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INFLUENCE OF FOLIAR APPLICATION OF GIBBERELLIC ACID AND LIQUORICE ROOT EXTRACT ON GROWTH, VOLATILE OIL YIELD PRODUCTIVITY AND ANTIMICROBIAL ACTIVITY IN GERANIUM (*PELARGONIUM GRAVEOLENS* L. HER.) PLANTS

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ABSTRACT: This work was carried out during the two successive seasons (2019/2020 and 2020/2021) in the Experimental Farm of Horticulture Research Station at Sids, Beni-Suef Governorate, to investigate the effect of foliar application of gibberellic acid (GA_3) at 100, 200 and 300 ppm and spraying of two extractions of liquorice root (aqueous LRE at 5 and 10 g/l and ethanolic LRE at 5 and 10 g/l) and their interaction on the vegetative growth (plant height, number of branches, herb fresh weight per plant and per feddan), volatile oil productivity (oil %, yield per plant and per feddan), total chlorophyll and total carbohydrates, NPK percentages, as well as antimicrobial activity of geranium plants. Obtained results revealed that the best vegetative growth characteristics, volatile oil productivity, total chlorophyll and carbohydrates were obtained due to the use of the high dose (300 ppm) and medium dose (200 ppm) of gibberellic acid with no significant differences between them. Concerning liquorice root extract treatments, all of the prementioned growth parameters, oil yield and chemical traits were considerably augmented due to the high dose of aqueous LRE at 10 g/l treatment followed by ethanolic LRE at 10 g/l, while LRE aqu. at 5 g/l gave the least values. In regard to the interaction between the two studied factors, the highest growth, yield and chemical composition values were given by GA_3 at 200 or 300 ppm in combination with LRE aqu. at 10 g/l. Overall, the most powerful antimicrobial activity was recorded of the combination treatment in the two geranium cuts. Therefore, it could be advised from the economical and environmental point of view, to supply geranium plants with GA_3 at 200 ppm and LRE aqu. at 10 g/l to improve the volatile oil yield and the antimicrobial activity.

Keywords: geranium, gibberellic acid, liquorice root extract, volatile oil.

INTRODUCTION

Geranium (*Pelargonium graveolens* L. Herit) belongs to Geraniaceae family. It's a fragrant plant native to Southern Africa with a high value. It is grown commercially in Egypt for valuable volatile oil (Rana, 2002; Singh *et al*., 2013). Forty percentages (40%) of the world's production of geranium oil is dominated by Beni-Suef, Egypt (International Trade Center Report, July 2015). The major constituents of geranium oil are citronellol and geraniol, as well as their esters (Cavar, and Maksimovi, 2012). Pelargonium oil is commonly used in the treatment of inflammation, haemorrhoids, dysentery, heavy menstrual flows, and even

cancer due to its high antioxidant properties, potential immune-modulating effects, and antimicrobial characteristics (Kang *et al*., 2010; Saraswathi *et al*., 2011). Also is used in a variety of perfumes and flavorings. This is owing to the strong odor of liquid and concentrated essence used in the creation of numerous food products such as yoghurt, jelly, and confectionery (Saraswathi *et al*, 2011). In addition, geranium leaves are known to have antifungal activity and repel insects (Rajeswara, 2002).

The use of sustainable and eco-friendly agricultural practices in the production of cleaner and better foods is critical in determining their market price and nutritional value. Farmers' reliance on chemical fertilizers as a source of nutrients, as well as their massive cost, has been linked to land and soil erosion, as well as pollution (Phiri, 2010). Furthermore, the extensive and/or excessive usage of manufactured chemical fertilizers diminishes the crops' export acceptance (Abdel-Rahman *et al*., 2008). Foliar spray treatment with exogenous plant growth regulators like gibberellin is one of the most effective methods for enhancing plant growth and development (Hazzoumi *et al*., 2014).

Gibberellins can promote germination, stem and root elongation, leaf enlargement, flowering and fruit maturity (Hedden and Sponsel, 2015). Synthetic substances, on the other hand, are environmentally hazardous, toxic and costly. For these reasons, natural plant growth stimulants are advised for sustainable agriculture. Alternative and natural stimulant sources have recently attracted interest as means of achieving sustainable agriculture and enhancing crop productivity (Abdalla, 2013).

Plant extracts contain a variety of bioactive metabolites that may improve a variety of biological processes, hence promoting plant yield and quality. Otherwise, natural stimulants have been shown to reduce chemical fertilizers and increase nutrient utilization efficiency (Bulgari *et al*., 2015). Liquorice root extract (LRE) obtained from (*Glycyrrhiza glabra*) that can be used as a foliar spray, liquorice is considered a natural stimulant for plants and increase yield. It has high antioxidants and osmoprotectants such as amino acids (arginine, alanine, lysine), minerals (N, Ca, K, Mg, Fe, Zn, P), vitamins (α-tocopherol, thiamine, riboflavin, pyridoxine), as well as carbohydrate. It also contains mevalonic acid, which is used in the production of gibberellins (Sabry *et al.*, 2009; Moses *et al.* 2002 and Al-Ajeeli, 2005). Glycyrrhizin, the calcium and potassium salts of glycyrrhizic acid, and trihydroxy acid are all found in LRE (Musa *et al*., 2002).

Therefore, the purpose of this work is to determine how gibberellic acid (GA_3), aqueous and ethanolic extracts of (LRE), and their interactions affect geranium (*Pelargonium graveolens* L. Herit) plant development, oil yield and some chemical components finally, antimicrobial action of geranium essential oil.

