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GROWTH BEHAVIOR AND PRODUCTIVITY OF LEMONGRASS (*CYMBOPOGON CITRATUS*) AS AFFECTED BY FOLIAR APPLICATIONS OF VARIOUS PROMOTING

M.M. Moussa
Horticulture Dept., Fac. of Agric., Menoufia Univ., Shebin El-Kom, Egypt.

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ABSTRACT: ***This work was performed during two successive growth seasons (2013 and 2014) at the Experimental Farm, Faculty of Agriculture, Menoufia University, Shebin El – Kom , Egypt to study the individual and combined effects of foliar application of benzyl adenine (BA) at (0, 50 and 100 mg/l) and mixture of some micronutrients (iron, manganese, zinc and boron) as a compound chelated (EDTA form) at different levels on growth, yield and active constituents of lemongrass plant (Cymbopogon citratus L.) grown on a clayey soil. Micronutrients were sprayed at different concentrations, i.e., M0 = irrigation water without any of micronutrients, M1= 100, 50, 50 and 25 mg/l, M2 = 150, 100, 100 and 50 mg/l, M3 = 200, 150, 150 and 75 mg/l for Fe, Mn, Zn and B, respectively. The experiment was carried out in a split plot design with three replicates.***

Results indicated that, the combinations between different rates of BA and mixture of micronutrients had a significant improvement effect on growth and yield characters in most cases expressed as plant height (cm), number of tillers/plant, fresh and dry weights of herb (g/plant) and fresh weight of herb (ton/fed) in the 1st and 2nd cuts during the two seasons. Their highest values were obtained in the plants treated with BA at 100 mg/l combined with M2 level of micronutrients in the two cuts through the first and second seasons. The highest oil percentages were obtained by using BA at 50 mg/l + M2 level of micronutrients and BA at 100 mg/l + M1 level of micronutrients for the first and second cuts respectively during the two seasons. Citral a (geranial), citral b (neral) and myrcene were found to be the major compounds in the essential oil of Cymbopogon citrates which reached its maximum values by using BA at 100 mg/l + M1 level of micronutrients, BA at 50 mg/l + M2 level of micronutrients and M1 level of micronutrients without using BA respectively, during the 2nd cut in the first season.

Key words: ***Lemongrass, Benzyl adenine, Micronutrients (Fe, Mn, Zn and B), Vegetative growth parameters and Chemical compositions.***

INTRODUCTION

The Egyptian government needs to increase the production of medicinal and aromatic plants in order to cover the extending demands of local markets and exportation. One of the most important medicinal and aromatic plants is lemongrass (*Cymbopogon citratus*) which belongs to genus *Cymbopogon,* family poaceae (Graminaceae). It is a perennial herb widely cultivated in the tropics and subtropics regions around the world. The propagation of lemongrass carried out by using plant division. *Cymbopogon citratus* contains o.2 to 1.5 % volatile oil on a dry basis with widely variation of the chemical composition as a function of habitat genetic diversity and different agronomic treatment of the culture (Carlson *et al.,* 2001). The volatile oil is described by a high content of citral A (geranial) and citral B (neral) which is used as a raw material for the production of ionone, vitamin A and beta carotene (Paviani *et al.,* 2006) and represented about 80 % of

the essential oil (Aziz and El-Ashry, 2002; Aziz *et al.,* 2010 and Koffil *et al.,* 2009). As a medicinal herb, lemongrass has been considered as anti-oxidant (Dorman *et al.,* 2000), carminative, antimicrobial (Horne *et al.,* 2001), acts as central nervous system depressant, has antifungal and antibacterial activity (Chao and Young, 2000). Also the essential oil which extracted from fresh leaves is used for its analgesic spasmolytic, antipyretic, anti-inflammatory, diuretic and tranquilizing properties in treating various digestive disorders, diabetes, inflammation, nervous disorders and fever (Onawunmi *et al.,* 1984 and Negrelle and Gomes, 2007).

Benzyl adenine (BA) is an important plant hormone that regulates different processes of plant growth and physiological responses including cell division and differentiation, enhancement of leaf expansion and nutrient mobilization in high values to increase the yield (Davies, 1995). In this respect, evidence suggests that (BA) belongs to a group of plant hormones named cytokinines and its role is connected with the growth and development of plants. It is also implicated in the vascular development and synthesis of secondary metabolites such as alkaloids, anthocyanins and indols. It influences chlorophyll biosynthesis and chloroplast differentiation by stimulation of 5-aminolevulinc acid synthesis (Duszka *et al.,* 2009). When exogenously applied, BA has been shown to result in increasing plant height (Letham, 1969), leaf area (Abdullah *et al.,* 1986), branching (Hrotko *et al.,*1996).

Micronutrient deficiency is widespread in plants, animals and humans, especially in many arid countries due to the calcareous nature of soils, high pH, low organic matter, salt stress, continual drought, high bicarbonate content in irrigation water and/or imbalanced application of fertilizers (Malakouti, 2008). However, micronutrient deficiencies can result in great deal of limitation in the physiological and metabolic processes even if the plants need only small amount of micronutrient for satisfactory crop growth and production (Nasiri *et al.*, 2010). Micronutrient elements like manganese (Mn), boron (B), zinc (Zn) and iron (Fe) play a major role in enhancement agricultural production and quality (Gomaa *et al*., 1986). Iron (Fe) deficiency impairs many plant physiological processes because it is involved in chlorophyll and protein synthesis (Fahad *et al*., 2014). Boron (B) encourages the stability and rigidity of cell wall structure and subsequently, supports shape and strength of the plant cell (Brown *et al*., 2002). Zinc (Zn) is an essential micronutrient for sugar regulation and assorted enzymatic activity associated with plant growth, carbonic anhydrase activity, synthesis of chlorophyll and uptake of nitrogen and protein quality (Cakmak, 2008; Khosa *et al*., 2011 and Fahad *et al*., 2014). Manganese (Mn) plays an important roles in photosynthesis (Mousavi *et al*., 2011) and also serves as electron storage and delivery to the chlorophyll reaction centers (Millaleo *et al*., 2010).

