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# Response of Lemongrass Plants to Magnesium Nanoparticles Loaded on Chitosan under Sandy Soil Conditions

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**Abstract:** An experiment was conducted during 2017/2018 and 2018/2019 seasons to evaluate the response of *Cymbopogon flexuosus* L. and *Cymbopogon citratus* L. lemongrass plants to spraying of Chitosan either alone or loaded with magnesium nanoparticles under Siwa Oasis region conditions. The treatments were control, chitosan 0.2%, chitosan + 0.1 g/L magnesium nanoparticles, chitosan + 0.2 g/L magnesium nanoparticles and chitosan + 0.3 g/L magnesium nanoparticles. Plant height (cm), fresh and dry weights/ plant (g), estimated fresh and dry weights (kg) /fed., total chlorophyll (reading) and Mg % were recorded. However, volatile oil attributes including volatile oil %, volatile oil content/ plant (ml) and estimated yield of volatile oil per fed. (L) were determined. However, volatile oil constituents resulted from the used treatments in both species of lemongrass was also determined in the first season. The great effect on studied measurements were obtained with chitosan loaded with 0.3 g/L Mg nanoparticles, however, all used treatments were recorded higher values than control. Sometimes the treatment of chitosan + 0.2 g/L Mg exhibited similar values to those obtained in chitosan + 0.3 g/L Mg especially in fresh weights per plant or per fed. On the other hand, *C. flexuosus* L. was superior than *C. citratus* in most measurements except fresh weights values where they exhibited similar values in the first cut but *C. flexuosus* was superior in the second cut. The treatments of chitosan loaded with 0.3 g/L nano Mg exhibited higher values of Mg and this finding was correlated with higher values of volatile oil %, volatile oil yield/plant (ml) and yield of volatile oil per fed. (liter). However, *C. citratus* was superior than *C. flexaosus* in Mg content and consequently in volatile oil production. Data also showed that the volatile oil attributes were decreased in the second cut than in the first one. Regarding volatile oil fractions, data showed that the main component was Citral in both species of lemongrass. The used treatments greatly affected volatile oil fractions than control. Generally, it could be extracted that the higher volatile oil fractions values in *C. flexuosus* were Citral, Benzene methoxy, Geranyl acetate, Octane dimethyl and Hydroxy methylpropyl. However, in *C. citratus* the main components were Citral, Myrcene, Geraniol, Bicyclo heptan and Linalool oxide.

**Key words:** Lemongass · *Cymbopogon flexuosus* · *Cymbopogon citratus* · Chitosan · Magnesium nanoparticles · Vegetative growth · Oil productivity · Volatile oil compound · Citral

## INTRODUCTION

Lemongrass (*Cymbopogon flexuosus)*, lemongrass (*Cymbopogon citratus*), plamarosa (*Cymbopogon martini*) and citronella (*Cymbopogon winterianus*) are the elite members of genus Cymbopogon. Lemongrass is an essential aromatic cum medicinal herb. It belongs to the family Poaceae and genus Cymbopogon, which consist of extra than eighty species.

*Cymbopogon flexuosus*, East Indian origin, (E) its integral oil has been traditionally used as a treatment for a variety of fitness conditions. Recent scientific research have furnished proof supporting its antimicrobial, antioxidant, antifungal and anti-inflammatory. However, *Cymbopogon citratus,* West Indian origin, (W) which has a place with fam. Poaceae, is one of the basic oil crops. It is developed in numerous tropical nations in South America, Asia and Africa [1].

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Both species are turfed lasting grass with various hardened stems emerging from a short, rhizomatous rootstock. The leaves are 100 cm long and 3 cm wide and utilized as a wellspring of cellulose and paper creation [2]. Fundamental oil substance of the stems and leaves normal 0.25-0.35% with citral being the primary segment (80-86%). They used for its lemon flavor and aroma. It is utilized in cooking as a significant wellspring of lemon enhancing. Therapeutically, it is calming, antidiabetic, pain relieving, anthelmintic, antibacterial, antifungal, anticancer, cancer prevention agent, antiplatelet, hepatoprotective, narcotic and vasorelaxant. Citral is the significant constituent of its fundamental oil. The oil is carminative, depressant, pain relieving, antipyretic, antibacterial and antifungal [3-6].

Magnesium is a piece of chlorophyll in green plants and it helps in initiation of many plant compounds required for development [7]. Numerous examiners announced the invigorating impact of applied mineral and micronutrients as foliar splash on development and blossoming of various therapeutic and sweet-smelling plants. In this regard El-Khyat [8] on *Rosmarinus officinalis* and Amran [9] on *Pelargonium graveolens*, outlined that foliar utilization of Mg improved the development and substance arrangement of the plants. In addition, Youssef [10] on *Echinacea purpurea*, Yadegari [11] on borago, thyme and marigold and Abou-Shleell [12] on *Moringa oleifera* who referenced that foliar use of Mg in chelated structure at 500 ppm altogether expanded all the concentrated vegetative development parameters and synthetic organization of the plants. In addition, magnesium is basic to every living cell, where it assumes a critical job in controlling significant organic polyphosphate compound like ATP, DNA and RNA. It is has basic parts or as protein co-factors for plant digestion. The advancement of nanoscale of Mg may subsequently help in setting off the metabolic pathways including photosynthesis prompting better development and better return of plant.

Nano-particles applied science are utilized to assess their consequences for plant development, yield and for the control of plant sicknesses [13]. Late investigations indicated that nano-particles actuate an advantageous impact on plant development and improvement [14]. Lithovit compound particles contain calcium carbonate (80%), magnesium carbonate (4.6%) and Fe (0.75%). The helpful impact of this compound is being contains calcium carbonate ($CaCO_3$) disintegrates to calcium oxide (CaO) and carbon dioxide ($CO_2$) in leaves stomato and this $CO_2$ expands photosynthesis force, prompting expanded carbon take-up and digestion, consequently expanding plant development [15]. The beneficial outcomes of lithovit compound on plant development and concoction constituents were accounted for by Abd El Ghafar *et al.* [16] on onion plants, Abo-Sedera *et al*. [17] on snap bean plants, Abou-Shleell [12] on *Moringa oleifera.* They announced that foliar application with lithovit at 500 ppm fundamentally expanded all the concentrated vegetative development parameters and substance structure of moringa plants.