MATERIALS AND METHODS

Plant material, experimental procedures and design:

A field experiment was conducted during the two consecutive seasons of 2019/2020 and 2020/2021 in the Experimental Farm of Horticultural Research Station at Sids, Agricultural Research Center, Beni-Suef Governorate, Egypt. The aim of this study was to examine the impact of foliar application of gibberellic acid (GA_3) as a synthetic plant growth regulator and liquorice root extract as a natural plant growth promoter on the growth, biomass, volatile oil yield and some of chemical components such as total chlorophyll and carbohydrates, as well as antimicrobial activity of geranium plants. In the first week of November for both seasons, geranium terminal cuttings (15 cm length) were grown in 3 × 3.60 m^2 plots with 60 cm row spacing and 30 cm hill spacing within each row. As shown in Table (1), soil samples were taken at 0-30 cm depth for nutrient and trace element analysis and some physical and

chemical characteristics of the soil were determined using the procedures given by Jackson (1973). The mineral NPK fertilization was added at 300 kg/fed ammonium nitrate (33.5% N), 200 kg/fed calcium superphosphate (15.5% P_2O_5) and 150 kg/fed potassium sulphate (48.5% K_2O). All other agricultural practices were followed as usual.

The experimental design was split-plot in a randomized complete block design with three replicates. Gibberellic acid (Titan Biotech Ltd., India) was represented in the main plots at four applications (0, 100, 200 and 300 ppm) and sub-plot displayed at five concentrations of liquorice roots extract (control as tap water, 5 and 10 g/l aqueous and ethanolic extracts).

Preparation of liquorice root extract:

The liquorice root was obtained from the local market, and washed with a distillated water and dried in the shade. The dried roots were finely ground to powder. Each dose (5 and 10 g) of that powder form was homogenized by laboratory blender in 200 ml of ethanol (96.7%) and distilled water (80:20 v/v) for 10 minutes, and then left in dark glass bottles for three days for complete extraction. The extract was filtered through paper (Whattman No. l). The final extract was collected separately in other dark glass bottles and exposed to 60 °C in a water bath for 30 min for ethanol evaporation. The collected extract was then stored in a refrigerator at 5 °C until needed. The liquorice root extract was subjected to GC-MS analysis using a Gas Chromatograph. (Almehemdi *et al*., 2011 and Ezzat *et al*., 2016). The main compounds of liquorice root extract (LRE eth.) were: glycyrrhizin 14.7%, liquiritin 0.56%, apignin 27.97 µg/g, benzoic acid 12.42 µg/g, cinnamic acid 34.22 µg/g, kaempherol 31.72 µg/g, p-coumaric 24.67 µg/g, phenol 19.70 µg/g, rutin 21.23 µg/g and vanillin 23.51 µg/g.

Aqueous extract of liquorice roots was prepared by soaking dried 5 and 10 g powder of roots in one liter of a distilled water at 50 °C for 24 hours then filtered and supplemented the final volume to one liter, (Abd El-Azim *et al*., 2017 and El-Sayed, *et al*., 2019).

Chemical analysis of the aqueous liquorice root extract (LRE aqu.) on dry mass (DM) basis:

- Antioxidants and osmoprotectants: free proline 32, soluble sugars 128, glutathione 33.2 **(**g kg^{-1} DM**)**; ascorbic acid 42.0, selenium 0.90 (mg kg^{-1}) and DPPH-radical scavenging 83.2% .
- Phytohormones (mg kg^{-1} DM): total auxins 4.2, total gibberellins 5.2 and zeatin-type cytokinin 4.1.
- Mineral nutrients (g kg^{-1} DM): nitrogen 20.2, phosphorus 21.3, potassium 47.2, calcium 2.20, magnesium 3.80, sulfur 2.40, iron 0.94, manganese 0.62, zinc 0.21 and cupper 0.02.

As a foliar spray, gibberellic acid and liquorice root extracts (LRE) were used. With all treatments, a few drops of Tween-20 was utilized as a wetting agent. Spraying was done to the point of runoff, that as a surfactant to assure an effective and complete penetration of the spray solutions. All treatments were administered four times at three-week intervals, with the first treatment occurring 45 days following planting. All other farming techniques were followed as recommended.

Table 1. Physical and chemical properties of the used soil during the two seasons of 2019/2020 and 2020/2021.

Seasons	Particle size distribution			Chemical properties									Textural Class
	Clay %	Silt %	Sand %	Available (ppm) N	P	K	Fe	Zn	Mn	OM %	EC, dSm^{-1} (at 25 °C)	pH	
2019/20	48.10	33.60	18.30	38.0	12.60	244.6	2.25	0.30	0.65	1.60	1.03	7.8	Clayey
2020/21	45.80	34.70	19.50	35.0	13.42	256.5	2.30	0.28	0.62	1.72	1.08	7.6	

Growth and yield parameters:

In both seasons, the first cut (1st cut) of geranium plants was in May and the second cut (2nd cut) was in November. The vegetative growth characters were determined as plant height (cm), number of branches/plant and herb fresh weight per plant (g) and per feddan (ton).

Volatile oil productivity:

After 48 hours from cutting, 100 g of geranium herb were hydro-distilled for three hours using a Clevenger-type apparatus, as reported by British Pharmacopoeia, (1963)

Oil percentage = oil volume in the graduated tube/weight of sample × 100; and the volatile oil yield per plant (ml) and per feddan (l) were calculated.

Volatile oil components: the GC-MS analysis of essential oils was conducted in the second season using Gas Chromatography-Mass Spectrometry instrument.

Total chlorophyll content:

According to Fadeels (1962), total chlorophyll was determined as mg/g fresh weight from leaf samples extracted using pure acetone.