MATERIALS AND METHODS

The present work was conducted in two successive growth seasons (2013 and 2014) at the Experimental Farm, Faculty of Agriculture, Menoufia University, Shebin El – Kom , Egypt (30.52^{o}N and 30.99^{o}E), to study the individual and combined effects of foliar application of benzyl adenine (BA) at (0, 50 and 100 mg/l) and mixture of some micronutrients (iron, manganese, zinc and boron) as a compound chelated (EDTA form) at different concentrations on growth, yield and active constituents

of lemongrass plant (*Cymbopogon citratus* L.) grown on a clayey soil.

Representative surface soil samples (0 – 30 cm) were taken from the used soil before performance of the experiment. Soil samples were air - dried, ground, mixed well, sieved through a 2 mm sieve. The samples then were analyzed for determination of some physical and chemical properties. Also, the contents of some available macro - and micronutrients were described according to the methods by Cottenie *et al*. (1982); Page *et al.* (1982) and Kim (1996). The obtained data were recorded in Table (1).

The experiment was carried out in a split plot design with three replicates. The experimental plots were 36 units (12 treatments × 3 replicates) and the area of each plot was 4 m² (2 m length × 2 m width) including four ridges. Before transplanting, at final soil preparation, all plots were fertilized by ordinary super phosphate (15.5 % P_2O_5) at rate of 200 kg/fed. + 50 kg / fed. of agricultural sulphur + 25 m^3/fed. of mature compost. Also, the experimental plots were divided into three main groups (12 plots / main group), which treated with one rate of benzyl adenine (BA) (0, 50 and 100 mg/l). The sub main plots were treated with mixture of some micronutrients (iron, manganese, zinc and boron) as a compound chelated (EDTA form), i.e., M0 = irrigation water without any of micronutrients, M1 = 100, 50, 50 and 25 mg/l, M2 = 150, 100, 100 and 50 mg/l, M3 = 200, 150, 150 and 75 mg/l for Fe, Mn, Zn and B, respectively. Foliar application of micronutrients was done after three weeks of transplanted and repeated monthly in the early morning till the end of the experiment while, BA was sprayed twice at 14 days after transplanting and 10 days after harvesting the 1st cut through the first and second seasons.

Table (1): Some physical and chemical properties of the used soil.

Physical properties	Particles size distribution (%)				Textural grade	Bulk density (Mg / m^3)	Total porosity (%)	Water field capacity (%)
	Coarse sand	Fine sand	Silt	Clay				
	6.62	14.22	28.50	50.66	Clayey	1.33	49.81	34.5

Chemical properties	pH 1:2.5 soil : water susp.	EC (soil paste) dS m^{-1}	Soluble cations (meq / l)				Soluble anions (meq / l)			OM (%)	CEC (cmol / kg)	Ca CO_3 (%)
			Na^+	K^+	Ca^{2+}	Mg^{2+}	Cl^-	HCO_3^-	SO_4^{2-}			
	7.81	2.03	9.1	2.81	5.21	3.18	11.13	2.19	6.98	1.97	34.20	3.22

Available nutrients	Macronutrients (mg / kg)			Micronutrients (mg / kg)			
	N	P	K	Fe	Mn	Zn	B
	45.00	7.21	354	10.42	4.11	3.23	1.16

*** SO_4^{2-} were calculated as the difference between the content of soluble cation (Na^+ , K^+ , Ca^{2+} and Mg^{2+}) and soluble anions (Cl^- and HCO_3^-) .**

Uniform plants of lemongrass (15 cm in height) were secured from Medicinal and Aromatic Plants Res. Dept., Hort. Res. Inst., Agricultural Research Centre, Ministry of Agriculture, Giza, Egypt and were transplanted on the first of March during two growing seasons, 2013 and 2014. The plants were transplanted to the Experimental Farm at a distance of 50 cm between the plants. All agricultural practices beginning from transplanting to harvesting were performed as recommended by Egyptian Ministry of Agriculture.

The plant samples were harvested (cutting) twice after 6 and 9 months from transplanting in each season and leaving about 15 cm above the soil surface. In each cut, plant samples were taken carefully from each replicate to estimate the following parameters:

1- Vegetative growth characters

Plant height (cm), number of tillers/plant, fresh and dry weights of herb (g/plant) and fresh weight of herb and (ton/fed.). A portion of each herb sample was air – dried, oven – dried at 70 °C for 72 hrs. and dry weights were measured as (g/plant).

2- Chemical constituents

Photosynthetic pigments (chlorophyll a, b and carotenoids) were determined in fresh leaves (mg/g fresh weight) as the methods described by Witham *et al*. (1971).

Essential oil percentages were determined in the fresh herb through the 1st and 2nd cuts in both seasons as described by British (1963).

The volatile oil obtained from the fresh leaves in the 2nd cut during the first season was analyzed by using GLC Model HP-5890 with flame ionization detector that was fitted with capillary column, coated with carbowax 20M. The operating conditions were injector temperature 190 ^{o}C, detector temperature 110 ^{o}C, linear temperature programmed at 5 ^{o}C min, to 175 ^{o}C min, nitrogen (carrier gas) flow 2 ml/min, hydrogen 30 ml/min, air 330 ml/min. The peaks were recorded and the areas were determined by using HP-integrator. Oil components were identified by comparing the relation times of the authentic compound.

Plant samples were washed several times with a tap-water and then two times with distilled water, air-dried, oven-dried at 70 ^{o}C for 48 hour, ground separately to a fine powder in a stainless grinder and stored in plastic bags until analysis. Total carbohydrate (%) in the dried herb of lemongrass plants was determined using the colorimetric method described by Dubois *et al.* (1956). A half g portion of each dried plant sample was digested by 5 ml of concentrated mixture of H_2SO_4 + $HClO_4$ at (5: 0.5 ratio) according to Chapman and Pratt (1982). The content (%) of N, P and K were determined as described by Cottenie *et al.* (1982).

