P/W gave significantly higher oil yield than those of watering at 12, 8 and 4 L/P/W in the two experimental seasons.

Table (5): Effect of water regime on the essential oil percentage%.

| Treatment of Water regime liters/plant/week | Essential oils percentage | | | | Oil yield (cc/ plant) | | | | Oil yield (L/ hectare) | | | |
|--|---------------------------|---------------------|------------------------|---------------------|------------------------|---------------------|------------------------|---------------------|------------------------|---------------------|------------------------|---------------------|
| | 1 st season | | 2 nd season | | 1 st season | | 2 nd season | | 1 st season | | 2 nd season | |
| | 1 st cut | 2 nd cut | 1 st cut | 2 nd cut | 1 st cut | 2 nd cut | 1 st cut | 2 nd cut | 1 st cut | 2 nd cut | 1 st cut | 2 nd cut |
| 24 | 0.357 | 0.334 | 0.341 | 0.33 | 2.32 | 5.26 | 2.42 | 4.73 | 92.80 | 210.40 | 96.80 | 189.20 |
| 12 | 0.403 | 0.38 | 0.386 | 0.37 | 1.79 | 5.21 | 1.75 | 3.82 | 71.60 | 208.40 | 70.00 | 152.80 |
| 8 | 0.485 | 0.423 | 0.427 | 0.422 | 0.98 | 4.81 | 0.87 | 3.55 | 39.20 | 192.40 | 34.80 | 142.00 |
| 4 | 0.451 | 0.413 | 0.413 | 0.408 | 0.76 | 3.44 | 0.71 | 2.99 | 30.40 | 137.60 | 28.40 | 119.60 |
| LSD (5%) | 0.015 | 0.0012 | 0.009 | 0.006 | 0.06 | 0.05 | 0.06 | 0.06 | 2.40 | 2.00 | 2.40 | 2.40 |

Meanwhile, the irrigated plants every 4 liters/plant/week significantly produced the lowest oil yield compared with the other irrigation levels. The total oil yield/hectare/ season was (210.4), (208.4), (192.4) and (137.6) L/hectare for the treatments of irrigation at 24, 12, 8 and 4 L/P/W respectively in the first experimental season.

The increment in the obtained oil yield as a result of reducing water quantities could be attributed to the increment in the corresponding fresh herb yield (Table 4). Water deficit in plants may lead to physiological disorders, such as a reduction in photosynthesis and transpiration that may cause changes in the yield and composition of essential oil in aromatic plants has been suggested by (Eiasu *et al.* 2009). Beside this alterations in oil accumulation are considered to be mainly due to its effect on plant growth and differentiation. Reduction of leaf area under stress enhances the density of the oil glands and oil accumulation, the highest essential oil yield per unit area was produced under moderate water stress (Golezani *et al.*, 2008).

2.3 Alterations in oil composition with water regime:

The selected samples of lemongrass

essential oil were obtained by hydro distillation of the fresh herb from the 2nd cutting at the end of the second season. Essential oil constituents were identified based on their retention time and by co-injection with authentic compounds and mass- spectrophotometry to determine the relative peak area for individual constituents for each volatile oil sample. In all cases number of peaks was identical and there were some of changes in the concentration of individual essential oil constituent.

Differences in the concentration of 7 identified constituent of lemongrass oil were observed in Table (6). There were 4 major hydrocarbons constituent in the volatile oil: the volatile oil: myrcene, allo & cis ocimene, limonine and α & β pinen. The citral content in lemongrass oil higher than 75% is considered as high quality product (Rehman *et al.* 2016). It could be observed that, total hydrocarbon constituents decreased with decreasing of water regime. Maximum limonene content (4.02%) was obtained with the treatment of irrigated at 12 L/P/W. Meanwhile limonene content (2.02%, 2.8 % and 3.52%) was obtained from plants irrigated at 24, 8 and 4 L/P/W respectively.