Total carbohydrates content:

The anthrone reagent carbohydrate determination method described by Yemm and Willis (1954) was used. After homogenizing 0.5 g of dry herb powder in 10 ml of methanol (80%), it was centrifuged for ten minutes at 3000 rpm. The resulting supernatant was retained, and the same amount of solvent was utilized to re-extract the pellets. To remove the chlorophyll, the pooled supernatant was partitioned with an equivalent volume of petroleum ether in a separating funnel. Methanolic layer was used to evaluate total soluble sugars and 4 mL anthrone reagent was added to 1 ml of the aforementioned extract from the test tube's sidewalls and heated in a water bath for 10 minutes. The mixture was then allowed to cool to room temperature. One ml of a distilled water was used as a reference to prepare a blank. At a wavelength of 625 nm, the optical density was measured using a spectrophotometer.

Total NPK percentages:

Total nitrogen, phosphorus and potassium percentages (N, P, K %) were determined according to Black *et al.* (1965), Jackson (1973) and Cottenie *et al.* (1982), respectively.

Antimicrobial activity:

The antimicrobial activity of geranium volatile oil was studied for the second season on the two cuts with four samples to compare the control of both cuts with the recommended interaction dose treatment, which that divided as follows:

A: control of 1st cut.

B: control of 2nd cut.

C: GA_3 at 200 ppm x LRE aqu. at 10 g/l of 1st cut.

D: GA_3 at 200 ppm x LRE aqu. at 10 g/l of 2nd cut.

Test bacteria:

Clinical isolates of Gram-positive bacteria (*Staphylococcus aureus*, *Bacillus cereus*, and *Listeria monocytogenes*) and Gram negative bacteria (*Escherichia coli*, *Salmonella typhi*, and *Shigella boydii*) were propagated in a nutrient broth at 37 °C for 24 h before being tested for antibacterial activity but tested isolates for antifungal activity were *Aspergillus niger* and *Candida albicans* which were cultivated in potato dextrose broth for 48 hours at 28 °C. To determine the antimicrobial activity of the test substances, the diameters of the zone of inhibition in millimeters was measured using a modified Kirby-Bauer disc diffusion method (Narayanankutty *et al*., 2021a; Narayanankutty *et al.*, 2021b). Filter discs soaked with 10 > l of sterilized water served as a negative control for antimicrobial activity, while standard discs of Gentamycin (antibacterial agent) and *Nystatin (antifungal agent)* served as positive controls.

Statistical analysis:

The collected data during the two seasons were statistically analyzed using the MSTAT-C (1986) according to Mead *et al*. (1993), the least significant differences (L.S.D.) test was used to compare means at a 5% level of probability.

RESULTS

Growth and yield parameters:

It appears from the presented tabulated data in Tables (2 and 3) that the three GA_3 treatments had considerable and significant impacts on plant height, number of branches/ plant and herb fresh weight per plant and per feddan compared to control plants in both seasons and two cuts. In this concern, gibberellic acid at the high concentration (300 ppm) produced the highest values for the above mentioned parameters followed by the moderate concentration (200 ppm) without significant differences in between, then the low concentration (100 ppm). These three treatments increased the growth and yield parameters over those of untreated check plants, for plant height in the first season by 26.55, 24.47 and 10.32% for the first cut and by 25.46, 24.01 and 10.18% for the second cut, while in the second season those reached 27.19, 27.44 and 10.98% for the first cut, and 21.12, 19.04 and 13.63% for the second cut over the control successively. The increment of number of branches due to the abovementioned treatments over those of control plants in for the first cut reached 58.47, 47.43 and 18.78% and for the second cut reached 41.35, 42.02 and 11.46% in the first season, respectively.

However, in the second season reached 48.09, 38.31 and 15.10% for the first cut and 49.95, 43.64 and 24.36% for the second cut, successively. Numerically, the increase in yield per plant due to the three gibberellic acid treatments (300, 200 and 100 ppm), over that of control treatment came to 40.98, 38.86 and 23.58% for the first cut and 45.13, 35.52 and 17.27% for the second cut respectively in the first season and 47.65, 43.93 and 18.68% for the first cut and 47.44, 46.40 and 28.23% for the second cut successively in the second season. Yield per feddan recorded, a descending order of 14.86, 14.83, 13.09 and 10.57 ton for the three gibberellic acid treatments and control in the first cut and 15.49, 15.26, 12.27 and 10.20 ton in the second cut, respectively, in both seasons. The corresponding yield values for the same respective treatments were 13.91, 13.25, 11.54 and 9.83% for the first cut and 14.30, 13.84, 12.01 and 9.38 for the second cut, successively, in the second season.

Data presented in Tables (2 and 3) declared that liquorice root extract (LRE) treatments resulted in significant increases in plant height, number of branches/plant and herb fresh weight per plant and per feddan over those of untreated plants in both seasons and two cuts, except for aqueous liquorice extract at 5 g/l for all above mentioned characters. Among LRE treatments, the plants which received aqueous and ethanolic liquorice root extract at 10 g/l gave considerably the best values of growth and yield parameters in the two growing seasons and two cuts. Numerically, the above mentioned two treatments increased plant height by 9.62 and 5.25% in the first cut and by 10.41 and 6.29% in the second cut respectively, in the first season and for second season by 10.00 and 5.85% for the first cut and by 10.33 and 7.85% for the second cut, successively, over the control plants. Such two superior treatments recorded 14.59 and 14.01 for 1st cut and 25.68 and 24.52 for 2nd cut for number of branches/plant in the first season, respectively, and 16.94 and 16.22 for 1st cut and 28.28 and 26.84 for 2nd cut in the second one. For yield per plant and per feddan the same trends were observed.