Chitosan, a direct polysaccharide evaluated by Azuma *et al.* [18]; Jayakumar *et al.* [19] and Merzendorfer [20] connected 2-amino-deoxy-β-D-glucan, is a deacetylated subsidiary of chitin, which is the second most plenteous polysaccharide found in nature after cellulose. Chitosan has been seen as non-harmful, biodegradable, biofunctional, biocompatible and is accounted for by a few specialists to have solid antimicrobial and antifungal exercises [21]. It can frame a film on products of the soil surfaces and diminishes breath rate by changing the penetrability of carbon dioxide and oxygen. The 3 - NH+ gathering of chitosan may likewise limit the proliferation of hurtful germs, therefore adequately controlling organic product rot. Considering these predominant properties of chitosan, it has been effectively utilized in numerous post harvested organic products, vegetables or their crisp cut examples [22]. Nowadays numerous reports including chitosan covering for the most part center around the assortments of foods grown from the ground or compound covering dependent on chitosan [23, 24]. Be that as it may, with respect to the saving attributes, for example, physiological quality, biochemical parameters, microbial markers and supplement status of post-reap leafy foods, there is no definite report at present. This audit endeavors to condense the impact of chitosan coatings on saving character of post-gather foods grown from the ground. We expect that this survey will give bits of knowledge to analysts dealing with post-collect conservation. [25, 26]. As of late, a few specialists announced that chitosan upgraded plant development and improvement [27-29]. They detailed that utilization of chitosan expanded key compounds exercises of nitrogen digestion (nitrate reductase, glutamine synthetase and protease) and improved the transportation of nitrogen (N) in the practical leaves which upgraded plant development and advancement.

The main target of this work was to evaluate the efficacy of chitosan either alone or loaded with magnesium nanoparticles on growth, volatile oil production and components of *Cymbopogon flexuosus* (East Indian lemongrass, E) and *Cymbopogon citratus* (West Indian lemongrass, W) plants under Siwa Oasis conditions.

## MATRIALS AND METHODS

This work was conducted during the two successive seasons of 2017/2018 and 2018/2019 in north western desert of Egypt, Siwa Oasis region at the Agricultural Experimental Station of the Desert Research Center (29.21° N and 25.40° E) to evaluate the response of *Cymbopogon flexuosus* (East Indian lemongrass, E) and *Cymbopogon citratus* (West Indian lemongrass, W) plants to spraying of chitosan either alone or loaded on magnesium nanoparticles under sandy soil conditions.

Chitosan nanoparticles molecular weight (71.3 kDa,) was purchased from Polymar Ciência e Nutrição S/A (Fortaleza, Brazil). Magnesium oxide (MgO) and methacrylic acid were purchased from Sigma-Aldrich.

**Preparation of Magnesium Oxide (MgO) Nanoparticles:** A Nd:YAG laser was used for preparing the magnesium oxide (MgO) nanoparticles. Output laser power was 100mJ/, wavelength was 1064nm, repetition rate was 7ns and pulse duration was 8ns. The beam with a diameter of 6 mm. Using pulsed laser ablation in ethanol. Magnesium oxide (MgO) was in purity of 99.9%).

**Preparation of Chitosan Nanoparticles:** Firstly, chitosan was dissolved in a methacrylic acid solution (0.5 in-v:v%) for 12 h under magnetic stirring. The chitosan concentration was 0.2% (w/v).

Magnesium oxide (MgO) nanoparticles at 0.1, 0.2 and 0.3 g was added to 1 liter of the chitosan solution under continuous stirring at 70°C for 1 h, leading to the formation of chitosan magnesium oxide nanoparticles, which were cooled in an ice bath. The suspension was centrifuged for 30 min at 4000 rpm and the supernatant was discarded.

Lemongrass plants were propagated vegetative through slips obtained by the splitting up of individual adult clumps. The rooted slips were cultivated on 15th of April during the two successive seasons the experiment at spacing of 50 cm between hills and 50cm between rows (16800 plant/ fed) under drip irrigation system with the drippers of four liters / hr for one hour twice every week. The experiment was laid out in split plot design with three replicates (each replicate contained 22 plants). The two species of Cymbopogon were arranged in the main plot and the applied treatments of magnesium nanoparticles loaded on chitosan were hold in sub-main plots. The used treatments were as follows:

- Control
- Chitosan, 0.2 %
- Chitosan, 0.2 % + 0.1 g /L magnesium nanoparticles
- Chitosan, 0.2 % + 0.2 g /L magnesium nanoparticles
- Chitosan, 0.2 % + 0.3 g /L magnesium nanoparticles

All treatments were applied as foliar spraying after 30 and after 60 days from transplanting date and were carried out again after 15 and after 45 days from the first cut date.

All agricultural practices of growing lemongrass plants were adopted when ever needed. Compost at a rate of 10 $m^3$/feddan and Calcium superphosphate (15.5% $P_2O_5$) at a rate 100 kg/fed were added during soil preparation. All treatments were fertilized with 200 kg/fed ammonium sulphate (20.5% N) and 50 kg/fed potassium sulphate (48% $K_2O$). Nitrogen and potassium fertilizers were applied in two equal doses in the season. The first dose was added 30 days after transplanting, the second dose was added one week after the first cut of plants (Recommendation Ministry of Agriculture).

Soil and irrigation water analysis of experiment were determined according to Page *et al.* [30] and Rainwater and Thatcher [31].

(A). The mechanical analysis of the experimental soil area.

| Depth (cm) | Sand (%) | Silt (%) | Clay (%) | Soil texture |
|---|---|---|---|---|
| 0-30 | 92.91 | 5.21 | 1.88 | Sandy |

(B). The chemical analysis of the experimental soil area.

| | | | Soluble anions (meq/L) | | | | Soluble cations (meq/L) | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| pH | EC (ds/m) | O.M. (%) | $CO_3^{--}$ | $HCO_3^-$ | $Cl^-$ | $SO_4^{--}$ | $Ca^{++}$ | $Mg^{++}$ | $Na^+$ | $K^+$ |
| 7.5 | 4.1 | 0.5 | - | 3.6 | 31.3 | 6.1 | 8.6 | 7.5 | 0.2 | 24.7 |

(C). The chemical analysis of irrigation water.

| | | Soluble anions (meq/L) | | | | Soluble cations (meq/L) | | | |
|---|---|---|---|---|---|---|---|---|---|
| EC (ds/m) | ppm | $CO_3^{--}$ | $HCO_3^-$ | $Cl^-$ | $SO_4^{--}$ | $Ca^{++}$ | $Mg^{++}$ | $Na^+$ | $K^+$ |
| 4.23 | 2709.60 | - | 2.17 | 22.02 | 15.77 | 9.47 | 7.75 | 21.75 | 0.99 |

Lemongrass plants were harvested twice per season on November 15th and February 4th by cutting the vegetative parts of plants 15 cm above the soil surface.

**The Following Data Were Recorded**

**Vegetative Growth Parameters and Yield Attributes:** Plant height (cm), fresh weight /plant (g), estimated fresh weight of herb /fed. (kg), dry weight/plant (g) and estimated dry weight of herb/fed.(kg).

**Chemical Analyses:** Volatile oil percentage (%): was determined in the air dried herb by hydrodistillation for 3 hours using a Clevenger apparatus. The volatile oil (%) was calculated as a relative percentage (v/w) according to British Pharmacopoeia [32], volatile oil yield / plant (ml) and estimated volatile oil yield / fed. (L).