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Table (6): Effect of water regime on the percentage of essential oil constituents in the dried leaves of plant.

| Constituents % | 24 liters/plant/ week | 12 liters/plant/ week | 8 liters/plant/ week | 4 liters/plant/ week |
|-----------------------|-----------------------|-----------------------|----------------------|----------------------|
| 2 Pentanol | 0.27 | 0.27 | 0.27 | 0.48 |
| Myrcene | 7.59 | 7.28 | 6.75 | 3.66 |
| p-mentha 1,5,8 triene | 0.86 | 0.8 | 0.76 | 1.91 |
| Allo,cis ocimene | 0.96 | 0.53 | 0.44 | 1.5 |
| Limonene | 2.02 | 4.02 | 2.8 | 3.52 |
| Fenchone | 0.24 | 0.22 | 0.18 | 0 |
| Myrtanal | 0.32 | 0.15 | 0 | 0 |
| Caran 4ON,3hydroxy | 0.21 | 0.24 | 0 | 0 |
| & β Pinene | 0.66 | 0.32 | 0.3 | 0.71 |
| Linalool | 1.75 | 1.23 | 1.22 | 2.98 |
| Trans chrysanthmal | 0.39 | 0.38 | 0.35 | 0.25 |
| Verbenol | 1.06 | 0.9 | 0.88 | 2.64 |
| E,z Cirtal | 76.89 | 78 | 81.2 | 76.85 |
| Nerol | 0.40 | 0.36 | 0.33 | 0.73 |
| Geraniol | 3.16 | 4.85 | 4.21 | 3.55 |
| Trans caryophyllen | 0.32 | 0.34 | 0.31 | 0.73 |
| Unknown compounds | 2.91 | 0.12 | 0 | 0 |

Otherwise, citral as major aldehyde constituent in the oil was increased by decreasing water regime. For example, the highest citral percentage was (81.2%) in samples from plants irrigated at 8 L/P/W. These results are agreement with (Abdel-kader *et al.*, 2014), who assured the above mentioned results and attributed it to the higher density of glandular hairs and greater content of major constituents with water deficit. Moreover, showed same trend. Some changes in the peaks of α and β pinene in the chromatograms could be due to

the breakdown of occurring components on relative percentage.

Similarly, (Khorasaninejad *et al.*, 2011) on peppermint (*Mentha piperita* L.) noticed that the highest content of mentone and menthofuran were obtained under 100% field capacity, while the highest values of menthol were obtained under the water stress of 70% field capacity. Beside (Radacsi *et al.*, 2010) noticed a significant decrease in the proportion of linalool content in the essential oil in *Ocimum basilicum* plant.

Likewise (Eiasu *et al.*, 2008) argued that citronellol and citronellyl formate in geranium increase with an increase in the stress level, but the reverse was true for other major essential oil components geraniol and geranyl formate were unaffected by water stress.

3. Mineral content of the dry herb:

3.1 Nitrogen content:

The data in Table (7) show that in most cuts of the two growing seasons the total nitrogen percentages in the dried herb slightly increased with the increasing water regime. In general, the treatment of irrigation at 24 L/P/W gave relatively the highest total nitrogen percentages in the dried herb in the two cuttings during the two growing seasons. Otherwise, the irrigation treatment 4 L/P/W generally resulted in lower nitrogen percentage in the herb than the treatment of nitrogen 8 and 12 L/P/W in the two cuttings in the two growing season respectively.

This decrease tendency in the total nitrogen percentages in the dried herb of

Cymbopogon citratus plants as a result of reducing water amount could be explained through the increment in the produced dry matter yield, which may lead to a dilution in nitrogen percentages in the dried herb. The decrease in Nitrogen percent a result of water stress may be due to the mobilization of nitrogen ions to the leaves of the plant for the synthesis of special proteins and amino acids as a mechanism to withstand the effect of water stress (Khalil and Yousef 2014), water application improves the growth parameters.

Under water stress, lemon grass removed large quantities of nutrients particularly nitrogen and potassium (Panwar *et al.*, 2011), These results could be supported by the findings of (El- Attar and Ashour, 2016) on chamomile plants who mentioned that, concentrations of N % were generally were affected by the different levels of irrigation intervals. In both seasons, the nitrogen was reduced steadily with increasing irrigation intervals.

Table (7): Effect of water regime on N, P and K percentage in the dried leaves of lemongrass plant.