Statistical analysis declared the existence of significant differences for the interaction between gibberellic acid and liquorice root extract treatments, in both seasons for the two cuts, for growth and yield parameters (plant height, number of branches/plant and

Table 2. Influence of gibberellic acid (GA_3) and liquorice root extract (LRE) on plant height (cm) and number of branches/plant for two cuts of geranium plants during 2019/2020 and 2020/2021 seasons.

Liquorice roots extract (LRE) g/l	Gibberellic acid (GA_3)									
	Control (zero)	GA_3 100 ppm	GA_3 200 ppm	GA_3 300 ppm	Mean (LRE)	Control (zero)	GA_3 100 ppm	GA_3 200 ppm	GA_3 300 ppm	Mean (LRE)
	First season: 2019/2020					Second season: 2020/2021				
Plant height (cm)										
1st Cut										
Control	50.12	54.33	62.45	63.11	57.50	51.27	55.96	64.48	64.67	59.10
LRE eth.5	51.63	56.28	64.75	65.25	59.48	52.67	57.04	67.34	66.56	60.90
LRE eth.10	51.88	59.25	64.12	66.84	60.52	52.92	60.75	67.68	68.88	62.56
LRE aqu.5	53.48	56.67	65.88	66.67	60.68	54.33	58.37	68.22	68.54	62.37
LRE aqu.10	54.05	61.55	67.85	68.65	63.03	55.05	63.40	71.56	70.02	65.01
Mean (GA_3)	52.23	57.62	65.01	66.10		53.25	59.10	67.86	67.73	
L.S.D. 5%	GA: 3.12		LRE: 2.37	GA×LRE: 4.74		GA: 3.47		LRE: 2.48	GA×LRE: 4.96	
2nd Cut										
Control	53.85	58.42	66.41	67.52	61.55	55.82	65.20	67.74	69.17	64.48
LRE eth.5	55.36	59.55	69.36	69.49	63.44	59.38	67.60	69.03	71.54	66.89
LRE eth.10	56.62	63.42	69.71	71.91	65.42	61.51	68.94	73.67	74.02	69.54
LRE aqu.5	57.10	62.94	70.27	71.56	65.47	59.79	68.78	72.54	73.97	68.77
LRE aqu.10	58.86	66.19	73.71	73.10	67.96	63.94	70.84	74.63	75.16	71.14
Mean (GA_3)	56.36	62.10	69.89	70.71		60.08	68.27	71.52	72.77	
L.S.D. 5%	GA: 4.15		LRE: 2.08	GA×LRE: 4.16		GA: 4.85		LRE: 3.17	GA×LRE: 6.34	
Number of branches/plant										
1st Cut										
Control	9.33	11.53	14.05	15.22	12.53	11.61	13.61	16.15	17.63	14.75
LRE eth.5	9.88	11.71	14.33	15.64	12.89	12.29	13.82	16.59	17.91	15.15
LRE eth.10	10.75	12.37	15.88	17.05	14.01	13.37	14.60	18.05	18.85	16.22
LRE aqu.5	10.42	12.45	15.75	16.25	13.72	12.48	14.69	17.45	18.56	15.80
LRE aqu.10	11.25	13.28	16.15	17.67	14.59	13.15	15.67	18.75	20.19	16.94
Mean (GA_3)	10.33	12.27	15.23	16.37		12.58	14.48	17.40	18.63	
L.S.D. 5%	GA: 1.25		LRE 0.84	GA×LRE: 1.68		GA: 1.44		LRE: 0.68	GA×LRE: 1.34	
2nd Cut										
Control	17.88	20.01	25.36	25.92	22.29	18.19	23.64	27.15	27.94	24.23
LRE eth.5	18.93	20.54	26.43	26.33	23.06	19.27	24.01	27.84	29.78	25.22
LRE eth.10	20.59	21.46	28.34	27.71	24.52	20.96	25.59	30.01	30.79	26.84
LRE aqu.5	19.22	22.59	27.97	27.28	24.27	20.32	25.52	29.78	31.25	26.72
LRE aqu.10	20.25	23.35	29.44	29.68	25.68	22.67	27.34	30.85	32.28	28.28
Mean (GA_3)	19.37	21.59	27.51	27.38		20.28	25.22	29.13	30.41	
L.S.D. 5%	GA: 1.48		LRE: 0.93	GA×LRE: 1.86		GA: 1.73		LRE: 1.18	GA×LRE: 2.36	

LRE eth.5: Liquorice root extract, ethanol at 5 g/l; LRE eth. 10: Liquorice root extract, ethanol at 10 g/l
LRE aqu.5: Liquorice root extract, aqueous at 5 g/l; LRE aqu.10: Liquorice root extract, aqueous at 10 g/l

Table 3. Influence of gibberellic acid (GA_3) and liquorice root extract (LRE) on fresh weight per plant and feddan for two cuts of geranium plants during 2019/2020 and 2020/2021 seasons.