**Volatile Oil Constituents:** Were determined by using the GC-MS analysis of volatile oils was conducted in the second season using Gas Chromatography-Mass Spectrometry instrument stands at the Laboratory of Medicinal and Aromatic Plants, National Research Center, Egypt by the method described by Adame [33] with the following specifications. Instrument: a TRACE GC Ultra Gas Chromatographs (THERMO Scientific Corp., USA), coupled with a THERMO mass spectrometer detector (ISQ Single Quadrupole Mass Spectrometer). The GC-MS system was equipped with a TR-5MS column (30 m x 0.32 mm i.d., 0.25 µm film thickness). Analyses were carried out using helium as carrier gas at a flow rate of 1.3 ml/min at a split ratio of 1:10 and the following temperature program: 80°C for 1 min; rising at 4°C/min to 300°C and held for 1 min. The injector and detector were held at 220 and 200°C, respectively. Diluted samples (1:10 hexane, v/v) of 1 µL of the mixtures were always injected. Mass spectra were obtained by electron ionization (EI) at 70 eV, using a spectral range of m/z 40-450. The separated components of the volatile oil were identified by matching with the National Institute of Standards and Technology (NIST) published.

Total chlorophyll content in leaves: were measured as SPAD units using Minolta chlorophyll meter (model SPAD 502). Chlorophyll measurements were made using the recently fully expanded leaf and 10 readings were averaged per experimental unit according to A.O.A.C [34].

Magnesium content (%) in leaves: were determined according to Pohl *et al* [35].

The differences between means were assessed using the least significance difference (L.S.D.) test at 5% by using computer program of Statistix version [36].

## RESULTS AND DISCUSSION

**Vegetative Characters**

**Plant Height (cm):** It is clear from data in Table (1) that all treatments either chitosan only or loaded with magnesium nanoparticles greatly increased plant height in the two lemongrass species. The highest values of plant height (80.2 and 68.6 cm) were obtained with chitosan + 0.3 g/L magnesium nanoparticles in the first and second cuts in the first season. However, chitosan + 0.2 g/L nano magnesium, chitosan + 0.1 g/L nano and chitosan recorded descending values and all values were significantly differed. However, *C. flexuosus* (East Indian lemongrass, E) was superior than *C. citratus* (West Indian lemongrass, W) in the first and second cuts of both seasons regardless of the used treatments. Interaction between lemongrass species and the used treatments was significant, the highest interaction values (91.5 and 92.0 cm) of plant height were obtained with *C. flexuosus* treated with chitosan + 0.3 g/L Mg nanoparticles in the first cut of the two seasons respectively.

**Herb Fresh Weight/ Plant (g):** Data in (Table 2) showed that the values of fresh weights/plant in *C. flexuosus* and *C. citratus* were superior than control due to Chitosan and Mg nanoparticles treatments during two studied seasons. The treatment of chitosan with 0.3 g/L nano Mg recorded the highest values of plant fresh weight in the two cuts of both seasons. However, the treatments of chitosan with 0.2 g/L nano Mg or with 0.1 g/L or chitosan alone recorded values of fresh weights were arranged in descending orders. The two species of lemongrass were similar in their fresh weight in the first cut whereas *C. flexuosus* (E) were superior than *C. citratus* (W) in second cut of the two seasons. The highest values of interaction between the two studied factors were recorded in the two cuts in the two studied seasons with *C. flexuosus* (E) treated with chitosan with 0.3 g/ L nano Mg.

Table 1: Effect of chitosan and magenisum nanoparticles on plant height (cm) of *Cymbopogon flexuosus* L (E) and *Cymbopogon citratus* L (W) lemongrass species during 2017/ 2018 and 2018/ 2019 seasons.

| | 1st cut | | | 2nd cut | | |
|---|---|---|---|---|---|---|
| Treatments | E | W | Mean | E | W | Mean |
| | | | First season | | | |
| Control | 74.3 e | 62.0 h | 68.1E | 56.6 h | 60.6 ef | 58.6 E |
| Chitosan | 81.0 d | 64.0 h | 72.5 D | 58.3 gh | 64.6 d | 61.5 D |
| Chitosan +Mg 0.1 g/L | 84.9 c | 65.0 g | 74.9 C | 59.6 fg | 66.6 c | 63.1 C |
| Chitosan +Mg 0.2 g/L | 88.1 b | 66.0 g | 77.0 B | 62.3 e | 70.3 b | 66.3 B |
| Chitosan +Mg 0.3 g/L | 91.5 a | 65.0 f | 80.2A | 64.6 d | 73.0 a | 68.6A |
| Mean | 84.0 A | 65.2 B | | 84.0 A | 65.2 B | |
| | | | Second season | | | |
| Control | 72.5 d | 59.0 i | 65.7E | 59.0 f | 63.6 e | 61.0 D |
| Chitosan | 81.2 c | 61.3 h | 71.2 D | 60.6 ef | 66.6 cd | 63.6 C |
| Chitosan +Mg 0.1 g/L | 83.9 b | 63.6 g | 73.7 C | 61.6 fg | 68.6 c | 65.1BC |
| Chitosan +Mg 0.2 g/L | 86.0 b | 66.3 f | 76.1 B | 62.6 e | 70.3 b | 66.3 B |
| Chitosan +Mg 0.3 g/L | 92.0 a | 70.0 e | 81.0A | 65.3 d | 74.0 a | 69.6A |
| Mean | 83.1 A | 64.0 B | | 84.0 A | 65.2 B | |

Values followed by the same letter (s) are not significantly different at 5% level

*Cymbopogon flexuosus* L= East Indian lemongrass (E)

*Cymbopogon citratus* L = West Indian lemongrass (W)

Table 2: Effect of chitosan and magenisum nanoparticles on herb fresh weight / plant (g) of *Cymbopogon flexuosus* L (E) and *Cymbopogon citratus* L (W) lemongrass species during 2017/ 2018 and 2018/ 2019 seasons

| | 1st cut | | | 2nd cut | | |
|---|---|---|---|---|---|---|
| Treatments | E | W | Mean | E | W | Mean |
| | | | First season | | | |
| Control | 127.1 g | 155.5 fg | 141.3 E | 285.8 ef | 167.2 h | 226.1 E |
| Chitosan | 154.8 fg | 195.0 de | 174.9 D | 316.1 c-e | 221.7 g | 268.6 D |
| Chitosan +Mg 0.1 g/L | 185.7 ef | 224.1 cd | 204.9 C | 327.2 cd | 257.5 f | 292.3 C |
| Chitosan +Mg 0.2 g/L | 252.2 bc | 242.7 bc | 247.5 B | 361.9 b | 301.1 de | 331.5 B |
| Chitosan +Mg 0.3 g/L | 345.0 a | 265.0 b | 305.0 A | 410.0 a | 337.2 bc | 373.6 A |
| Mean | 213.0 A | 216.5 A | | 340.2 A | 256.8 B | |
| | | | Second season | | | |
| Control | 143.1 h | 174.6 f | 158.9 E | 290.5 d | 252.2 h | 271.3 C |
| Chitosan | 157.2 g | 212.8.0 e | 185.0 D | 317.8 c | 225.7 g | 271.8 C |
| Chitosan +Mg 0.1 g/L | 206.2 e | 235.1 c | 220.6 C | 332.1 c | 349.5 f | 317.3 B |
| Chitosan +Mg 0.2 g/L | 212.8 d | 244.0 b | 232.9 B | 347.6 b | 287.0 de | 340.8 A |
| Chitosan +Mg 0.3 g/L | 336.1 a | 248.0 b | 292.1 A | 394.9 a | 269.6 bc | 345.7 A |
| Mean | 212.9 A | 222.9 A | | 336.9 A | 282.2 B | |

