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Vegetative growth and essential oil productivity of lemongrass (*Cymbopogon citratus*) as affected by NPK and some growth stimulators

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Abstract
Split plot field experiments were conducted at Khamisa village, Siwa Oasis during 2016 and 2017 seasons to study the effect of NPK doses (main plot) and spraying with some growth stimulators (control, and extracts of compost tea, *Spirulina platensis* algae and lithovit) as sub plot on vegetative growth traits and essential oil productivity of lemongrass. The obtained results indicated that NPK full dose significantly improved vegetative growth traits and essential oil% and yield per plant and fedd. over than NPK half dose in the two cuts for both seasons. Compost tea had caused significant increases in vegetative growth traits and oil yield/ plant and fedd. in comparison of the other growth stimulators, while lithovit significantly enhanced oil% than the other growth stimulators for the two cuts in the two seasons. For the interaction between NPK doses and the growth stimulators data pointed out that NPK full dose combined with compost tea had resulted in the best values of vegetative growth traits and essential oil yield per plant and fedd. On the other side, the highest essential oil% was found in the treated plants with either NPK full dose or NPK half dose combined with lithovit for the two cuts in both seasons**.** Nine compounds of essential oil of lemongrass were identified. The main components were citral A (geranial), followed by citral B (neral), then D-limonene which were resulted from the plants had been received NPK dose combined with compost tea and 1/2 NPK dose combined with either algae extract or lithovit, respectively.

Keywords: lemongrass, chemical fertilizers, compost tea, blue green algae, lithovit

1. Introduction
The medicinal and aromatic plants are great importance in many purposes (perfumery, cosmetics, soap, toothpastes, treat many diseases and safety natural alternatives for chemical drugs). These plants are the most important agricultural export products and are an important source of revenue and foreign currency. Recently, Egypt has taken an interest in improving the growth and production of various medicinal and aromatic plants suitable for climatic and agricultural conditions.
Lemongrass (*Cymbopogon citratus* (DC.) Stapf. is a perennial plant, it's propagated by slips or offsets and divided the plants. It's like remain to over 10 years. A grassy, long - lasting grassy plant reaches 120 cm in height, with curved, round stalks, a sword - like striped paper that has a distinctive aromatic smell that is similar to the lemon fruits smell. It does not bloom in compact soil which may retain stagnant water groups. Warmth and sunshine lead to varying percentages of oil in the plant**.** In regions of abundant rainfall the plant may be harvested more frequently, during the year, than is possible in dry regions, but the oil will be lower of citral content [1]. The importance of lemongrass is concentrated in its leaves that are extracted from lemon oil. This is due to the presence of citral compound in the oil, which reaches 55-85% of the essential oil components. Beside of citral the oil contains myrcine (10-30%), geraniol (1-2%), limonene, nerol and linalool [2, 3]. The herb tea of lemongrass is used in treatment of digestive disorders, reduced blood pressure, cholesterol and heat, antioxidant, antifungal and insects, antidiabetic, diuretic and strengthens the nervous system. Also, its oil is used in soap, cosmetics and little in perfumes [4, 5].
The fertilization is one of the important factors affecting the growth, chemical composition and active materials in the aromatic and medicinal plants. N, P and K fertilizers are very important elements that partake in many compounds in the plant cells (carbohydrates, proteins, lipids, amino acids, nucleic acids, energy compounds and regulation of water relation) as reported by [6]. Also, lithovit is a compound made of limestone ($CaCo_3$) and limestone of CaMg $(Co_3)_2$ found in abundance in nature. Experiments have shown that the use of lithovit has increased the production by 50% in some crops and increased the ability of the plant to withstand the different environmental conditions of heat, frost, salinity, water shortage and increased the plant ability to resist disease [7, 8, 9].
As well as, compost tea is a liquid contains nutrients, microorganisms and plant hormones that promoting plants growth and production [10]. In addition, *Spirulina plantensis* algae is a species of blue green algae found in nature. Its extract containing 62% amino acids and a mixture of carotene dyes and xanthophyll, which is a source of $V.B_{12}$, macro and micro elements, antioxidants, poly screed and plant hormones such as auxin, cytokinin which are important and vital factor for plant growth and production [11, 12].
This study was carried out to find out the best fertilization treatment which achieves the best growth, chemical composition and essential oil productivity of lemongrass plant will using lithovit, compost tea and *Spirulina platensis* algae

under Siwa Oasis conditions.