| Treatment of Water regime liters/plant/week | N % | | | | P % | | | | k % | | | |
|---|------------------------|---------------------|------------------------|---------------------|------------------------|---------------------|------------------------|---------------------|------------------------|---------------------|------------------------|---------------------|
| | 1 st season | | 2 nd season | | 1 st season | | 2 nd season | | 1 st season | | 2 nd season | |
| | 1 st cut | 2 nd cut | 1 st cut | 2 nd cut | 1 st cut | 2 nd cut | 1 st cut | 2 nd cut | 1 st cut | 2 nd cut | 1 st cut | 2 nd cut |
| 24 | 1.33 | 1.18 | 1.18 | 1.03 | 0.213 | 0.168 | 0.21 | 0.17 | 3.57 | 3.92 | 3.59 | 3.88 |
| 12 | 1.30 | 1.17 | 1.17 | 1.21 | 0.197 | 0.162 | 0.2 | 0.163 | 3.49 | 3.62 | 3.38 | 3.68 |
| 8 | 1.26 | 1.15 | 1.17 | 1.16 | 0.182 | 0.150 | 0.19 | 0.158 | 3.53 | 3.61 | 3.55 | 3.65 |
| 4 | 1.25 | 1.03 | 1.15 | 1.11 | 0.147 | 0.152 | 0.15 | 0.157 | 3.48 | 3.54 | 3.51 | 3.66 |
| Mean | 1.29 | 1.13 | 1.17 | 1.13 | 0.18 | 0.16 | 0.19 | 0.16 | 3.52 | 3.67 | 3.51 | 3.72 |

In general, moisture stress induces an increase in N (Wu and Garg 2003). These results similar with (Chakraborty *et al.* 2010) showed that the N uptake of lemongrass was positively influenced by different irrigation regimes.

3.2 Phosphorus content:

The data in Table (7) show that, the water regime had no clear effect on the total phosphorus percentage in the dried herb of lemongrass plants in the two cuttings during the two growing seasons. The reduction in phosphorus % might be due to the reduction of root activity and leaf water potential (Wu and Garg 2003), due to water stress which restricted the plant's ability to absorb P through its root (Khalil and Yousef, 2014).

3.3 Potassium content:

The data in the Table (7) show that, potassium percentage in the leaves of the dried lemongrass herb were increased with increasing water regime in the two cuttings in the growing seasons of 2015 and 2016 respectively. The treatment of irrigated at 24 L/P/W resulted in relatively higher K% in the dried herb compared to treatments of watering at 12 , 8 and 4 liters/plant/week. Whereas, the obtained herb from the irrigated plants at 4 L/P/W was contained generally the lowest K-percentages compared to the other water regime during the two experimental seasons. For example, K% was between (3.92%) and (3.54 %) in the second cutting of the first season for the treatments of watering at 24 and 4 L/P/W respectively. These decrease in potassium % as water quantity decrease might be as a result of the mobilization of K ions from the leaves to the roots in response to water stress to increase the osmotic potential of the sap of the roots to help the plants to withstand the effects of water stress (Khalil and Yousef, 2014).

Opposite to that (Bahreininejad *et al.* 2013) on *Thymus daenensis* demonstrated that the plant under moderate water stress had no effect on K⁺ content, but severe water stress increased K⁺ content. Due to in plants coping with water stress, the accumulation of K⁺ may be more important than the production of organic solutes during the initial adjustment phase, also (El- Attar and Ashour 2016) on chamomile assured that.

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دراسة تأثير ندرة ماء الري على النمو والمحصول ومحتوى الزيت الطيار لنبات حشيشة الليمون حقليا .

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الملخص العربي

أجريت تجربتان حقليتان على نبات حشيشة الليمون بمزرعة خاصة بزمام الخطاطبة -مركز السادات - محافظة المنوفية- مصر خلال موسمي 2015 و 2016 بهدف دراسة تأثير أربعة مستويات من الري بالتنقيط (4, 8, 12, 24 لتر/نبات/أسبوع) على كل من النمو الخضري ونسبة ومحتوى محصول الزيت الطيار ومكوناته وكذلك التركيب الكيماوي لنبات حشيشة الليمون. وتم اخذ جميع النتائج بمعمل التقنيات الحيوية للنباتات الطبية والعطرية بقسم البيوتكنولوجيا النباتية بمعهد بحوث الهندسة الوراثية والتكنولوجيا الحيوية جامعة مدينة السادات خلال موسمي التجربة وأضحت النتائج أن طول النبات و عدد الخلفات و الوزن الطازج و الوزن الجاف للنبات ومحصول العشب الطازج والجاف للهكتار ومحتوى الأوراق من عناصر (النيتروجين و الفسفور والبوتاسيوم) وكذلك نسبة الزيت الطيار انخفضت قيمها مع تقليل كمية مياه الري في كلا موسمي التجربة وأعطى معدل الري ب (24 لتر/نبات/أسبوع) أفضل النتائج في حين أعطى معدل ري (8 لتر /نبات/ أسبوع) أفضل جودة لمحصول الزيت الطيار (محتواه من السترال الكلي).

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