Values followed by the same letter (s) are not significantly different at 5% level

*Cymbopogon flexuosus* L= East Indian lemongrass (E)

*Cymbopogon citratus* L = West Indian lemongrass (W)

**Herb Fresh Weight per Fed. (Kg):** As it is shown in Table (3) estimated herb fresh weight per fed. followed the same trend of results which is found in fresh weight/ plant. As it mentioned later, the number of lemongrass plants/ fed. are 16800 plants it as a result of applying 50 x 50 $cm^2$ distance between plants, so the estimated fresh weight increased from 2375 Kg for control to 5124 Kg for chitosan with 0.3 g/L nano Mg. However, all used treatments were effective in improving estimated herb fresh weight per fed. than control with significant differences between all treatments and between treatments and control. The two species of lemongrass were similar in their estimated fresh weight per fed. in the first cut, whereas in second cut *C. flesxuosus* was significantly superior than *C. citratus*. The highest interaction values were recorded by *C. flexuosus* sprayed with chitosan with 0.3 g/L nano Mg.

Table 3: Effect of chitosan and magenisum nanoparticles on herb fresh weight /fed. (Kg) of *Cymbopogon flexuosus* L (E) and *Cymbopogon citratus* L (W) lemongrass species during 2017/ 2018 and 2018/ 2019 seasons

| | 1st cut | | | 2nd cut | | |
|---|---|---|---|---|---|---|
| Treatments | E | W | Mean | E | W | Mean |
| | | | First season | | | |
| Control | 2137 g | 2613 fg | 2375 E | 4802 ef | 2809 h | 3806 E |
| Chitosan | 2602 fg | 3276 de | 2939 D | 5310 c-e | 3714 g | 4512 D |
| Chitosan +Mg 0.1 g/L | 3120 ef | 3766 cd | 3443 C | 5497 cd | 4326 f | 4912 C |
| Chitosan +Mg 0.2 g/L | 4237 bc | 4078 bc | 4158 B | 6080 b | 5058 de | 5569 B |
| Chitosan +Mg 0.3 g/L | 5796 a | 4452 b | 5124 A | 6888 a | 5665 bc | 6277 A |
| Mean | 3578 A | 3637 A | | 5715 A | 4315 B | |
| | | | Second season | | | |
| Control | 2405 h | 2933 f | 2699 E | 4881 d | 2237 e | 4559 C |
| Chitosan | 2641 g | 3575 e | 2108 D | 5339 c | 3793 f | 4566 C |
| Chitosan +Mg 0.1 g/L | 3464 e | 3951 c | 3707 C | 5580 c | 5871 b | 5331 B |
| Chitosan +Mg 0.2 g/L | 4727 d | 4100 b | 4914 B | 5840 b | 4822 d | 2726 A |
| Chitosan +Mg 0.3 g/L | 5647 a | 4169 b | 4908 A | 6635 a | 4982 d | 5809 A |
| Mean | 3577 A | 3746 A | | 5655 A | 4741 B | |

Values followed by the same letter (s) are not significantly different at 5% level
*Cymbopogon flexuosus* L= East Indian lemongrass (E)
*Cymbopogon citratus* L = West Indian lemongrass (W)

Table 4: Effect of chitosan and magenisum nanoparticles on herb dry weight / plant (g) of *Cymbopogon flexuosus* L (E) and *Cymbopogon citratus* L (W) lemongrass species during 2017/ 2018 and 2018/ 2019 seasons

| | 1st cut | | | 2nd cut | | |
|---|---|---|---|---|---|---|
| Treatments | E | W | Mean | E | W | Mean |
| | | | First season | | | |
| Control | 46.7 g | 52.9 g | 49.8E | 114.7cd | 67.4 g | 91.1 D |
| Chitosan | 54.0 fg | 64.3 de | 59.1 D | 120.8b-d | 89.0 f | 104.9 C |
| Chitosan +Mg 0.1 g/L | 62.6 ef | 72.4 cd | 67.5 C | 124.2bc | 102.1 e | 113.1 C |
| Chitosan +Mg 0.2 g/L | 82.8 b | 77.8 bc | 80.3 B | 132.4 b | 111.7 de | 122.0 B |
| Chitosan +Mg 0.3 g/L | 111.2 a | 84.0 b | 97.6 A | 146.4 a | 127.2 a | 136.8A |
| Mean | 71.5 A | 70.3 B | | 127.7 A | 99.5 B | |
| | | | Second season | | | |
| Control | 49.1 g | 69.1 ef | 54.6 E | 113.1 d | 81.1 f | 99.6 D |
| Chitosan | 55.7 fg | 71.2 cd | 63.4 D | 117.8 cd | 99.7 e | 108.7 C |
| Chitosan +Mg 0.1 g/L | 67.8 de | 75.9 b-d | 71.9 C | 120.8 cd | 111.6 d | 116.2 B |
| Chitosan +Mg 0.2 g/L | 79.7 bc | 78.1 bc | 78.9 B | 127.9 bc | 118.0 cd | 123.0 B |
| Chitosan +Mg 0.3 g/L | 108.6 a | 81.5 b | 95.1 A | 145.9 a | 135.5 b | 140.7 A |
| Mean | 72.2 A | 73.3 B | | 125.1 A | 110.2 B | |

Values followed by the same letter (s) are not significantly different at 5% level
*Cymbopogon flexuosus* L= East Indian lemongrass (E)
*Cymbopogon citratus* L = West Indian lemongrass (W)

**Herb Dry Weight/ Plant (g):** It is clear from data in Table (4) that herb dry weight of the two studied lemongrass plants was greatly affected with the studied species and the applied treatments. However, all treatments were superior than control in producing high herb dry weight / plant in the two cuts of the two studied seasons. The great effect to the used treatments was obtained with chitosan with all nano Mg concentrations, as nano Mg concentrations increased the herb dry weight/ plant of the two species of lemongrass plant was increased. However, regardless of the used treatments, East Indian lemongrass was superior in herb dry weights than West Indian in the two cuts of the two studied seasons. Interaction values showed that *C. flexuosus* sprayed with chitosan loaded with 0.3 g/L Mg exhibited the highest values of plant herb dry weight/ plant.