2. Materials and Methods

Field experiments were done in the Agricultural Experimental Station of the Desert Research at Khamisa village during two seasons of 2016 and 2017 to study the effect of NPK fertilizers and foliar application of lithovit, compost tea and *Spirulina plantensis* algae extract on vegetative growth and essential oil productivity of lemongrass (*Cymbopogon citratus* (DC.) stapf.) under Siwa Oasis conditions.

2.1 The cultivated adult plants in the Agricultural Experimental Station were the source of lemongrass slips. The rooted slips were cultivated under drip irrigation system on March 29th and 5th for the two seasons, respectively. The planting was in rows 75 cm apart and 50 cm between hills (11200 plant/fedd.) Drip irrigation system was used with emitters (GR, 50 cm dripper spacing) with a nominal emitter's discharge of 4 l/h. Soil samples of the experimental area were taken at 0-30 cm before planting. The soil texture was sandy (92.91% sand, 5.21% silt and 1.88 clay). The chemical analysis of the used soil and irrigation water are shown in Tables 1 and 2, respectively.

Table 1: The chemical analysis of the experimental soil area (average two seasons)

pH	E.C. (ds/m)	O.M. (%)	Soluble anions (meq/l)				Soluble cations (meq/l)			
			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

Table 2: The chemical analysis of irrigation water (average along the experimental period)

pH	E.C. (ppm)	Soluble anions (meq/l)				Soluble cations (meq/l)			
		CO_3^{--}	HCO_3^-	Cl^-	SO_4^{--}	Ca^{++}	Mg^{++}	Na^+	K^+
7.00	2824	-	1.57	16.68	22.73	11.43	8.98	19.80	0.77

2.2 Experimental factors

2.2.1 N, P and K treatments: Full dose of NPK as 400 kg ammonium sulphate (20.5% N), 300 kg calcium superphosphate (15.5% P_2O_5) and 100 kg potassium sulphate (48% K_2O) / fedd. / season and half NPK dose were applied. Whereas, calcium superphosphate and organic manure (applied for all treatments, Table 3) at rate of 10 m^3/ fedd. were added at soil preparation before planting as one dose**.** Ammonium sulphate was divided into 3 equal doses, the first and second ones were applied after 45 and 90 days from planting and the third one was added two weeks after the first cut. Potassium sulphate was divided into two equal doses, the first one was utilized 45 days after the planting and the second dose was done two weeks after the first cut [13, 14].

Table 3: The chemical analysis of used organic manure

pH	EC (ds/m)	O.M. (%)	C/N ratio (%)	N (%)	P (%)	K (%)	Fe (%)	Mn (%)	Zn (mg/kg)	Cu (mg/kg)
8.15	6.49	33.21	1 : 12.35	1.56	0.11	1.08	0.22	0.1	163.00	27.10

2.2.2 The growth stimulators treatments: These treatments were used as foliar spray as follows: 1-control (without growth stimulators), 2-compost tea, it was prepared by soaking compost in water (1: 4 v/v) for 24 hours and plants were sprayed with water extract of the compost [15]; 3-blue-green algae (extract of *Spirulina platensis*) at the rate of 5 ml / l [12] and 4-lithovit at the rate of 5 g / l [16], it is a natural intensified CO_2 foliar fertilizer. Foliar application was conducted after 45 and 90 days of planting date and repeated 3 weeks after the first cut. The plants had been sprayed to run off. The chemical analysis of aqueous extract of compost tea, *Spirulina platensis* and lithovit are presented in Table 4.