Statistical analysis

The obtained data of growth parameters were exposed to proper statistical analyses of variance (ANOVA) by using Minitab computer program and least significant difference (L.S.D.) which was calculated at level of 5% (Barbara and Brain, 1994).

RESULTS AND DISCUSSION

Effect of foliar application of benzyl adenine (BA) and mixture of micronutrients (Fe, Mn, Zn and B) either individually or in combination on:

1-*Growth and yield characters*

Data recorded in Table (2) explain that, growth and yield parameters of lemongrass plants expressed as plant height (cm), number of tillers/plant, fresh

and dry weights of herb (g/plant) and fresh weight of herb (ton/fed) were significantly increased by the application of both benzyl adenine (BA) concentrations in most cases, with superiority for 100 mg/l BA was sprayed as compared to the control in two cuts during the first and second seasons. The increment in the studied growth parameters could be explained through the role of BA in stimulating xylem differentiation and vascular strand development, consequently more absorption of water and essential macro - and micronutrients from the soil, which was reflected in more growth, as mentioned by (Sorokin and Thimann, 1964). In this connection, the obtained results have been supported by Mazrou (1992) on *Datura innoxia* and Eraki (1994) on *Hibiscus sabdariffa*. They found that, foliar application of BA significantly increased plant height, number of branches/plant as well as fresh and dry weights of whole plant than the control.

As for the effect of mixture micronutrients, data in Table (2) reveal that, different levels of micronutrients (M1, M2 and M3) statistically increased growth and yield parameters as compared to the control (M0) in most cases. The highest values of these traits were obtained in the plants sprayed by moderate level (M2) of micronutrients. Enhancing growth characters in response to the foliar application of micronutrients may be due to their positive action on increasing cell division in the meristematic tissues and accelerating carbohydrates and proteins formation (Ghanta and Mitra, 1993). Also, these elements play an important role in the multi-biological processes such as the role of Zn in the synthesis of IAA (Nijjar, 1985).The obtained results concerning the positive effect of using mixture of micronutrients (Zn , Mn , Fe and B) on some vegetative growth parameters of lemongrass plants go in line with the findings of Younis *et al*. (2013), who reported that, using micronutrients increased the growth and the quality of *Rosa hybrida*. Also Yadegari (2015) found that, the application of micronutrients increase the growth of *Borago officinalis, Thymus vulgaris* and *Tagetes erecta.*

Referring to the interactions effect between different foliar applications of BA and micronutrients, data in Table (2) illustrate that, growth and yield parameters of lemongrass were increased due to all tested combinations as compared to the control in the two cuts during both seasons. However, the combined treatment between BA at 100 mg/l and micronutrients at M2 level induced the highest values in this concern during the 1st and 2nd cuts through two seasons. These results are in quite agreement with the finding of Eid *et al.* (2010) on tuberose plants

2-Essential oil production.

It was noticed from Table (3) that, all tested BA treatments increased essential oil production such as oil content (%), oil yield (cc/plant) and oil yield (l/fed), particularly at high application rate (100 mg/l BA) in the two cuts during both seasons exception of essential oil content (%) in the first cut through the first season which reached its maxima by using BA at the lowest concentration. This improvement impact might be attributed to increased capacity of meristematic cells to build active substrate necessary for biosynthesis of essential oils (Mok and Mok, 2001). The influence of cytokinins on the biosynthesis and accumulation of volatile oil were studied by many researchers. Youssef *et al.* (2004) reported that, foliar application of kinetin on matthiola plant significantly promoted the growth and gave the highest oil percentage.

Table (2): Effect of foliar applications of benzyl adenine (BA) and mixture of micronutrients (Fe, Mn, Zn and B) either individually or in combination on growth and yield characters of lemongrass plants in two cuts during both seasons.

Treatments		Plant height (cm)		Number of tillers/plant		Fresh weight of herb (g/plant)		Dry weight of herb (g/plant)		Fresh weight of herb (ton/fed.)	
First season											
BA (mg/l)	Micronutrients	1st cut	2nd cut	1st cut	2nd cut	1st cut	2nd cut	1st cut	2nd cut	1st cut	2nd cut
0	-	77.70	86.38	26.11	34.48	331.68	380.09	80.99	96.87	5.30	6.08
50	-	92.93	105.17	50.27	59.30	463.50	504.83	116.37	132.38	7.41	8.07
100	-	107.01	120.47	67.81	79.28	553.94	606.04	142.88	158.94	8.86	9.69
L SD		*16.21*	*19.24*	*11.25*	*8.68*	*73.25*	*66.51*	*23.28*	*20.87*	*0.38*	*0.43*
-	M0	84.64	92.83	39.90	47.99	378.37	419.03	91.63	105.11	6.05	6.70
-	M1	91.25	102.39	46.31	55.55	436.98	480.18	109.89	125.45	6.99	7.68
-	M2	98.10	111.05	55.21	66.15	505.00	558.17	131.28	146.92	8.08	8.93
-	M3	96.19	109.76	50.84	61.06	478.49	530.57	120.85	140.10	7.65	8.49
	L SD	*10.64*	*8.33*	*10.27*	*6.52*	*66.55*	*58.72*	*17.99*	*16.73*	*0.26*	*0.39*
0	M0	68.59	73.20	18.92	26.51	263.52	320.61	60.96	76.13	4.22	5.13
	M1	75.74	85.89	22.67	31.43	324.68	363.18	77.82	90.20	5.19	5.81
	M2	84.35	94.16	33.15	42.78	381.73	439.27	95.51	114.03	6.11	7.03
	M3	82.12	92.30	29.73	37.20	356.80	397.33	89.67	107.14	5.71	6.36
50	M0	85.44	94.57	42.13	50.16	395.20	411.69	94.34	102.30	6.32	6.59
	M1	92.67	102.72	49.02	58.09	447.11	481.25	111.77	125.85	7.15	7.70
	M2	97.83	111.39	57.33	66.18	521.95	572.81	134.18	154.60	8.35	9.16
	M3	95.80	112.00	52.61	62.77	489.77	553.57	125.20	146.77	7.84	8.86
100	M0	99.91	110.73	58.67	67.30	476.40	524.80	119.60	136.91	7.62	8.40
	M1	105.35	118.58	67.24	77.15	539.15	596.11	140.08	160.32	8.63	9.54
	M2	112.13	127.61	75.15	89.49	611.33	662.43	164.16	172.13	9.78	10.60
	M3	110.66	124.99	70.20	83.21	588.90	640.82	147.69	166.40	9.42	10.25
L SD		*18.41*	*14.41*	*17.77*	*11.28*	*115.13*	*101.59*	*31.12*	*28.94*	*0.45*	*0.67*

Table (2): Cont.