Liquorice roots extract (LRE) g/l	Gibberellic acid (GA_3)									
	Control (zero)	GA_3 100 ppm	GA_3 200 ppm	GA_3 300 ppm	Mean (LRE)	Control (zero)	GA_3 100 ppm	GA_3 200 ppm	GA_3 300 ppm	Mean (LRE)
	First season: 2019/2020					Second season: 2020/2021				
	Fresh weight/plant (g)									
	1st Cut									
Control	520.2	705.5	795.1	814.3	708.8	494.7	656.3	814.1	842.1	701.8
LRE eth.5	567.4	733.3	818.2	825.5	736.1	539.8	688.2	838.6	854.0	730.2
LRE eth.10	645.6	785.1	866.4	885.3	795.6	613.8	722.6	887.3	916.6	785.1
LRE aqu.5	617.5	743.2	875.6	867.1	775.9	626.1	746.3	896.4	897.2	791.5
LRE aqu.10	715.2	822.1	902.3	930.4	842.5	755.2	782.1	924.2	963.1	856.2
Mean (GA_3)	613.2	757.8	851.5	864.5		605.9	719.1	872.1	894.6	
L.S.D. 5%	GA: 83.1		LRE: 78.3		GA×LRE:156.6	GA: 74.5		LRE: 69.2		GA×LRE: 138.4
	2nd Cut									
Control	466.2	604.6	724.7	775.3	642.7	458.1	649.4	739.0	749.7	649.1
LRE eth.5	507.3	633.5	746.5	786.4	668.4	497.5	674.3	761.4	759.8	673.3
LRE eth.10	576.2	674.8	779.3	843.6	718.5	566.3	722.1	805.2	814.3	727.0
LRE aqu.5	588.8	686.4	754.1	825.2	713.6	559.4	684.1	835.7	838.1	729.3
LRE aqu.10	672.6	697.1	805.1	849.3	756.0	637.9	756.7	839.3	847.1	770.3
Mean (GA_3)	562.2	659.3	761.9	815.9		543.8	697.3	796.1	801.8	
L.S.D. 5%	GA: 57.3		LRE: 65.2		GA×LRE: 130.4	GA: 44.9		LRE: 52.35		GA×LRE: 104.7
	Fresh weight/feddan (ton)									
	1st Cut									
Control	9.09	12.18	13.78	13.90	12.24	8.56	11.15	14.37	14.63	12.18
LRE eth.5	9.84	12.66	14.18	14.09	12.69	9.43	11.87	14.70	15.04	12.76
LRE eth.10	11.27	13.75	15.37	15.12	13.88	10.66	12.75	15.61	15.77	13.70
LRE aqu.5	11.08	12.68	15.28	15.40	13.61	10.77	12.27	15.46	15.62	13.53
LRE aqu.10	11.55	14.18	15.54	15.81	14.27	11.58	13.30	16.14	16.36	14.35
Mean (GA_3)	10.57	13.09	14.83	14.86		10.20	12.27	15.26	15.49	
L.S.D. 5%	GA: 1.03		LRE: 0.58		GA×LRE: 1.16	GA: 1.15		LRE: 0.77		GA×LRE: 1.54
	2nd Cut									
Control	8.14	10.43	12.55	13.23	11.09	7.94	11.03	13.05	14.01	11.51
LRE eth.5	8.79	10.93	12.93	13.42	11.52	8.70	11.63	13.35	14.15	11.96
LRE eth.10	10.07	12.47	13.51	14.39	12.61	9.84	12.75	14.18	14.41	12.80
LRE aqu.5	10.33	11.84	12.99	14.03	12.30	9.61	11.81	14.20	14.29	12.48
LRE aqu.10	11.80	12.03	14.26	14.47	13.14	10.83	12.86	14.45	14.62	13.19
Mean (GA_3)	9.83	11.54	13.25	13.91		9.38	12.01	13.84	14.30	
L.S.D. 5%	GA: 0.93		LRE: 0.81		GA×LRE: 1.62	GA: 0.79		LRE: 0.65		GA×LRE: 1.30

LRE eth.5: Liquorice root extract, ethanol at 5 g/l; LRE eth. 10: Liquorice root extract, ethanol at 10 g/l
LRE aqu.5: Liquorice root extract, aqueous at 5 g/l; LRE aqu.10: Liquorice root extract, aqueous at 10 g/l

herb fresh weight per plant and per feddan). GA_3 at 200 or 300 ppm in conjunction with aqueous LRE at 10 g/l were the most effective interaction treatments that produced the highest values as shown in Tables (2 and 3).

Volatile oil productivity:

Obtained data in Tables (4 and 5) show that the three gibberellic acid (GA_3) treatments, (100, 200 and 300 ppm) caused noticeable and great increase in geranium volatile oil percent and yield per plant and per feddan in the two cuts, over those of untreated plants (control). The three essential oil parameters were gradually increased, in an ascending order, due to foliar spray of GA_3 at 100, 200 and 300 ppm. Volatile oil percentage was significantly augmented due to foliar spraying of GA_3 at 200 and 300 ppm concentrations treatments in comparison with that of (control) untreated geranium plants, as indicated in Table (4). The highest values of oil % were produced due to the application of GA_3 at 300 ppm then 200 ppm and without significance between them in the two seasons and two cuts. Presented data in Table (5) indicated that essential oil yield per plant and per feddan were significantly increased, in both seasons and the two cuts, as a result of supplying geranium plants with any one of the tested gibberellic acid treatments.

The highest values, in a descending order, were given by GA_3 at 300, 200 and 100 ppm. The numerical increase in oil yield per feddan for such three sprayed treatments, in comparison with that of non-sprayed treatment reached in the first season 66.9, 63.2 and 27.6% for 1st cut and 78.2, 67.7 and 32% respectively in the 2nd cut. The corresponding increase, due to the same respective treatment, came to 81.5, 73.3 and 31.5% for 1st cut and 86.8, 83.4 and 40% for 2nd cut, in the second season.

Table 4. Influence of gibberellic acid (GA_3) and liquorice root extract (LRE) on oil percentage for two cuts of geranium plants during 2019/2020 and 2020/2021 seasons.