Table 4: The chemical analysis of aqueous extracts of compost tea, *Spirulina platensis* and lithovit

Properties	Compost tea	*Spirulina platensis* extract	Lithovit
Mineral elements			
N (%)	7.40	1.60	0.40
P (%)	-	0.01	0.70
K_2O (%)	0.98	0.90	0.98
Fe (mg/l)	14.8	269.00	-
Mn (mg/l)	4.00	89.00	18.10
Zn (mg/l)	-	81.00	1.60
Cu (mg/l)	-	54.00	-
$MgCO_3$ "micron" (%)	-	-	41
$CaCO_3$ "micron" (%)	-	-	24
Phytohormones:			
Cytokinin (mg/l)	999.13	428.70	-
Gibberellic acid (mg/l)	1936.40	1770.10	-
Auxin (mg/l)	269.20	256.30	-

2.3 Experimental design: The experiment was designed as a split plot design, whereas, NPK doses were the main plots and the foliar application of plant growth stimulators were arranged as sub plots. The experiment was included 8 treatments (2 NPK doses × 4 foliar applications). Each treatment was replicated 4 times. All agricultural practices as irrigation, weeding, insecticides and pesticides control... etc. were done when it's needed.

2.4 Harvesting: Lemongrass plants were harvested by cutting the vegetative parts of plants at 15 cm above soil surface, on 7th Oct. and 27th Dec. in the first season and 23th Sept. and 24th Dec. in the second one.

2.4.1 Vegetative growth traits: Plant height (cm), number of tillers / plant and fresh and dry weights of herb/ plant (g) and per fedd (ton).

2.4.2 Essential oil% and oil yield / plant and / fedd.

Essential oil% was estimated according to [17], as oil% =

$$\frac{\text{oil in graduate tube (ml)}}{\text{Sample weight (g)}} \times 100$$

Oil yield / plant (ml) = oil% × plant dry weight and oil yield / fedd. (l) = oil yield / plant × plant numbers / fedd**.**

2.5 Statistical analysis: L.S.D test at 0.05 was used to compare the means of treatments, according to [18]. SPSS Software was used for conducting the statistical analysis.

3. Results and Discussion

3.1 Effect of NPK doses

3.1.1 Vegetative growth traits

Data are presented in Table 5 clear the effect of full and half doses of NPK on plant height, number of tillers/ plant and

fresh and dry weights of plant and fedd. during the two cuts in the both seasons. It's noticed from data that NPK full dose resulted in significant increases values of the traits mentioned before in comparison of NPK half dose for the two cuts in the two seasons, exception of plant height at the first cut in the first season whereas, the difference between NPK doses did not reach the significant level. It's obvious that the values of vegetative traits under either NPK full dose or NPK half dose at the first cut higher than the second cut for the both season. It's might be due to environmental condition (temperature, day light period, RH) are more suitable during 1st cut time (April to Oct.) than 2nd cut (Oct. to Dec.). These results may be due to that NPK full dose rich the root zone with sufficient amount of N, P and K which essential nutrients for many processes in plant cells. N plays an important role in the synthesis of plant components through the work of various enzymes, and also, in the structure of the protein part and effects the quantity and quality of plant secondary metabolites [19]. N is an integral part of biological critical molecules such as nucleic acids, structure and catalytic production, which are not eliminated as plant nutrients for successful fertilization [20]. Also, P is a necessary nutrient in metabolic processes and a main constituent of energy compounds, nucleic acids, phospholipids and co-enzymes [21]. P plays a central and regulatory role in metabolism and relationship between many physiological and biochemical processes in plants, in addition, photosynthesis, energy conservation, inter- and intracellular co-ordination of carbohydrate metabolism and in energy transfers [22]. Over all K plays an essential role in activating the enzyme and protein synthesis, photosynthesis, osmoregulation, stomatal movement, energy transfer, phloem transport, cation-anion balance, and stress resistance [6, 23]. All the NPK functions are dependent on the amount of them in the root zone and its uptake by plant roots and that effects on the plant growth. Some researchers have found that 80 kg N/ ha/ year lead to an increase in the total production of biomass of *Cymbopogen martinii* [24], urea at 150 kg / fedd. Resulted in the highest harvest in the two cuts of the season in relative to 70 kg urea/ fedd. [2], the application of 60 + 30 + 30 and 90 + 45 + 45 kg NPK/ ha gave a significant improvement in quality standards of C. *flexuosus* and 120+ 60+ 60 kg/ ha was superior in growth parameters [25] and [26] found that 300 kg urea/ fedd. gave a significant increase in the plant height, leaves number and herb fresh and dry weights.