Treatments		Plant height (cm)		Number of tillers/plant		Fresh weight of herb (g/plant)		Dry weight of herb (g/plant)		Fresh weight of herb (ton/fed.)	
Second season											
0	-	76.49	90.81	21.93	30.20	298.51	364.88	76.42	89.25	4.77	5.83
50	-	87.68	107.54	44.93	53.55	402.59	449.40	103.32	110.80	6.44	7.19
100	-	98.89	129.13	63.15	74.68	525.08	582.04	125.75	147.65	8.40	9.31
L SD		*10.13*	*15.57*	*20.11*	*18.75*	*92.74*	*85.64*	*23.21*	*30.57*	*0.96*	*0.84*
-	M0	79.00	97.35	33.85	45.64	336.93	387.60	83.43	94.92	5.39	6.20
-	M1	85.24	106.86	41.87	51.93	388.28	447.85	99.68	107.94	6.21	7.16
-	M2	93.84	117.48	51.02	59.09	469.09	529.44	117.13	133.50	7.50	8.47
-	M3	92.67	114.95	46.60	54.59	440.61	496.88	107.09	127.24	7.05	7.94
	L SD	*11.36*	*12.52*	*17.68*	*11.62*	*73.55*	*63.34*	*33.59*	*25.47*	*0.82*	*0.61*
0	M0	65.20	76.80	16.60	23.25	225.13	289.40	58.30	78.81	3.60	4.63
	M1	72.19	88.12	19.55	29.81	293.67	351.66	79.12	80.55	4.70	5.63
	M2	83.64	98.75	28.18	35.42	348.19	418.30	86.29	100.75	5.57	6.69
	C3	84.95	99.60	23.39	32.34	327.05	400.19	81.99	96.90	5.23	6.40
50	M0	80.02	97.70	34.48	47.93	322.40	360.07	85.16	82.60	5.16	5.76
	M1	86.35	106.15	42.91	51.18	361.63	421.62	97.30	101.18	5.79	6.75
	M2	93.77	115.50	53.70	60.70	486.37	533.88	121.55	133.80	7.78	8.54
	M3	90.59	110.81	48.63	54.42	439.99	482.05	109.29	125.64	7.04	7.71
100	M0	91.80	117.55	50.47	65.76	463.27	513.34	106.84	123.37	7.41	8.21
	M1	97.20	126.32	63.15	74.80	509.54	570.29	122.62	142.11	8.15	9.12
	M2	104.11	138.20	71.20	81.15	572.71	636.16	143.56	165.95	9.16	10.18
	M3	102.48	134.46	67.80	77.03	554.80	608.40	130.00	159.19	8.88	9.73
L SD		*19.65*	*21.66*	*30.59*	*20.10*	*127.24*	*109.58*	*58.11*	*44.06*	*1.42*	*1.06*

Table (3): Effect of foliar applications of benzyl adenine (BA) and mixture of micronutrients (Fe, Mn, Zn and B) either individually or in combination on essential oil production of lemongrass plants in two cuts during both seasons.

Treatments		Oil (%)		Oil yield (cc/plant)		Oil yield (l/fed)	
First season							
BA (mg/l)	Micronutrients	1st cut	2nd cut	1st cut	2nd cut	1st cut	2nd cut
0	-	0.32	0.41	1.10	1.59	17.61	25.56
50	-	0.42	0.51	1.97	2.63	31.49	42.04
100	-	0.35	0.55	1.99	3.35	31.90	53.68
LSD		*NS*	*0.09*	*0.36*	*1.05*	*8.64*	*10.58*
-	M0	0.30	0.42	1.15	1.78	18.46	28.57
-	M1	0.34	0.54	1.51	2.71	24.10	43.42
-	M2	0.44	0.55	2.24	3.13	35.92	50.08
-	M3	0.38	0.46	1.84	2.48	29.51	39.64
	LSD	*NS*	*0.10*	*0.32*	*1.62*	*11.68*	*19.85*
0	M0	0.25	0.35	0.66	1.12	10.55	17.96
	M1	0.31	0.42	1.01	1.53	16.09	24.40
	M2	0.39	0.49	1.49	2.15	23.83	34.45
	M3	0.35	0.40	1.25	1.59	19.99	25.44
50	M0	0.36	0.48	1.42	1.98	22.75	31.63
	M1	0.40	0.52	1.79	2.50	28.60	40.04
	M2	0.49	0.57	2.56	3.27	40.92	52.21
	M3	0.43	0.50	2.11	2.77	33.71	44.30
100	M0	0.29	0.43	1.38	2.26	22.10	36.12
	M1	0.32	0.69	1.73	4.11	27.62	65.83
	M2	0.44	0.60	2.69	3.97	43.03	63.60
	M3	0.37	0.48	2.18	3.08	34.85	49.20
LSD		*NS*	*0.17*	*0.55*	*2.80*	*20.21*	*34.34*
Second season							
0	-	0.47	0.36	1.47	1.35	22.78	21.66
50	-	0.63	0.47	2.56	2.14	41.08	34.31
100	-	0.63	0.51	3.32	2.98	53.09	47.82
LSD		*0.12*	*0.15*	*1.08*	*1.12*	*16.25*	*14.88*
-	M0	0.52	0.42	1.83	1.72	29.29	27.61
-	M1	0.57	0.47	2.27	2.19	36.40	35.07
-	M2	0.62	0.47	3.04	2.54	47.75	40.68
-	M3	0.59	0.44	2.65	2.18	42.50	35.03
	LSD	*0.08*	*NS*	*1.35*	*0.61*	*11.39*	*13.67*
0	M0	0.43	0.27	0.97	0.78	15.48	12.50
	M1	0.45	0.33	1.32	1.16	21.15	18.58
	M2	0.50	0.41	1.92	1.72	27.85	27.43
	M3	0.51	0.44	1.67	1.76	26.67	28.16
50	M0	0.57	0.48	1.84	1.73	29.41	27.65
	M1	0.62	0.50	2.24	2.11	35.89	33.75
	M2	0.73	0.50	3.55	2.67	56.79	42.70
	M3	0.60	0.43	2.64	2.07	42.24	33.15
100	M0	0.58	0.52	2.69	2.67	42.98	42.69
	M1	0.64	0.58	3.26	3.31	52.16	52.90
	M2	0.64	0.51	3.67	3.24	58.62	51.92
	M3	0.66	0.45	3.66	2.73	58.61	43.79
LSD		*0.14*	*0.32*	*2.34*	*1.06*	*19.70*	*23.65*