**Herb Dry Weight / Fed. (kg):** Maximum values of estimated herb dry weight per fed, (Table 5) were obtained with chitosan loaded with 0.3 g/L nano Mg in the two cuts and the two studied seasons. Generally, estimated herb

Table 5: Effect of chitosan and magenisum nanoparticles on estimated herb dry weight/ fed. (Kg) of *Cymbopogon flexuosus* L (E) and *Cymbopogon citratus* L (W) lemongrass species during 2017/ 2018 and 2018/ 2019 seasons.

| | 1st cut | | | 2nd cut | | |
|---|---|---|---|---|---|---|
| Treatments | E | W | Mean | E | W | Mean |
| | | | First season | | | |
| Control | 785.1 g | 889.8 g | 837.4 E | 1927.9c-e | 1133.8 g | 1530.8 E |
| Chitosan | 907.9 fg | 1080. 0de | 994.1 D | 2031.0b-d | 1495.7 f | 1763.4 D |
| Chitosan +Mg 0.1 g/L | 1051.1ef | 1217.1 cd | 1134.5 C | 2086.8 b-d | 1716.4 e | 1901.6 C |
| Chitosan +Mg 0.2 g/L | 1392.9 b | 1308.5 bc | 1350.3 B | 2225.2 b | 1877.1 de | 2051.2 B |
| Chitosan +Mg 0.3 g/L | 1869.4 a | 1411.8 b | 1640.6 A | 2460.1 a | 2137.2 b | 2298.6 A |
| Mean | 1201.3 A | 1181.5 A | | 2146.2 A | 1672.0 B | |
| | | | Second season | | | |
| Control | 825.3 g | 100.1 ef | 917.5 E | 1900.5 d | 1447.8 f | 1674.2 E |
| Chitosan | 935.7 fg | 1196.1 cd | 1065.9 D | 1979.9 cd | 1675.1 e | 1827.5 D |
| Chitosan +Mg 0.1 g/L | 1140.6 de | 1276.5 b-d | 1208.5 C | 20.29.5 cd | 1876.1 d e | 1952.8 C |
| Chitosan +Mg 0.2 g/L | 1339.4 bc | 1312.2 bc | 1325.6 B | 2149.7 bc | 1983.5cd | 2066.6 B |
| Chitosan +Mg 0.3 g/L | 1825.1 a | 1370.3 b | 1597.7 A | 2452.7 a | 2276.4 b | 2364.5 A |
| Mean | 1213.2 A | 1233.1 A | | 2102.5 A | 1851.4 B | |

Values followed by the same letter (s) are not significantly different at 5% level

*Cymbopogon flexuosus* L= East Indian lemongrass (E)

Cymbopogon citratus L = West Indian lemongrass (W)

dry weight per fed. increased from 837.4 kg / fed in control to 1640.6 Kg/fed. in chitosan with 0.3 g/L nano Mg treated plants. No significant differences were detected between the two lemongrass species in their estimated dry weights per fed. in the first cut in both seasons, but *C. flexuosus* exhibited higher values of estimated dry weights than *C. citratus* in the second cut. Interaction between the two studied factors was significant in most cases where the highest values in this respect was recorded with *C. flexuosus* treated with chitosan loaded with 0.3 g nano Mg.

The obtained data are in harmony with those found by Guan *et al.* [37] who reported that the stimulating effect of chitosan on plant growth may be attributed to an increase in the availability and uptake of water and essential nutrients through adjusting cell osmotic pressure and increasing enzyme activities However, in another studies application of chitosan at 200 and 500 ppm promoted plant height growth of *Majorana vulgare* sp. whereas 50 and 200 ppm regulated the content of polyphenols [38]. On fennel plants, El-Bassiony *et al.* [39] indicated that foliar spray of chitosan gave the highest leaves number, dry weight of leaves and total yield. On snapdragon plants application of chitosan significantly increased total carbohydrates and N, P and K % in plant organs [40].

Massoud *et al.* [41] on *Coriandrum sativum* showed that chitosan significantly affected growth characters, fruit yield and essential oil productivity.

In another explain Uthairatanakij *et al.* [42] mentioned that chitosan as a biological stimulus may induce signs for the synthesis of plant hormones such as auxin and gibberellin and improvement plant growth and herbs by some signaling pathways related to auxin biosynthesis and the dependent pathway of tryptophan. It is also known that magnesium has an essential role in cell energy balance due to its interaction with various metabolites, mainly nucleoside tri- and di- phosphates [43]. Mg also serves as the regulator to balance the cation-anion in cell and as osmotic active ion to regulate cell turgor together with K [44, 45]. Particularly, Mg is most important to plants, about 75 % of the leaf Mg involves in protein synthesis and amount between 15 % and 20 % of total Mg is associated with chlorophyll pigments [46]. Mainly acting as a cofactor of a series of enzymes involved in photosynthetic carbon fixation and metabolisms [47-49].

**Chemical Constitutes**

**Volatile Oil %:** All treatments in this study (Table, 6) greatly affected volatile oil % in the two studied species of lemongrass in the two cuts of in both seasons, than control. The highest volatile oil (2.01%) and (1.20%) were obtained with chitosan + 0.3 g/L nano Mg in the first and the second cuts in the first season, respectively. However, the other treatments recorded less values of volatile oil % than the mentioned treatment with significant differences between them.

Table 6: Effect of chitosan and magenisum nanoparticles on volatile oil % of *Cymbopogon flexuosus* L (E) and *Cymbopogon citratus* L (W) lemongrass species during 2017/ 2018 and 2018/ 2019 seasons

| | 1st cut | | | 2nd cut | | |
|---|---|---|---|---|---|---|
| Treatments | E | W | Mean | E | W | Mean |
| | | | First season | | | |
| Control | 0.74 g | 2.73 d | 1.74 D | 0.20 h | 1.76 d | 0.98 D |
| Chitosan | 0.74 g | 2.87 c | 1.81 C | 0.21 h | 1.84 c | 1.03 C |
| Chitosan +Mg 0.1 g/L | 0.78 fg | 2.92 bc | 1.85 BC | 0.24 gh | 1.85 bc | 1.05 C |
| Chitosan +Mg 0.2 g/L | 0.82 f | 2.94 b | 1.88 B | 0.29 g | 1.92 b | 1.11 B |
| Chitosan +Mg 0.3 g/L | 0.91 e | 3.10 a | 2.01 A | 0.39 f | 2.00 a | 1.20 A |
| Mean | 0.80 B | 2.91 A | | 0.27 B | 1.88 A | |
| | | | Second season | | | |
| Control | 0.76 h | 2.58 d | 1.67 D | 0.19 h | 1.78 d | 1.00 D |
| Chitosan | 0.77 gh | 2.86 c | 1.82 C | 0.21 h | 1.83 cd | 1.02 D |
| Chitosan +Mg 0.1 g/L | 0.82 f | 2.92 c | 1.87 C | 0.28 g | 1.88 bc | 1.08 C |
| Chitosan +Mg 0.2 g/L | 0.87 ef | 3.10 b | 1.99 B | 0.35 f | 1.92 ab | 1.14 B |
| Chitosan +Mg 0.3 g/L | 0.93 e | 3.45 a | 2.19 A | 0.46 e | 1.95 a | 1.21 A |
| Mean | 0.83 B | 2.98 A | | 0.30 B | 1.87 A | |

Values followed by the same letter (s) are not significantly different at 5% level
*Cymbopogon flexuosus* L= East Indian lemongrass (E)
*Cymbopogon citratus* L = West Indian lemongrass (W)