3.1.2 Essential oil productivity

Data of the effect of NPK treatments on essential oil% and essential oil yield plant^{-1} and fedd^{-1}. During the two cuts in the both seasons are presented in Table 5. The obtained results indicated that NPK full dose caused a significant increase in oil% during the first cut and non-significant increase during the second cut in relative to the half NPK dose for the two seasons. Also, it's clear that oil% is higher in the second cut than the first cut. This may be referred to the high temperature during the first cut than the second cut, which lead to a fractional loss in the essential oil. The results showed that NPK full dose had resulted in a significant increment in essential oil yield plant^{-1} and fedd^{-1}. For the two cuts in the two seasons. Too, it's noticed that the oil yield of either plant or fedd. in the first cut is much more than the second cut in the both seasons. This fact may be attributed to the highest herb dry weight in the first cut in comparison of the second cut. The enhancing effect of NPK full dose may be due to more NPK elements in the root zone and more uptake, because the element play important role in secondary metabolites, especially N element, consequently more essential oil amount. The obtained results have been supported by [27] who stated that N applications increase the oil yield in aromatic plants by encouraging the amount of biomass yield per unit of land area. Essential oil yield of *Mentha ardencies* increased with increasing NPK levels, the maximum oil yield was with the application of N, P and K kg/ha, respectively [28]. The highest values of volatile oil% of sage plant was at 230 kg N with 80 kg P/ ha [29]. Likewise, oil yield of mint was maximum with NPK at 150, 45 and 45 kg/ ha [30].

Table 5: Effect of NPK fertilization on vegetative growth and essential oil traits during 2016 and 2017 seasons

Traits	First season 2016				Second season 2017			
	1st cut		2nd cut		1st cut		2nd cut	
	½ NPK	NPK	½ NPK	NPK	½ NPK	NPK	½ NPK	NPK
Plant height (cm)	64.36	65.34	61.03	63.86	59.06	60.93	57.71	59.24
LSD 0.05	n.s.		1.66		1.61		1.47	
Number of tillers/plant	29.84	32.78	28.18	31.63	22.38	25.72	21.63	24.29
LSD 0.05	0.67		1.00		0.85		0.84	
Fresh weight of herb/plant (g)	183.78	204.71	149.37	168.83	142.73	166.22	115.75	139.87
LSD 0.05	6.22		6.13		3.08		3.66	
Fresh weight of herb/fed. (ton)	2.06	2.29	1.68	1.89	1.60	1.87	1.30	1.57
LSD 0.05	0.07		0.08		0.03		0.04	
Dry weight of herb/plant (g)	62.79	69.92	47.76	54.18	57.10	66.40	37.85	45.77
LSD 0.05	2.06		1.96		1.24		1.21	
Dry weight of herb/fed. (ton)	0.70	0.78	0.54	0.61	0.64	0.75	0.43	0.52
LSD 0.05	0.02		0.02		0.02		0.01	
Essential oil percentage	1.59	1.63	1.78	1.82	1.42	1.50	1.76	1.76
LSD 0.05	0.02		n.s.		0.06		n.s.	
Essential oil yield/plant (ml)	0.97	1.13	0.85	0.98	0.81	1.00	0.67	0.79
LSD 0.05	0.04		0.04		0.03		0.03	
Essential oil yield/fed. (l)	10.84	12.65	9.46	10.93	9.04	11.26	7.42	8.83
LSD 0.05	0.48		0.42		0.32		0.35	

Table 6: Effect of foliar spray treatments with some growth stimulants on vegetative growth and essential oil traits during 2016 and 2017 seasons