Also El-Quesni *et al.* (2007) showed that, spraying kinetin produced the highest seed oil content of *Cupressus sempervirens*.

Additionally, the three levels of sprayed micronutrients exhibited highly increments in these values of oil production, especially the treatment of M2 level when compared with untreated plants (control) in 1st and 2nd cuts through two seasons. Many investigators reported that, micronutrient elements can lead to increase oil percentage (Yari *et al*., 2004 and Ravi *et al*., 2008) due to the enzymatic activity enhancement and increasing photosynthesis (Heidarian *et al*., 2011). As the volatile oil is secondary output of photosynthesis, so increasing microelements lead to increase the volatile oil content. Also, similar effect of micronutrients supply on these parameters were also reported by Nasiri *et al*. (2010) on *Matricaria chamomilla* and Eid *et al*. (2010) on *Polianthes tuberose.*

Regarding the interaction effect between foliar applications of BA and micronutrients in both growing seasons, data in Table (3) reveal that, the highest record for essential oil percentage was found in plants sprayed by BA at 50 mg/l plus M2 level of micronutrients in 1st cut during two seasons while the application of BA at 100 mg/l combined with M1 level of micronutrients induced the greatest enhancement in the essential oil percentage through the 2nd cut during two seasons. Also the highest oil yield (cc/plant or l/fed) was registered by spraying BA at 100 mg/l + each of M2 or M1 level of micronutrients for the first and second cuts respectively, during two seasons. These results are similar to those obtained by Eid *et al.* (2010) on tuberose plants which reported that, both Zn an BA increased essential oil percentage compared to untreated plants.

3-Macronutrients (N, P and K) and total carbohydrate percentages

The effect of foliar application with BA at both concentrations on the content (%) of macronutrients (N, P and K) as well as the content (%) of total carbohydrate were reviewed in Table (4). These contents were increased with all BA treatments however, the highest values of N and P % were scored by using low BA concentration, while the high concentration of BA produced the highest K and total carbohydrate content (%) in the dried herb through 1st and 2nd cuts in two seasons compared to the control. These results could be explained through the role of BA in increasing the width of conductive tissues (xylem and phloem) and consequently increasing the absorption and translocation of the elements necessary for plant growth (Krishnamoorthy, 1981). This again suggests, the influence of BA on the mechanism of ions uptake may be related to its effect on membrane permeability and rate of ion entry through the membrane or enhance their translocation to the shoot (Van-Steveninck, 1976). Furthermore, kinetin altered membrane composition (Merillon *et al.,* 1993), its selectivity (Dhakal and Erdei,1986) and increased membrane fluidity (Vodanik *et al*., 1999). These results pointed in the same direction of Abd El-Aziz (2007) and Eid and Abou-Leila (2006) on croton plants.

Also, data in Table (4) revealed strong improvement in plant content (%) of N, P, K and total carbohydrate under the applying of micronutrients as foliar application. The greatest increments in the content (%) of K, P and N were done by the application of micronutrients at M1, M2 and M3 levels respectively, compared to the control. Also spraying plants by M3 level produced the highest total content (%) of carbohydrate in the two seasons with the exception of 2nd cut

Table (4): Effect of foliar applications of benzyl adenine (BA) and mixture of micronutrients (Fe, Mn, Zn and B) either individually or in combination on some macronutrients (N, P and K) and total carbohydrate content (%) of lemongrass plants in two cuts during both seasons.