Table 7: Effect of chitosan and magenisum nanoparticles on volatile oil yield per plant (ml) of *Cymbopogon flexuosus* L (E) and *Cymbopogon citratus* L (W) lemongrass species during 2017/ 2018 and 2018/ 2019 seasons.

| | 1st cut | | | 2nd cut | | |
|---|---|---|---|---|---|---|
| Treatments | E | W | Mean | E | W | Mean |
| | | | First season | | | |
| Control | 0.34 i | 1.45 e | 0.90 E | 0.23 h | 1.19 e | 0.71 E |
| Chitosan | 0.40 hi | 1.85 d | 1.13 D | 0.25 h | 1.64 d | 0.95 D |
| Chitosan +Mg 0.1 g/L | 0.49 h | 2.11 c | 1.30 C | 0.30 gh | 1.89 c | 1.10 C |
| Chitosan +Mg 0.2 g/L | 0.68 g | 2.28 b | 1.48 B | 0.39 g | 2.14 b | 1.27 B |
| Chitosan +Mg 0.3 g/L | 1.01 f | 2.60 a | 1.81 A | 0.59 f | 2.53 a | 1.56 A |
| Mean | 0.58 B | 2.06 A | | 0.35 B | 1.88 A | |
| | | | Second season | | | |
| Control | 0.37 i | 1.55 e | 0.96 E | 0.21 i | 1.53 e | 0.87 E |
| Chitosan | 0.42 i | 2.03 d | 1.23 D | 0.25 hi | 1.83 d | 1.04 D |
| Chitosan +Mg 0.1 g/L | 0.55 h | 2.23 c | 1.39 C | 0.34 gh | 2.10 c | 1.22 C |
| Chitosan +Mg 0.2 g/L | 0.70 g | 2.42 b | 1.53 B | 0.44 g | 2.26 b | 1.35 B |
| Chitosan +Mg 0.3 g/L | 1.01 f | 2.81 a | 1.91 A | 0.68 f | 2.64 a | 1.66 A |
| Mean | 0.61 B | 2.21 A | | 0.38 B | 2.07 A | |

Values followed by the same letter (s) are not significantly different at 5% level
*Cymbopogon flexuosus* L= East Indian lemongrass (E)
*Cymbopogon citratus* L = West Indian lemongrass (W)

Also, it is clear that volatile oil % values were superior in the first cut than in the second cut and this finding was correlated with the same trend found in Mg result which discussed later. However, *C. citratus* was superior and recorded higher significant values of volatile oil % than *C. flexuosus* in the two cuts of the two studied seasons. Chitosan treatment or chitosan + 0.1 g/L nanoparticles Mg were similar in their effect on volatile oil % and exhibited similar non-significant values in most cases. The higher volatile oil % interaction values (3.10 & 3.45%) were recorded by *C. citratus* lemongrass plants with chitosan loaded with 0.3 g/L nanoparticles Mg in the first cut in the first and second seasons, respectively.

**Volatile Oil Yield/ Plant (ml):** As it shown in Table (7), all applied treatments were effective than control in increasing volatile oil content/ plant of the two species of lemongrass. The highest volatile oil yield values (1.81 & 1.56 ml / plant) were obtained with chitosan loaded with 0.3 g/L nanoparticles magnesium in the first and second

Table 8: Effect of chitosan and magenisum nanoparticles on volatile oil yield / fed. (L) of *Cymbopogon flexuosus* L (E) and *Cymbopogon citratus* L (W) lemongrass species during 2017/ 2018 and 2018/ 2019 seasons

| Treatments | 1st cut E | 1st cut W | Mean | 2nd cut E | 2nd cut W | Mean |
|---|---|---|---|---|---|---|
| First season | | | | | | |
| Control | 5.84 g | 24.34 d | 15.09 D | 3.79 g | 20.00 e | 11.90 D |
| Chitosan | 6.75 g | 31.05 c | 18.90 C | 4.34 g | 27.48 d | 15.91 C |
| Chitosan +Mg 0.1 g/L | 8.26 fg | 35.54 b | 21.90 C | 5.01 g | 31.82 c | 18.42BC |
| Chitosan +Mg 0.2 g/L | 11.47 f | 38.59 b | 25.03 B | 6.55 fg | 35.92 b | 21.24 B |
| Chitosan +Mg 0.3 g/L | 17.02 e | 43.79 a | 30.41 A | 9.53 f | 42.48 a | 26.01 A |
| Mean | 9.87 B | 34.66 A | | 5.84 B | 31.54 A | |
| Second season | | | | | | |
| Control | 6.30 g | 26.07 d | 16.19 D | 3.61 g | 25.79 d | 14.70 C |
| Chitosan | 7.20 g | 34.17 c | 20.69 C | 4.09 g | 30.21 c | 17.15 C |
| Chitosan +Mg 0.1 g/L | 9.36 fg | 37.37 bc | 23.37BC | 5.68 fg | 35.21 b | 20.45 B |
| Chitosan +Mg 0.2 g/L | 11.70 f | 40.68 b | 26.19 B | 9.70 ef | 37.96 b | 23.83 B |
| Chitosan +Mg 0.3 g/L | 16.99 e | 47.33 a | 32.16 A | 11.57 e | 44.41 a | 27.99 A |
| Mean | 10.31 B | 37.12 A | | 6.93 B | 34.72 A | |

Values followed by the same letter (s) are not significantly different at 5% level

*Cymbopogon flexuosus* L= East Indian lemongrass (E)

*Cymbopogon citratus* L = West Indian lemongrass (W)

cuts, respectively in the first season. However, *C. citratus* was superior than *C. flexuosus* regardless of the used treatments and exhibited higher values of volatile oil yield/ plant in the two cuts of the two studied seasons. It is clear that values of volatile oil content and volatile oil% which discussed later both were correlated with the trend of Mg content of the plant. Interaction between the two studied factors was significant in most cases, where the higher values of volatile oil yield (2.81 ml/plant) was recorded with West Indian lemongrass sprayed with chitosan loaded with 0.3 g/L nano Mg in the first cut of the second season.

**Volatile Oil Yield per Fed. (L.):** Table (8) showed that the same trend of results found in volatile oil content per plant was also found in the trend of estimated yield of volatile oil per fed. The most effective treatment in this respect was those of chitosan loaded on 0.3 g/L nanoparticles of magnesium where it recorded 30.41 and 26.01 L/fed in the first and second cuts, respectively in the first season. The significant differences between the used treatments and compared with control were clear in both studied seasons. Also, *C. citratus* produced higher values of volatile oil per fed. than *C. flexuosus* in most cases. The higher value of interaction between the two factors (47.33L/fed) of volatile oil was recorded by West Indian lemongrass plant treated with chitosan + 0.3 g/L nanoparticles Mg in the first cut of the second season.

**Volatile Oil Constituents:**

***Cymbopogon flexuosus L.* (East Indian Lemongrass, E):** It is clear from data in Table (9) that volatile oil fractions were greatly affected with different treatments applied in *C. flexuosus* plant.