Traits	First season 2016								Second season 2017							
	1st cut				2nd cut				1st cut				2nd cut			
	Control	Compost tea	Algae extract	Lithovit	Control	Compost tea	Algae extract	Lithovit	Control	Compost tea	Algae extract	Lithovit	Control	Compost tea	Algae extract	Lithovit
Plant height (cm)	63.98	66.53	64.87	64.02	59.28	67.82	62.31	60.38	56.91	64.83	59.97	58.27	54.94	64.15	58.42	56.40
LSD	2.45				2.35				2.27				2.08			
Number of tillers/plant	24.49	46.80	28.54	25.42	25.42	36.19	31.71	26.29	20.55	29.25	24.92	21.48	18.57	31.04	22.19	20.04
LSD	0.94				1.41				1.20				1.19			
Fresh weight of herb/plant (g)	160.10	244.07	198.17	174.64	130.24	195.76	164.65	145.75	124.87	193.67	159.25	140.12	98.82	175.77	131.08	105.57
LSD	8.80				8.67				4.36				5.17			
Fresh weight of herb/fed. (ton)	1.79	2.73	2.22	1.96	1.46	2.20	1.85	1.64	1.41	2.17	1.79	1.57	1.11	1.97	1.48	1.19
LSD	0.10				0.11				0.05				0.06			
Dry weight of herb/plant (g)	54.75	83.34	67.65	59.69	41.74	62.88	52.54	46.72	49.91	77.41	63.58	56.10	32.33	57.56	42.86	34.51
LSD	2.92				2.77				1.76				1.72			
Dry weight of herb/fed. (ton)	0.62	0.93	0.76	0.67	0.47	0.71	0.59	0.53	0.56	0.87	0.72	0.64	0.36	0.65	0.49	0.39
LSD	0.03				0.03				0.02				0.02			
Essential oil percentage	1.66	1.50	1.59	1.69	1.77	1.73	1.70	2.00	1.43	1.45	1.44	1.52	1.73	1.72	1.74	1.86
LSD	0.03				0.08				0.09				0.09			
Essential oil yield/plant (ml)	0.91	1.26	1.03	1.01	0.74	1.09	0.89	0.93	0.72	1.13	0.92	0.86	0.56	0.96	0.75	0.64
LSD	0.06				0.05				0.04				0.04			
Essential oil yield/fed. (l)	10.15	14.03	11.51	11.30	8.18	12.18	9.97	10.46	8.18	12.61	10.25	9.55	6.26	10.72	8.37	7.15
LSD	0.68				0.60				0.46				0.49			

3.2 Effect of the growth stimulants

3.2.1 Vegetative growth traits

Data in Table 6 pointed out that the treated plants with compost tea, algae extract and lithovit had recorded significant increases in the values of plant height, tillers numbers / plant and fresh and dry weights of plant and fedd. over than untreated plants in the two cuts during the both seasons, exception the difference between lithovit plants and untreated plants did not reach the significant level in case of tillers number per plant in the two cuts for both seasons. The sprayed plants with compost tea achieved the highest significant values of the aforementioned growth parameters in comparison of the other treatments for the two cuts in the both seasons. The enhancing effect of the growth stimulants was in order of compost tea > algae extract > lithovit. The superiority of compost tea in relative to the other used stimulators, because it's a liquid contains nutrients, microorganisms and plant hormones, and its benefits are to supply the plant with macro and micro nutrients which are absorbed by the plant through leaves, in addition to protecting plant tissues from pathogenic factors, promoting growth and increasing production [10] therefore compost tea may be the suitable stimulator for lemongrass much more than the other ones. Similarly, [31] found that 20 l./fed. of compost tea significantly increased plant height, fresh and dry weights of aerial parts and flowers and branches number and suckers of borage plant in relative to control. Spraying *Silybum marianum* with compost tea led to an increase in growth and yield measurements [32]. Spraying mint and capsicum plants with lithovit increased the total vegetative growth and roots in comparing to the control [16]. Spraying *Aloe vera* plants with blue green algae extract led to an increase in plant height, number, weight and width of leaves [33]. In the same direction, sprinkling garlic plants with *Spirulina platensis* extract increased the yield compared to the control plants [11]. Likewise, spraying fenugreek plants with *Spirulina platensis* caused an increase in plant height, number of leaves and branches and fresh and dry weights of vegetative growth [12].