Liquorice roots extract (LRE) g/l	Gibberellic acid (GA_3)									
	Control (zero)	GA_3 100 ppm	GA_3 200 ppm	GA_3 300 ppm	Mean (LRE)	Control (zero)	GA_3 100 ppm	GA_3 200 ppm	GA_3 300 ppm	Mean (LRE)
	First season: 2019/2020					Second season: 2020/2021				
					Oil %					
					1st Cut					
Control	0.132	0.142	0.156	0.166	0.149	0.135	0.139	0.159	0.170	0.151
LRE eth.5	0.138	0.148	0.161	0.172	0.155	0.141	0.145	0.166	0.174	0.156
LRE eth.10	0.145	0.156	0.168	0.174	0.161	0.148	0.157	0.171	0.176	0.163
LRE aqu.5	0.144	0.155	0.166	0.171	0.159	0.147	0.152	0.169	0.173	0.160
LRE aqu.10	0.148	0.158	0.174	0.175	0.164	0.151	0.158	0.177	0.177	0.166
Mean (GA_3)	0.141	0.152	0.165	0.172		0.144	0.150	0.168	0.174	
L.S.D. 5%	GA: 0.015		LRE: 0.012	GA×LRE: 0.024		GA: 0.018		LRE: 0.011	GA×LRE: 0.022	
					2nd Cut					
Control	0.104	0.116	0.133	0.134	0.122	0.101	0.113	0.129	0.138	0.120
LRE eth.5	0.109	0.121	0.137	0.139	0.127	0.105	0.116	0.138	0.141	0.125
LRE eth.10	0.115	0.129	0.143	0.145	0.133	0.110	0.126	0.143	0.146	0.131
LRE aqu.5	0.114	0.125	0.141	0.144	0.131	0.106	0.122	0.139	0.145	0.128
LRE aqu.10	0.119	0.135	0.148	0.149	0.138	0.115	0.127	0.146	0.147	0.134
Mean (GA_3)	0.112	0.125	0.140	0.142		0.108	0.121	0.139	0.143	
L.S.D. 5%	GA: 0.011		LRE: 0.009	GA×LRE: 0.018		GA: 0.014		LRE: 0.010	GA×LRE: 0.020	

LRE eth.5: Liquorice root extract, ethanol at 5 g/l; LRE eth. 10: Liquorice root extract, ethanol at 10 g/l
LRE aqu.5: Liquorice root extract, aqueous at 5 g/l; LRE aqu.10: Liquorice root extract, aqueous at 10 g/l

Table 5. Influence of gibberellic acid (GA_3) and liquorice root extract (LRE) on volatile oil per plant (ml) and per feddan (l) for two cuts of geranium plants during 2019/2020 and 2020/2021 seasons.

Liquorice roots extract (LRE) g/l	Gibberellic acid (GA_3)									
	Control (zero)	GA_3 100 ppm	GA_3 200 ppm	GA_3 300 ppm	Mean (LRE)	Control (zero)	GA_3 100 ppm	GA_3 200 ppm	GA_3 300 ppm	Mean (LRE)
	First season: 2019/2020					Second season: 2020/2021				
	Volatile oil/plant (ml)									
	1st Cut									
Control	0.699	1.009	1.268	1.367	1.086	0.678	0.920	1.321	1.447	1.092
LRE eth.5	0.797	1.093	1.346	1.435	1.168	0.773	1.006	1.423	1.501	1.176
LRE eth.10	0.913	1.234	1.488	1.557	1.298	0.885	1.143	1.551	1.630	1.302
LRE aqu.5	0.867	1.161	1.485	1.499	1.253	0.897	1.142	1.548	1.568	1.289
LRE aqu.10	1.032	1.309	1.605	1.646	1.398	1.124	1.245	1.673	1.723	1.441
Mean (GA_3)	0.861	1.161	1.438	1.501		0.871	1.091	1.503	1.574	
L.S.D. 5%	GA: 0.173		LRE: 0.134	GA×LRE: 0.268		GA: 0.188		LRE:0.168	GA×LRE: 0.336	
	2nd Cut									
Control	0.486	0.713	0.961	1.042	0.801	0.487	0.750	0.998	1.032	0.817
LRE eth.5	0.553	0.778	1.022	1.096	0.862	0.553	0.812	1.074	1.070	0.877
LRE eth.10	0.660	0.874	1.113	1.189	0.959	0.662	0.941	1.171	1.203	0.994
LRE aqu.5	0.670	0.883	1.064	1.143	0.940	0.649	0.862	1.200	1.232	0.986
LRE aqu.10	0.786	0.914	1.191	1.174	1.016	0.761	0.992	1.264	1.274	1.073
Mean (GA_3)	0.631	0.832	1.070	1.129		0.622	0.872	1.141	1.162	
L.S.D. 5%	GA: 0.130		B: 0.114	GA×LRE: 0.228		GA: 0.092		LRE: 0.128	GA×LRE:0.256	
	Volatile oil yield/ feddan (l)									
	1st Cut									
Control	12.23	16.95	21.88	23.08	18.53	11.24	15.89	22.14	24.13	18.35
LRE eth.5	13.85	18.37	23.23	24.23	19.92	12.94	17.64	23.67	25.36	19.90
LRE eth.10	16.67	21.02	26.29	26.30	22.57	15.38	20.50	25.89	26.92	22.17
LRE aqu.5	16.28	19.25	25.82	26.33	21.92	15.42	19.09	25.34	26.19	21.51
LRE aqu.10	17.43	21.96	27.53	27.67	23.65	17.04	21.52	27.74	28.08	23.59
Mean (GA_3)	15.29	19.51	24.95	25.52		14.40	18.93	24.96	26.14	
L.S.D. 5%	GA: 2.16		LRE:2.56	GA×LRE: 5.12		GA: 2.31		LRE: 2.86	GA×LRE: 5.72	
	2nd Cut									
Control	8.51	12.47	16.82	18.24	14.01	8.53	13.13	17.46	18.07	14.29
LRE eth.5	9.68	13.62	17.88	19.17	15.09	9.68	14.21	18.80	18.73	15.35
LRE eth.10	11.55	15.29	19.47	20.81	16.78	11.58	16.47	20.48	21.06	17.40
LRE aqu.5	11.72	15.45	18.62	20.02	16.45	11.36	15.09	21.01	21.55	17.25
LRE aqu.10	13.76	16.00	20.84	20.55	17.79	13.31	17.37	22.11	22.29	18.77
Mean (GA_3)	11.04	14.57	18.73	19.76		10.89	15.25	19.97	20.34	
L.S.D. 5%	GA: 1.75		LRE: 1.66	GA×LRE: 3.32		GA: 2.11		LRE: 1.82	GA×LRE: 3.64	