Treatments		N (%)		P (%)		K (%)		Total carbohydrate (%)	
First season									
BA(mg/l)	Micronutrients	1st cut	2nd cut	1st cut	2nd cut	1st cut	2nd cut	1st cut	2nd cut
0	-	0.98	1.08	0.29	0.26	2.01	1.81	13.30	12.50
50	-	1.41	1.28	0.49	0.43	2.34	2.04	16.11	14.70
100	-	1.22	1.23	0.42	0.40	2.78	2.36	17.55	15.58
LSD		*0.21*	*0.13*	*0.17*	*0.13*	*0.26*	*0.31*	*1.65*	*2.06*
-	M0	1.09	1.14	0.34	0.30	2.21	1.96	14.77	13.42
-	M1	1.14	1.15	0.39	0.35	2.50	2.18	15.38	14.01
-	M2	1.26	1.23	0.46	0.41	2.44	2.14	16.00	14.79
-	M3	1.33	1.27	0.41	0.39	2.36	2.00	16.46	14.82
	LSD	*0.15*	*NS*	*0.10*	*NS*	*0.21*	*NS*	*1.22*	*1.15*
0	M0	0.82	1.04	0.24	0.21	1.85	1.64	12.40	11.97
	M1	0.93	1.04	0.29	0.26	2.13	1.90	13.11	12.15
	M2	1.07	1.13	0.35	0.30	2.09	1.93	13.60	12.40
	M3	1.11	1.12	0.31	0.30	1.97	1.80	14.09	13.50
50	M0	1.29	1.20	0.42	0.37	2.22	1.99	15.62	13.39
	M1	1.34	1.23	0.48	0.42	2.41	2.18	15.90	14.52
	M2	1.47	1.32	0.56	0.49	2.44	2.10	16.14	15.75
	M3	1.56	1.40	0.51	0.44	2.30	1.89	16.81	15.15
100	M0	1.16	1.19	0.37	0.33	2.58	2.26	16.30	14.90
	M1	1.16	1.18	0.40	0.38	2.96	2.47	17.15	15.37
	M2	1.25	1.24	0.48	0.45	2.80	2.39	18.26	16.23
	M3	1.34	1.31	0.43	0.45	2.81	2.33	18.50	15.82
LSD		*0.26*	*0.32*	*0.17*	*NS*	*0.36*	*0.42*	*2.11*	*1.99*
Second season									
0	-	1.07	1.17	0.35	0.37	2.19	2.17	14.40	11.95
50	-	1.48	1.37	0.55	0.56	2.49	2.48	16.08	13.39
100	-	1.27	1.32	0.43	0.53	2.71	3.05	16.80	15.10
LSD		*0.20*	*0.13*	*0.15*	*NS*	*0.34*	*0.42*	*1.06*	*1.24*
-	M0	1.14	1.21	0.38	0.47	2.39	2.39	14.62	13.02
-	M1	1.24	1.27	0.43	0.50	2.54	2.71	15.38	13.47
-	M2	1.35	1.32	0.49	0.51	2.51	2.59	16.25	13.90
-	M3	1.36	1.34	0.46	0.47	2.42	2.57	16.79	13.54
	LSD	*0.14*	*0.10*	*NS*	*NS*	*NS*	*0.28*	*1.23*	*NS*
0	M0	0.95	1.12	0.30	0.35	2.15	1.94	13.45	10.94
	M1	0.99	1.18	0.33	0.35	2.28	2.21	14.28	11.57
	M2	1.14	1.16	0.38	0.40	2.16	2.25	14.59	12.60
	M3	1.20	1.22	0.39	0.41	2.17	2.30	15.30	12.71
50	M0	1.30	1.28	0.47	0.52	2.40	2.31	14.81	13.30
	M1	1.45	1.36	0.52	0.59	2.57	2.71	15.79	13.66
	M2	1.60	1.43	0.61	0.59	2.59	2.52	16.60	13.61
	M3	1.59	1.43	0.60	0.54	2.43	2.38	17.15	13.02
100	M0	1.18	1.25	0.39	0.55	2.63	2.94	15.61	14.84
	M1	1.30	1.29	0.44	0.58	2.77	3.23	16.09	15.20
	M2	1.33	1.37	0.50	0.54	2.78	3.00	17.57	15.49
	M3	1.30	1.39	0.40	0.47	2.66	3.04	17.93	14.90
LSD		*0.25*	*0.17*	*NS*	*NS*	*NS*	*0.48*	*2.13*	*3.15*

during the second season which reached its maxima by using M2 level. These increases in constituents may be due to the effect of micronutrients on stimulating biological activities, i.e. enzyme activity, chlorophyll synthesis, rate of translocation of photosynthetic products and increased nutrient uptake through roots after foliar fertilization. Such improvement could be explained by the role of these elements in increasing adsorbing surface of the root and enhance the transportation of the nutrients from the soil to plant organs via the roots. The aforementioned results of micronutrients on chemical constituents are in parallel with those obtained by Gomaa (2008) on *Hibiscus sabdariffa* and Ajay *et al.* (2010) on *Mentha arvensis* L.

Moreover, all combined treatments among foliar micronutrients and BA concentrations induced remarkable increments in N, P and K and total carbohydrate content (%). Reached its maxima of N, P and K % in the treatments of BA at 50 mg/l + M3 level of micronutrients, BA at 50 mg/l + M2 level of micronutrients and BA at 100 mg/l + M1 level of micronutrients respectively, while the highest content (%) of total carbohydrate occurred by the application of both combined treatments BA at 100 mg/l + M3 level of micronutrients, BA at 100 mg/l + M2 level of micronutrients for 1st and 2nd cuts respectively, during two seasons. Similar results were obtained by Mohamed. (2016) on common bean.

4-Photosynthetic pigments

Data recorded in Table (5) showed that, photosynthetic pigments, i.e. the content of chlorophyll a, b as well as carotenoids (mg/g of fresh leaves) were progressively affected by spraying BA at different concentrations, where the highest increment in the readings of chlorophyll a, b and carotenoids were observed in all plants treated with BA at high concentration as compared to untreated plants in two cuts during the first and second seasons. These results are in agreement with Talaat and Youssef (1998) and Zayed *et al*. (1985) on *Hibiscus sabdariffa* they reported that, using BA increased chlorophyll a, b and carotenoids in the fresh leaves.

A steady increments in all of the above mentioned readings were also found by spraying micronutrients at different levels. A gradual increase in these values as micronutrients increased up to M3 level. The positive effect of micronutrients on the concentrations of leaf pigments may be due to its role in chlorophyll synthesis. In this respect, iron is essential for chlorophyll synthesis in that, it is necessary for the synthesis of δ-aminolevulinic acid and a precursor of chlorophyll (Bogorad, 1966). Iron played a somewhat similar role to Mg in the porphyrin structure of chlorophyll. Also iron is necessary in the oxidation step from coproporphyrinogen to protoporphyrinogen in chlorophyll synthesis (Machold and Stephan, 1969). With regard to the effect of Zn, Foy *et al.* (1978) hypothesized that, Zn interferes with Fe utilization in the leaves for chlorophyll synthesis. Similar findings were obtained by Ziedan and Eisa (2016) they reported that, the application of Zn and Mn increased total chlorophyll content compared with the control.