3.2.2 Essential oil productivity

It's obvious from data in Table 6 that the treated plants with lithovit have the highest essential oil% when compared to the other growth stimulators in the two cuts for the two seasons. Too, the oil% during the second cut is more than it in the first one. It's may be due to that temperature was higher during the first cut than the second one. On the other side, the significantly maximum essential oil yield of plant and fedd. was achieved from the sprayed plants with compost tea in the two seasons for the both cuts. In general the oil yield plant^{-1} and fedd^{-1} in the first cut were higher than in the second one. This fact may be referred to the increase in herb yield in the first cut from application of compost tea in comparison of the other growth stimulants treatments. In the majority of cases the difference among the used growth stimulators for oil% and yield reached the significance level during the two seasons for the both cuts. Application of lithovit improved essential oil% than the other growth stimulators may be due to that it the ease to be released into the active carbon dioxide needed for metabolism, and lithovit has increased the production by 50% in some crops and increased the ability of the plant to withstand the different environment conditions of heat, frost, salinity....etc [7, 9]. Also, compost tea caused an increase in essential oil yield that may be due to it has enhanced the herb dry weight by its contents from macro and micro elements and hormones, which reflected on the oil yield [10]. These results are in harmony with those of [34] who concluded that manure applications were effective on the increase of the essential oil content and per plant oil quantity of sage. **C**ompost tea had a significant effect on essential oil components of coriander fruits [15]. Also, 5t FYM/ ha led to an increase in oil yield of lemongrass [25].

3.3 Effect of interaction between NPK doses and the growth stimulators

3.3.1 Vegetative growth traits

Data are tabulated in Table 7 cleared that the interaction treatments between NPK doses and the used growth stimulants have significantly exhibit effects on the growth traits (plant height, tiller number/ plant and fresh and dry weights of plant and fedd.) during the two cuts in the both seasons. In the majority of cases, the differences among the interaction treatments have reached the significant level for all the vegetative parameters under study in the two cuts during the two seasons. Over all the highest significant values of the above mentioned traits had been resulted from NPK full dose combined with compost tea, while the least significant values of them were been recorded for half NPK dose without any stimulator in comparison of the other treatments in the two cuts during the two seasons**.** The improving effects of compost tea combined with NPK full dose on vegetative growth of lemongrass much more than the other used treatments may be referred to the same aforementioned reasons in case of effect of either NPK doses or growth stimulators on vegetative growth traits**.** Our results have been supported by results of [35] who recommended to spray *Plantago arenaria* plants with compost tea with half the amount of chemical fertilization to obtain the highest fresh and dry grass yield. 5 t / ha of FYM plus 40+ 40+ 12 kg NPK/ ha recorded the highest average seed yield [36]**.** 5 t/ ha organic fertilizer plus 75 kg NPK/ ha resulted in the best values of leaf numbers, yield performance, plant highest and stem diameter of Jute mallow [37]. Likewise, all agronomic trails of rosemary were very affected significantly by manure and chemical fertilizers compared to the control [38].

Table 7: Effect of interaction between NPK doses and foliar spray with some growth stimulants on vegetative growth and essential oil traits during 2016 and 2017 seasons