The main component in volatile oil was Citral followed by Benzene methoxy, Geranyl acetate and Octane dimethyl. However Citral recorded the highest value with chitosan loaded with 0.2 g/l nano Mg (83.17 %) against 56.03 % in control. However, Benzene methoxy recorded 8.24% in control compared to 10.13% in Chitosan and 4.87 in Chitosan with 0.1 g/L nano Mg whereas it did not appear in chitosan either with 0.2 or 0.3 g/L nano Mg. However, Geranyl acetate compound recorded 6.63% in control whereas all used treatments reduced it.

Finally, Octane dimethyl and Hydroxy methyl propyl components were only present in control and chitosan treatment whereas they were not detected in other treatments which included nano Mg.

***Cymbopogon citratus L.* (Wast Indian Lemongrass, W):** Data in Table (10) showed that Citral was the main component in volatile oil fractions in *Cymbopogon citratus* plant. However, all used treatments greatly increased Citral percentage than control where it recorded 54.01% in control increased to 80.73 % in chitosan treatment. The second component was Myrcene followed by Geraniol, Bicyclo heptan and

Table 9: Effect of chitosan and magenisum nanoparticles on volatile oil fractions of *Cymbopogon flexuosus L* (E).

| | Area % | | | | |
|---|---|---|---|---|---|
| Component name | Control | Chitosan | Chitosan + Mg 0.1 g/L. | Chitosan + Mg 0.2 g/L. | Chitosan + Mg 0.3 g/L. |
| Citral | 56.03 | 55.09 | 60.85 | 83.17 | 66.80 |
| Benzene methoxy | 8.24 | 10.13 | 4.87 | -- | -- |
| Geranyl acetate | 6.63 | 4.80 | 4.41 | 1.53 | 4.15 |
| Octane dimethyl | 3.85 | 4.37 | -- | -- | -- |
| Hydroxy methylpropyl | 3.72 | 4..84 | -- | -- | -- |
| Geraniol | 2.32 | -- | 2.24 | 3..89 | 4.60 |
| Myrcene | 2.27 | 0.49 | 0.62 | 1.01 | 0.70 |
| Caryophyllene Oxide | 1.34 | 1.06 | 1.26 | 1.78 | -- |
| Trimethyl Phenylthio | 1.33 | -- | 2.00 | 0.57 | -- |
| Citronellol | 1.01 | 0.89 | 0.94 | -- | -- |
| Pyrole Propanoic acid | 0.96 | 0.62 | -- | -- | -- |
| Camphor | 0.91 | 0.86 | -- | -- | -- |
| Linalool Oxide | 0.88 | 0.98 | 2.66 | 1.21 | 8.49 |
| Cadinene | 0.86 | 1.47 | 1.39 | -- | -- |
| Mentha 2,8 diene | 0.81 | 3.24 | 1.03 | 1.10 | 3.63 |
| Bicyclo heptan | 0.77 | -- | 2.11 | 1.34 | 1.68 |
| Verbenol | 0.70 | 0.50 | -- | -- | 0.52 |
| Trimethyl 2 Oxabicyclo | 0.56 | 1.45 | 2.79 | -- | 3.89 |
| Buten1one, | 0.48 | 0.48 | 0.19 | 0.51 | -- |
| Trimethyl bicyclo | -- | 1.61 | 2.59 | -- | -- |
| Juniper Camphor | -- | -- | 0.90 | 0.86 | 0.68 |
| Total | 93.67 | 92.88 | 90.85 | 96.97 | 95.14 |
| Unknown | 6.23 | 7.12 | 9.15 | 3.03 | 5.86 |

Table 10: Effect of chitosan and magenisum nanoparticles on volatile oil fractions of *Cymbopogon citratus* L (W).

| | Area % | | | | |
|---|---|---|---|---|---|
| Component name | Control | Chitosan | Chitosan + Mg 0.1 g/L. | Chitosan + Mg 0.2 g/L. | Chitosan + Mg 0.3 g/L. |
| Citral | 54.01 | 80.73 | 61.19 | 75.29 | 76.10 |
| β Myrcene | 9.60 | 2.29 | 6.67 | 6.9 | 6.05 |
| Geraniol | 6.08 | -- | 6.37 | 3.98 | 5.42 |
| Bicyclo heptan | 3.71 | 1.12 | 0.59 | 0.72 | 0.85 |
| Linalool Oxide | 3.22 | 1.24 | 2.00 | 2.00 | 2.20 |
| Caryophyllene Oxide | 2.21 | 2.65 | 1.27 | 0.71 | 1.04 |
| Citronellol | 1.50 | 0.74 | 0.46 | 0.48 | 0.47 |
| Juniper Camphor | 1.36 | 0.70 | 0.88 | 0.15 | 0.40 |
| Hydroxy methyl | 1.31 | -- | -- | 0.17 | 0.16 |
| Dimethyl dienal | 1.28 | 0.40 | -- | -- | 0.26 |
| Dimethyl 3pentenyl | 0.76 | 0.40 | 0.25 | -- | 0.20 |
| Octadien dimethyl | 0.76 | 0.30 | -- | 0.91 | -- |
| Mentha diene | 0.68 | 1.52 | 0.31 | 0.91 | 0.33 |
| Verbenol | 0.63 | -- | 0.72 | 0.46 | 0.23 |
| Buten trimethy | 0.62 | 0.22 | -- | -- | -- |
| Cyclopropane methanol | 0.59 | -- | 0.13 | 0.21 | -- |
| Eucalyptol | 0.53 | 0.38 | 0.48 | -- | -- |
| Trimethyl phenylthio | -- | 1.37 | 1.10 | 0.17 | -- |
| Thiogeraniol | -- | 0.46 | 0.20 | -- | -- |
| Undecanone | -- | -- | 0.50 | 0.61 | 0.63 |
| Tridecanone | -- | -- | 0.50 | 0.40 | 0.28 |
| Dimethyl methylene | -- | 0.21 | 0.19 | -- | -- |
| Methyl butenyl | -- | -- | 0.11 | 0.89 | 0.25 |
| Cyclohexene carboxaldehyde | -- | 0.80 | 0.70 | 0.53 | 0.35 |
| Total | 88.85 | 95.53 | 84.62 | 95.49 | 95.22 |
| Unknown | 11.15 | 4.47 | 15.38 | 4.51 | 4.78 |

Table 11: Effect of chitosan and magenisum nanoparticles on total chlorophyll (meter reading) of *Cymbopogon flexuosus* L (E) and *Cymbopogon citratus* L (W) lemongrass species during 2017/ 2018 and 2018/ 2019 seasons.