Treated lemongrass plants with dual application of BA and micronutrients with a variance degree improved chlorophyll a, b as well as carotenoids contents, especially the combined treatment of BA at 100 mg/l with micronutrients at M3 level the first and second cuts during two seasons as compared to other combinations and the control.

Table (5): Effect of foliar applications of benzyl adenine (BA) and mixture of micronutrients (Fe, Mn, Zn and B) either individually or in combination on photosynthetic pigments of lemongrass plants in two cuts during both seasons.

Treatments		Chlorophyll A (mg/g)		Chlorophyll B (mg/g)		Carotenoids (mg/g)	
First season							
BA (mg/l)	Micronutrients	1st cut	2nd cut	1st cut	2nd cut	1st cut	2nd cut
0	-	4.62	4.10	1.62	1.52	2.69	2.60
50	-	5.75	5.26	2.58	2.05	3.60	3.02
100	-	6.23	5.98	3.23	3.01	4.26	3.87
LSD		*0.59*	*0.42*	*0.98*	*1.05*	*1.12*	*0.57*
-	M0	4.97	4.61	2.11	1.80	3.01	2.84
-	M1	5.51	4.99	2.35	2.23	3.42	3.12
-	M2	5.72	5.27	2.53	2.31	3.70	3.25
-	M3	5.94	5.59	2.93	2.45	3.95	3.46
	LSD	*0.86*	*0.65*	*0.61*	*0.24*	*0.69*	*0.48*
0	M0	4.13	3.74	1.39	1.28	2.43	2.30
	M1	4.56	3.99	1.43	1.49	2.64	2.53
	M2	4.79	4.18	1.58	1.60	2.73	2.74
	M3	5.03	4.51	2.11	1.74	2.98	2.86
50	M0	5.20	4.40	2.08	1.59	2.97	2.60
	M1	5.78	5.17	2.35	2.13	3.42	2.98
	M2	5.94	5.60	2.71	2.20	3.86	3.12
	M3	6.10	5.89	3.20	2.31	4.18	3.41
100	M0	5.60	5.70	2.88	2.53	3.63	3.62
	M1	6.19	5.82	3.27	3.07	4.20	3.85
	M2	6.45	6.03	3.30	3.15	4.53	3.90
	M3	6.70	6.38	3.48	3.30	4.70	4.13
LSD		*1.51*	*1.12*	*1.06*	*0.42*	*1.19*	*0.83*
Second season							
0	-	4.87	3.32	1.76	1.21	2.78	1.99
50	-	5.33	3.93	2.04	1.62	3.12	2.74
100	-	5.53	4.95	2.55	2.06	3.74	3.18
LSD		0.35	0.94	0.62	0.42	0.73	1.02
-	M0	5.00	3.74	1.87	1.44	2.99	2.45
-	M1	5.12	3.90	2.02	1.52	3.16	2.54
-	M2	5.34	4.10	2.22	1.70	3.28	2.69
-	M3	5.50	4.53	2.36	1.85	3.41	2.88
	LSD	NS	0.51	NS	0.33	NS	NS
0	M0	4.72	2.96	1.57	1.08	2.68	1.75
	M1	4.85	3.15	1.64	1.16	2.76	1.84
	M2	4.79	3.34	1.88	1.24	2.80	2.11
	M3	5.12	3.86	1.97	1.38	2.88	2.29
50	M0	4.93	3.50	1.73	1.40	2.69	2.58
	M1	5.23	3.61	1.90	1.48	3.14	2.67
	M2	5.61	4.11	2.16	1.72	3.25	2.77
	M3	5.58	4.52	2.40	1.89	3.40	2.95
100	M0	5.37	4.77	2.31	1.85	3.60	3.02
	M1	5.30	4.95	2.52	1.94	3.59	3.12
	M2	5.64	4.86	2.64	2.15	3.81	3.21
	M3	5.81	5.22	2.73	2.30	3.96	3.40
LSD		0.85	0.88	0.92	0.57	1.12	1.23

5-Essential oil composition

Gas liquid–Mass spectrum analyses Table (6) showed that, the identified compounds were 10 for essential oil of *Cymbopogon citratus*. Citral a (geranial) was found to be the first major compound in the essential oil of *Cymbopogon citratus* and ranged from 36.84 to 44.63 %. Its minimum content was observed from plants treated by zero BA + M3 level of micronutrients while, the maximum content was recorded with plants that received BA at 100 mg/l + M1 level of micronutrients. The second main compound was identified as citral b (neral) which ranged from its minimum content (29.25%) by using zero BA + M3 level of micronutrients to its maximum relative percent (36.44%) by using BA at 50 mg/l + M2 level of micronutrients.

Table (6): Effect of foliar applications of benzyl adenine (BA) and mixture of micronutrients (Fe, Mn, Zn and B) either individually or in combination on essential oil composition of lemongrass plants in 2nd cut during the first season.