Traits		First season 2016								Second season 2017							
		1st cut				2nd cut				1st cut				2nd cut			
		Control	Compost tea	Algae extract	Lithovit	Control	Compost tea	Algae extract	Lithovit	Control	Compost tea	Algae extract	Lithovit	Control	Compost tea	Algae extract	Lithovit
Plant height (cm)	½ NPK	63.54	65.21	64.71	63.96	58.71	66.21	60.04	59.17	56.52	64.17	58.75	56.79	53.84	63.29	58.08	55.62
	NPK	64.41	67.84	65.02	64.08	59.84	69.42	64.58	61.59	57.29	65.48	61.19	59.75	56.04	65.00	58.75	57.17
LSD		3.47				3.33				3.21				2.93			
Number of tillers/plant	½ NPK	23.59	44.34	27.29	24.13	24.00	33.29	30.42	25.00	18.85	27.71	23.29	19.67	17.67	29.04	20.75	19.04
	NPK	25.38	49.25	29.79	26.71	26.84	39.08	33.00	27.58	22.25	30.79	26.54	23.29	19.46	33.04	23.63	21.04
LSD		1.33				2.00				1.70				1.68			
Fresh weight of herb/plant (g)	½ NPK	158.35	215.43	190.63	170.70	115.25	183.45	155.17	143.60	111.44	182.86	147.02	129.61	89.86	154.04	122.06	97.04
	NPK	161.85	272.70	205.70	178.57	145.23	208.07	174.13	147.90	138.29	204.48	171.48	150.62	107.77	197.50	140.10	114.10
LSD		12.45				12.26				6.17				7.31			
Fresh weight of herb/fed. (ton)	½ NPK	1.77	2.41	2.14	1.91	1.29	2.06	1.74	1.61	1.25	2.05	1.65	1.45	1.01	1.72	1.37	1.09
	NPK	1.81	3.05	2.30	2.00	1.63	2.33	1.95	1.66	1.56	2.29	1.92	1.69	1.21	2.21	1.58	1.29
LSD		0.14				0.15				0.07				0.08			
Dry weight of herb/plant (g)	½ NPK	54.20	73.57	65.10	58.30	36.90	58.95	49.17	46.00	44.54	73.19	58.73	51.95	29.44	50.44	39.89	31.62
	NPK	55.30	93.10	70.20	61.07	46.57	66.80	55.90	47.43	55.28	81.63	68.43	60.24	35.21	64.67	45.82	37.39
LSD		4.13				3.92				2.49				2.43			
Dry weight of herb/fed. (ton)	½ NPK	0.61	0.82	0.73	0.65	0.41	0.66	0.55	0.52	0.50	0.82	0.66	0.59	0.33	0.57	0.45	0.36
	NPK	0.62	1.04	0.79	0.68	0.52	0.75	0.63	0.53	0.62	0.92	0.77	0.68	0.39	0.73	0.52	0.42
LSD		0.05				0.05				0.03				0.03			
Essential oil percentage	½ NPK	1.58	1.46	1.54	1.76	1.83	1.73	1.61	1.94	1.36	1.39	1.39	1.52	1.72	1.73	1.74	1.86
	NPK	1.73	1.54	1.63	1.62	1.70	1.73	1.78	2.05	1.50	1.51	1.48	1.52	1.74	1.71	1.74	1.86
LSD		0.05				0.11				0.12				0.12			
Essential oil yield/plant (ml)	½ NPK	0.86	1.08	0.91	1.03	0.68	1.02	0.79	0.89	0.61	1.02	0.82	0.79	0.51	0.87	0.70	0.58
	NPK	0.96	1.43	1.15	0.99	0.79	1.15	0.99	0.97	0.83	1.24	1.01	0.92	0.61	1.05	0.80	0.70
LSD		0.09				0.08				0.06				0.06			
Essential oil yield/fed (l)	½ NPK	9.59	12.05	10.19	11.52	7.54	11.45	8.85	10.01	6.78	11.39	9.13	8.84	5.66	9.73	7.78	6.52
	NPK	10.70	16.01	12.82	11.08	8.82	12.91	11.09	10.90	9.58	13.82	11.36	10.26	6.86	11.71	8.95	7.78
LSD		0.96				0.84				0.65				0.69			

Table 8: Essential oil constituents of lemongrass as affected by NPK doses and some growth stimulants at 1st cut in the second season

Compounds (%)	NPK	NPK + compost tea	NPK + algae extract	NPK + lithovit	½ NPK	½ NPK + compost tea	½ NPK + algae extract	½ NPK + lithovit
D-Limonene	7.54	6.05	6.63	7.73	6.71	6.49	7.24	8.43
Linalool	1.07	1.11	1.09	1.78	1.16	1.43	1.08	1.05
Nerol	1.72	1.77	1.66	2.64	1.64	2.27	2.15	1.53
Borneol	2.67	2.84	2.46	1.11	2.98	2.66	2.46	2.40
Citral B (Neral)	33.32	33.51	33.38	33.80	33.29	33.57	34.14	33.02
Citral A (Geranial)	49.17	51.51	50.27	50.37	51.05	50.72	50.48	50.58
Methyl geranate	0.43	-	0.17	-	0.79	-	-	-
Beranyl acetate	1.40	1.21	1.11	1.11	0.24	2.66	1.34	1.17
n-hexadecane	0.11	0.24	0.58	0.24	0.33	0.24	0.32	0.22
Total citral content	82.49	85.02	83.65	84.17	84.34	84.29	84.62	83.60