| | 1st cut | | | 2nd cut | | |
|---|---|---|---|---|---|---|
| Treatments | E | W | Mean | E | W | Mean |
| | | | First season | | | |
| Control | 20.8 f | 24.7 d | 22.3 D | 20.5 f | 23.1 e | 21.8 E |
| Chitosan | 22.2 e | 26.5 c | 24.3 C | 21.9 e | 24. 6 d | 23.3 D |
| Chitosan +Mg 0.1 g/L | 23.0 e | 27.3 bc | 25.1 C | 22.4 e | 26.5 c | 24.5 C |
| Chitosan +Mg 0.2 g/L | 25.2 d | 27.8 b | 26.5 B | 23.1 e | 30.0 b | 26.5 B |
| Chitosan +Mg 0.3 g/L | 27.0 bc | 29.2 a | 28.1 A | 26.2 c | 31.2 a | 28.7 A |
| Mean | 23.6. B | 27.1 A | | 22.8. B | 27.1 A | |
| | | | Second season | | | |
| Control | 22.3 g | 24.1 f | 23. 2 E | 21.6 h | 22.3 gh | 22.0 E |
| Chitosan | 24.1 f | 25.2 e | 24.6 D | 23.6 fd | 28.3 d | 25.3 D |
| Chitosan +Mg 0.1 g/L | 26.3 d | 26.7 d | 26.5 C | 24. 6 ef | 31.0 c | 28.2 C |
| Chitosan +Mg 0.2 g/L | 26.8 cd | 28.9 b | 27.9 B | 25.9 e | 32.6 b | 29.2 B |
| Chitosan +Mg 0.3 g/L | 27.7 c | 30.2 a | 28.7 A | 28.1 d | 36.9 a | 32.5 A |
| Mean | 25.4. B | 27.0 A | | 24.8. B | 30.2 A | |

Values followed by the same letter (s) are not significantly different at 5% level

*Cymbopogon flexuosus* L= East Indian lemongrass (E)

*Cymbopogon citratus* L = West Indian lemongrass (W)

linalool oxide. In addition, the applied treatments show some components in volatile oil fraction in *Cymbopogon citratus* did not appear in control such as Trimethyl phenylthio, Thiogeraniol, Uvdecanone Tridecanone, Mythyl butenyl, Dimethyl methylene and Cyclohexene carboxaldehyde.

However, chitosan has been proven to stimulate and increase volatile oil yield and its composition can lead to the synthesis of secondary metabolites, such as polyphenols, lignin and flavonoids, increased growth rate and induced a significant increase in the oil concentrations [50-53]. On *Ruta graveolens* it has been stated that, chitosan significantly

**Total Chlorophylls (Meter Reading):** Table (11) showed that the used treatments and lemongrass species both greatly affected total chlorophyll values during the two cuts of the two studied seasons, The highest values of total chlorophyll were recorded by chitosan 0.3 g/L nano Mg followed by other treatments. However *C. citratus* exhibited higher significant values of total chlorophyll than *C. flexuosus* regardless of the used treatments.

However, interaction between the used treatments and lemongrass species was significant in most cases. The highest interaction values were recorded with *C. citratus* treated with chitosan in combined with 0.3 g/L nano Mg in the two cuts of the two studied seasons.

Chitosan is a natural biopolymer has been proven to stimulate chlorophyll content, photosynthetic and chloroplast enlargement [50-51]. Also, Salachna *et al.* [52] extracted that the primitive effect of chitosan on chlorophyll content and photosynthetic rate, through adjusting cell osmotic pressure and increasing enzyme activities.

**Mg %:** It is clear from data in Table (12) that Mg was % clearly affected with chitosan and magnesium nanoparticles treatments than control in both studied seasons. The highest values of Mg % were obtained with chitosan + 0.3 g/L nano Mg in the two cuts of the two studied seasons. Significant differences between different treatments were recorded in most cases, although in first season no significant differences were obtained between chitosan treatment and control. Generally, it is clear that *C. citratus* was superior than *C. flexuosus* in Mg content in the two cuts of the two seasons. Interaction values between the two studied factors showed that highest values were obtained with *C. citratus* treated with chitosan + 0.3 g/L nano Mg in the two cuts in both seasons.

Magnesium has a number of key functions in plants particular metabolic processes and reactions that are influenced by Mg include photophosphorylation, photosynthetic carbon dioxide (CO2) fixation, protein synthesis, chlorophyll formation, phloem loading, partitioning and utilization of photoassimilates and photooxidation in leaf tissues. Consequently, many critical physiological and biochemical processes in plants are adversely affected by Mg deficiency, leading to impairments in growth and herb yield in many ornamental and medicinal plants [54, 45].

Table 12: Effect of chitosan and magenisum nanoparticles on Mg (%) of *Cymbopogon flexuosus* L (E) and *Cymbopogon citratus* L (W) lemongrass species during 2017/ 2018 and 2018/ 2019 seasons

| | 1st cut | | | 2nd cut | | |
|---|---|---|---|---|---|---|
| Treatments | E | W | Mean | E | W | Mean |
| | | | First season | | | |
| Control | 0.19 g | 0.23 ef | 0.21 D | 0.17 f | 0.19 ef | 0.18 D |
| Chitosan | 0.20 fg | 0.25 de | 0.23 D | 0.18 f | 0.21 de | 0.19 D |
| Chitosan +Mg 0.1 g/L | 0.23 ef | 0.28 cd | 0.25 C | 0.22 de | 0.25 c | 0.23 C |
| Chitosan +Mg 0.2 g/L | 0.26 de | 0.32 b | 0.29 B | 0.24 cd | 0.29 b | 0.26 B |
| Chitosan +Mg 0.3 g/L | 0.31 bc | 0.37 a | 0.34 A | 0.27 bc | 0.33a | 0.30 A |
| Mean | 0.24 B | 0.29 A | | 0.22 B | 0.25 A | |
| | | | Second season | | | |
| Control | 0.20 e | 0.20 e | 0.20 D | 0.17 e | 0.18 e | 0.18 E |
| Chitosan | 0.21 de | 0.24 cd | 0.23 C | 0.19 e | 0.23 d | 0.21 D |
| Chitosan +Mg 0.1 g/L | 0.23 d | 0.27 bc | 0.25 C | 0.23 d | 0.26 cd | 0.25 C |
| Chitosan +Mg 0.2 g/L | 0.28 b | 0.33 a | 0.30 B | 0.27 d | 0.30 ab | 0.28 B |
| Chitosan +Mg 0.3 g/L | 0.32 a | 0.35 a | 0.33 A | 0.30 ab | 0.32 a | 0.31 A |
| Mean | 0.20 B | 0.28 A | | 0.23 B | 0.25 A | |

Values followed by the same letter (s) are not significantly different at 5% level

*Cymbopogon flexuosus* L= East Indian lemongrass (E)

*Cymbopogon citratus* L = West Indian lemongrass (W)

The great role of nano-compounds are attributed to that they are quickly absorbed by plants and supply the plants with required nutrients. Therefore, an increase in plant growth and herb yields occurs with the use of nano-materials [55].

Some compounds of nanoparticles of magnesium (MgONPs) have been recognized as safe materials by the United States Food and Drug Administration. Recent advances have led to conspicuous developments with enormous potential in plants and medicines [56].

Generally, it could be concluded that spraying of *Cymbopogon flexuosus* L. (East Indian lemongrass, E) *and Cymbopogon citratus* L. (West Indian lemongrass, W) plants with chitosan loaded with 0.1, 0.2 or 0.3 g/L nanoparticles of magensium greatly improved the yield of herb, volatile oil yield and active ingredients of volatile oil components such as Citral, Myrcene and Geraniol.

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