LRE eth.5: Liquorice root extract, ethanol at 5 g/l; LRE eth. 10: Liquorice root extract, ethanol at 10 g/l
LRE aqu.5: Liquorice root extract, aqueous at 5 g/l; LRE aqu.10: Liquorice root extract, aqueous at 10 g/l

Concerning liquorice root extract (LRE) treatments, the four used ones, ethanolic liquorice root extract (LRE eth.) at 5 and 10 g/l and aqueous liquorice root extract (LRE aqu.) at 5 and 10 g/l) treatments caused an increase in volatile oil percent and yield per plant and per fed, in both seasons and two cuts, over those of control plants as shown in Tables (4 and 5). The differences were significant for all volatile oil parameters of geranium plants by liquorice root extract applications except for the lowest dose of ethanolic extract at 5 g/l. The highest values being given by the aqueous liquorice root extract treatment at 10 g/l (LRE aqu.) followed by ethanolic liquorice root extract at 10 g/l (LRE eth.), while LRE aqu at 5 g/l, gave the significantly least values. The high dose of (LRE aqu. and LRE eth. 10 g/l) treatments increased volatile oil yield/fed in the first season by 27.6 and 21.8% in the first cut, and by 27.0 and 19.8% in the second cut respectively, also in the second season 28.6 and 20.8% in the first cut, and by 31.4 and 21.8% in the second cut, in comparison with those of control plants, as shown in Table (5).

The interaction between gibberellic acid and liquorice root extract treatments was significant, in both seasons, for the three geranium volatile oil parameters, percent and yield per plant and per fed, as clearly shown in Tables (4 and 5). The highest overall value for the three parameters was obtained when geranium plants were sprayed with the high dose of GA_3 at 300 ppm in combination with aqueous LRE at 10 g/l treatment. However, from the practical, economical and environmental point of view, non-significant differences were existed, in both seasons for the three essential oil parameters, between solely GA_3 at 300 ppm treatment and that GA_3 at 200 ppm treatment as illustrated in Table (4 and 5).

It is interesting to note, that higher volatile oil % and oil yield per plant and/ feddan were obtained in the first cut (May) in comparison with the second cut (November) in the two seasons. Therefore economically, many of geranium producers in the Beni-Suef Governorate resorted to cultivating it to obtain only one cut in May, and exploitation of the land and water for cultivating other summer crops.

Total chlorophyll and carbohydrates:

Data recorded in Table (6) show the response of photosynthetic pigments (total chlorophyll) in the fresh leaves and total carbohydrates% in the dry leaves of *Pelargonium graveolens* plants to the tested foliar gibberellic acid and application of two extraction of liquorice root, as well as, their interaction in the two experimental seasons. Obtained data in Table (6) proved that all foliar GA_3 applications, significantly enhanced total chlorophyll and carbohydrates in the leaves of geranium plants compared with untreated plants in the two seasons and two cuts, and no significant differences were detected between the medium level of GA_3 (200 ppm) and high (300 ppm) concentrations. The increase of total chlorophyll due to GA_3 at 100, 200 and 300 ppm in the 1st season reached 10.8, 31.0 and 40.9% respectively in the first cut and 17.1, 37.6 and 45.5% in the second cut over that of control treatment, in the 2nd season reached13.5, 35.1 and 47.4% in the first cut and 14.3, 31.4 and 36.2% in the second one.

A significant and positive influence of liquorice root extract treatments on total chlorophyll and carbohydrates were recorded in the present study. Only the low concentration of ethanolic liquorice root extract (LRE eth. at 5 g/l) had no significant effect. The gradual increase of aqueous or ethanol liquorice extracts led to a gradual increment in total chlorophyll and carbohydrates in both growing seasons and both cuts (Table, 6). The highest content of total chlorophyll and carbohydrates were produced from spraying geranium plants with LRE aqu. at 10 g/l followed by LRE eth. at 10 g/l then LRE aqu. at 5 g/l. These three treatments augmented total carbohydrates over that of check treatment by 13.3, 7.8 and 6.1% (1st cut) and 14.0, 8.5 and 5.3% (2nd cut) in the first season and by

Table 6. Influence of gibberellic acid (GA_3) and liquorice root extract (LRE) on total chlorophyll and total carbohydrates % for two cuts of geranium plants during 2019/2020 and 2020/2021 seasons.