BA (mg/l)	Micronutrients	α-Pinene	1-8 cineole	Geranyl acetate	Geraniol	Terpinolene	Linalool	Limonene	myrcene	Citral B (Neral)	Citral A (Geranial)
0	-	0.66	0.78	0.71	1.21	1.26	3.95	7.40	12.02	30.58	38.72
50	-	1.01	0.77	0.68	1.25	1.40	2.61	5.00	10.17	34.42	40.90
100	-	1.00	0.86	0.94	1.05	2.28	2.77	3.98	9.21	31.94	43.19
-	M0	1.13	0.93	1.04	1.57	1.60	3.68	5.34	10.32	32.03	39.51
-	M1	0.68	0.63	0.46	0.90	1.50	2.85	5.51	10.75	33.75	41.30
-	M2	0.60	0.71	0.78	0.62	1.60	2.38	5.54	10.49	32.84	41.95
-	M3	1.15	0.94	1.16	1.58	1.88	3.54	5.45	10.31	30.64	41.00
0	M0	0.45	0.55	0.63	1.20	1.50	4.52	6.74	11.93	30.15	38.76
	M1	0.58	0.75	0.70	1.36	1.49	3.50	6.82	12.35	31.40	39.16
	M2	0.71	0.84	0.71	0.70	0.64	2.62	7.90	12.01	31.52	40.15
	M3	0.92	0.98	0.80	1.58	1.41	5.18	8.15	11.82	29.25	36.84
50	M0	1.04	1.01	0.95	1.79	1.63	3.08	5.12	10.36	33.82	39.60
	M1	1.13	0.77	0.41	0.84	1.12	2.43	5.33	10.80	35.63	40.11
	M2	0.23	0.35	1.14	0.27	1.48	2.01	4.95	9.81	36.44	41.52
	M3	1.65	0.98	1.22	2.11	1.37	2.95	4.60	9.71	31.79	42.37
100	M0	1.91	1.25	1.54	1.74	1.68	3.46	4.17	8.69	32.12	40.18
	M1	0.33	0.39	0.27	0.51	1.89	2.63	4.40	9.11	34.22	44.63
	M2	0.88	0.96	0.49	0.90	2.70	2.53	3.78	9.66	30.56	44.18
	M3	0.90	0.87	1.46	1.05	2.88	2.49	3.60	9.41	30.88	43.79

The quality of *C. citratus* essential oil was related to its citral content which considered a mixture between neral and geranial with concentration range from 65 to 75% (Combrinck*et al*., 2011). Myrcene was identified as the third main constituent and ranged from 8.69 to 12.35%. Limonene was found to be the 4th main compound (3.60 – 8.15 %) followed by linalool (2.01 – 5.18%). These results agreed with Aziz and El-Ashry (2002); Koffi1 *et al.* (2009) and Aziz *et al.* (2010), they reported that, the main components of *C. citratus*oil are neral, geranial and citronellol which represented about 80 % of the essential oil.

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تأثير الإضافات الورقية لمنشطات النمو المختلفة علي نمو و إنتاجية حشيشة الليمون

محمد محمد موسي

قسم البساتين – كلية الزراعة – جامعة المنوفية– شبين الكوم –مصر

الملخص العربي

أُجريت تجربة خلال موسمي نمو متتاليين (2013 و 2014 م) بالمزرعة البحثية بكلية الزراعة – جامعة المنوفية – شبين الكوم – مصر، وذلك لدراسة التأثير الفردي و المشترك للإضافات الورقية لكلٍ من بنزيل أدينين عند مستويات مختلفة (صفر، 50 و 100 ملليجرام / لتر) مع خليط من المغذيات الصغري (الحديد، المنجنيز، الزنك و البورون) بمستويات مختلفة و في صورة مخلبية (إيثيلين داي أمين تترا أستيك أسيد) علي كلٍ من نمو و محصول و مكونات نباتات حشيشة الليمون النامية في أرض طينية. تم إضافة المغذيات الصغري رشاً و بتركيزات مختلفة كالآتي:- م$_{صفر}$ = الرش بالمياه المستخدمه في الري بدون أي نوع من المغذيات الصغري – م $_1$ = 100، 50، 50 و 25 ملليجرام / لتر – م$_2$ = 150، 100، 100 و 50 ملليجرام / لتر – م$_3$ = 200، 150 ، 150 و 75 ملليجرام / لتر لكلٍ من الحديد ، المنجنيز ، الزنك و البورون علي التوالي . وقد صُممت التجربة في تصميم قطع منشقة بثلاث مكررات.

وقد أوضحت النتائج أن الإضافات المشتركة لكلٍ من بنزيل أدينين مع خليط من المغذيات الصغري كان لهما تأثيرات معنوية في تحسين و زيادة النمو و المحصول مثل طول النبات (سم) ، عدد الفروع لكل نبات، الوزن الطازج (جم/نبات) ، (طن/فدان) و أيضاً الوزن الجاف للحشة الأولي و الثانية لموسمي النمو، كما كانت أعلي هذه المقاييس واضحة في النباتات المعاملة ببنزيل أدينين بمعدل رش 100 ملليجرام / لتر متحداً مع خليط من المغذيات الصغري عند مستوي الإضافة الورقية م$_2$ وظهر هذا جلياً في كلٍ من الحشة الأولي و الثانية خلال موسمي النمو. بينما كان أعلي محتوي للزيت في النباتات (نسبة مئوية) وجد في النباتات المعاملة ببنزيل أدينين عند مستوي 50 ملليجرام / لتر + خليط من المغذيات الصغري بمعدل رش م$_2$ و أيضاً في النباتات المعاملة ببنزيل أدينين بمعدل 100 ملليجرام / لتر متحداً مع خليط من المغذيات الصغري عند مستوي الإضافة الورقية م$_1$ ، سواءً في الحشة الأولي أو الثانية و في كلٍ من موسمي النمو. و إتضح أيضاً أن المكونات الأساسية في زيت حشيشة الليمون (سيترال أ ، ب و الميسين) كانت أكثر تواجداً و أعلي نسبة في النباتات المعاملة ببنزيل أدينين (100 ملليجرام / لتر) متحداً مع خليط من المغذيات الصغري بمستوي تركيز م$_1$ يتبعه النباتات المعاملة ببنزيل أدينين (50 ملليجرام / لتر) متحداً مع خليط من المغذيات الصغري بمستوي تركيز م$_2$ ثم النباتات المعاملة بخليط من المغذيات الصغري بمستوي تركيز م$_1$ وبدون إضافة لبنزيل أدينين ، علي التوالي وذلك في الحشة الثانية من الموسم الثاني.

أسماء السادة المحكمين

أ.د/ على عبدالحميد معوض كلية الزراعة – جامعة الزقازيق

أ.د/ مجدى رابح محمد رابح كلية الزراعة – جامعة المنوفية