3.3.2 Essential oil productivity

Data in Table 7 pointed out that the highest significant essential oil% resulted from the plants treated with lithovit combined with half NPK dose and those received NPK full dose only in the first cut and in the second one it was recorded for the plants treated by lithovit combined with either NPK full dose or NPK half dose during the first season. The differences between such treatments didn't reach the significant level during the two cuts. In the second season, the highest oil% was recorded for the treated plants by lithovit combined with either NPK full dose or NPK half dose and those treated by NPK full dose only and NPK full dose combined with compost tea or blue green algae without significant differences among themselves in the first cut. While in the second cut higher oil% was resulted from the same treatments in the first cut, exception NPK full combined with compost tea**.** It's clear that the difference among the used treatments didn't reach the significant level in the majority of cases in the two cuts during the two seasons for the oil%. On the other side, the significantly highest essential oil yield per plant and fedd. Resulted from the treated plants with NPK full dose plus spray by compost tea, while the least significant oil yield per plant and fedd. Was recorded for plants had been fertilized by NPK half dose only during the two cuts in the both seasons. Similarly, [39] mentioned that essential oil% and yield were higher in the treatments containing both chemical fertilizer and organic manure. Application of Royal Ofert biohumus and chemical fertilizers significantly increased essential oil content in anise. Although differences in the essential oil content of caraway and coriander were not significant, the two above mentioned fertilizers and vermicompost show the best results [40]. Applying NPK at 150+ 45+ 45 kg/ha and FYM 8t/ha resulted in maximum oil yield of mint [30].

3.3.3 Essential oil components

Among the essential oil constituents of lemongrass, it can be identified nine compounds are namely: D-limonene, linalool, nerol, borneol, citral B (neral), citral A (geranial), methyl geranate, beranyl acetate and n-hexadecane (Table 8). Whereas**,** the highest D-limonene% was found to be in the received plants to 1/2 NPK dose combined with lithovit as listed 8.43% against 6.05% for NPK dose plus compost tea which recorded the least% of D-limonene**.** Higher linalool and nerol% was resulted from NPK combined with lithovit treatment (1.78 and 2.64%), while the least% of them (1.05 and 1.53%) was been recorded for the treatment of 1/2 NPK plus lithovit**.** Higher borneol% was found in the leaves of applied plants by 1/2 NPK only (2.98), but lower percentage of it was recorded for NPK combined with lithovit (1.11)**.** Also, the treatments of 1/2 NPK combined with algae extract and NPK plus compost tea are the best to rich the essential oil of lemongrass with citral B (neral) and citral A (geranial) as gave 34.14 and 51.51%, respectively. Only, NPK, NPK combined with algae extract and 1/2 NPK treatments had exhibited methyl geranate in the essential oil**.** The treated plants by 1/2 NPK with compost tea and NPK with algae extract had induced essential oil has the highest beranyl acetate and n-hexadecane percentage as listed 2.66 and 0.58%, respectively. It's noticed from data that NPK doses combined with used growth stimulators had remarkable differently effects on the essential oil compounds of lemongrass**.** These results are in agreement with researches of [41, 42, 43] who stated that the chemical composition of lemongrass oil was affected by different farming practices.

4. Conclusion

It can suggests that to obtain the best results for vegetative growth and essential oil productivity of lemongrass, it must be fertilized by 400 kg ammonium sulphate (20.5% N), 300 kg calcium superphosphate (15.5% P_2O_5) and 100 kg potassium sulphate (48% K_2O) per fedd. Combined with compost tea. Whereas, calcium superphosphate is added at the soil preparation as one does**.** Nitrogen fertilizer is divided into 3 equal doses and it is added after 45 and 90 days from planting and two weeks after the first cut. Potassium fertilizer is divided into 2 equal doses and it is added after 45 days from planting and two weeks after the first cut. Compost tea is sprayed 3 times, 45 and 90 days from planting and 3 weeks after the first cut.

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