Liquorice roots extract (LRE) g/l	Gibberellic acid (GA_3)									
	Control (zero)	GA_3 100 ppm	GA_3 200 ppm	GA_3 300 ppm	Mean (LRE)	Control (zero)	GA_3 100 ppm	GA_3 200 ppm	GA_3 300 ppm	Mean (LRE)
	First season: 2019/2020					Second season: 2020/2021				
Total chlorophyll (mg/g F.W.)										
1st Cut										
Control	0.753	0.844	0.945	1.036	0.894	0.731	0.774	0.975	1.053	0.883
LRE eth.5	0.769	0.852	0.976	1.076	0.918	0.758	0.855	0.992	1.085	0.922
LRE eth.10	0.792	0.886	1.072	1.146	0.974	0.773	0.885	1.033	1.157	0.962
LRE aqu.5	0.774	0.867	0.984	1.112	0.934	0.766	0.872	1.013	1.132	0.946
LRE aqu.10	0.845	0.910	1.179	1.173	1.027	0.778	0.933	1.125	1.186	1.006
Mean (GA_3)	0.787	0.872	1.031	1.109		0.761	0.864	1.028	1.122	
L.S.D. 5%	GA: 0.082		LRE: 0.048		GA×LRE:0.096	GA: 0.097		LRE: 0.042		GA×LRE: 0.084
2nd Cut										
Control	0.685	0.767	0.914	0.922	0.822	0.703	0.761	0.886	0.915	0.816
LRE eth.5	0.716	0.843	0.938	0.963	0.865	0.727	0.849	0.894	0.981	0.863
LRE eth.10	0.730	0.869	0.988	1.114	0.926	0.749	0.866	0.968	0.995	0.894
LRE aqu.5	0.701	0.851	0.949	1.056	0.889	0.709	0.837	0.921	0.942	0.852
LRE aqu.10	0.760	0.877	1.157	1.175	0.993	0.776	0.875	1.145	1.155	0.988
Mean (GA_3)	0.719	0.842	0.989	1.046		0.733	0.838	0.963	0.998	
L.S.D. 5%	GA: 0.092		LRE: 0.065		GA×LRE: 0.130	GA: 0.085		LRE: 0.072		GA×LRE: 0.144
Total carbohydrates %										
1st Cut										
Control	12.85	14.33	17.28	18.85	15.83	13.70	15.11	18.19	19.06	16.51
LRE eth.5	13.22	15.67	17.65	19.35	16.47	14.16	16.21	19.06	19.56	17.25
LRE eth.10	13.95	16.15	18.25	19.88	17.06	14.62	17.98	19.76	20.55	18.23
LRE aqu.5	13.66	15.33	18.05	20.16	16.80	13.83	17.42	19.25	20.33	17.71
LRE aqu.10	14.15	17.05	19.42	21.08	17.93	14.94	19.23	20.76	21.41	19.09
Mean (GA_3)	13.57	15.71	18.13	19.86		14.25	17.19	19.41	20.18	
L.S.D. 5%	GA: 1.92		LRE: 0.85		GA×LRE: 1.70	GA: 1.77		LRE: 0.79		GA×LRE: 1.58
2nd Cut										
Control	14.92	18.38	18.77	19.33	17.85	13.65	17.92	19.49	19.90	17.74
LRE eth.5	16.26	18.67	19.07	19.64	18.41	15.37	18.02	19.60	20.22	18.30
LRE eth.10	16.39	19.81	20.45	20.85	19.37	15.62	18.93	19.84	21.46	18.96
LRE aqu.5	15.94	19.45	19.62	20.20	18.80	14.58	18.77	19.93	20.80	18.52
LRE aqu.10	18.46	20.34	20.99	21.61	20.35	17.81	19.63	21.68	22.05	20.29
Mean (GA_3)	16.39	19.33	19.78	20.33		15.41	18.65	20.11	20.89	
L.S.D. 5%	GA: 1.64		LRE: 0.77		GA×LRE: 1.54	GA: 1.55		LRE: 1.06		GA×LRE: 2.12

LRE eth.5: Liquorice root extract, ethanol at 5 g/l; LRE eth. 10: Liquorice root extract, ethanol at 10 g/l
LRE aqu.5: Liquorice root extract, aqueous at 5 g/l; LRE aqu.10: Liquorice root extract, aqueous at 10 g/l

15.6, 10.4 and 7.3% (1st cut) and14.4, 6.9 and 4.4% (2nd cut) in the second season, respectively.

Total chlorophyll and carbohydrates of the leaves of geranium plants were significantly improved due to the interaction between gibberellic acid applications and liquorice extracts in the two growing seasons as shown in Table (6). The most positive interaction treatments which resulted in the highest total chlorophyll and carbohydrates were GA_3 at 200 or 300 ppm in combination with LRE aqu. at 10 g/l.

Total NPK percentages:

Obtained data in Table (7) show that the three gibberellic acid (GA_3) treatments, (100, 200 and 300 ppm) caused a noticeable and great increase in geranium total nitrogen, phosphorus and potassium percentage (NPK %) in the first cut for the two successive seasons, over those of untreated plants (control). The three NPK % were gradually increased, in an ascending order, due to foliar spray of GA_3 at 100, 200 and 300 ppm. The highest values of NPK % were produced due to the application of GA_3 at 300 ppm then 200 ppm and without significance between them in the two seasons.

The highest values, in a descending order, were given by GA_3 at 300, 200 and 100 ppm. The numerical increase in N, P and K % for such three sprayed treatments, in comparison with that of non-sprayed treatment reached in the first season (1st cut) 47.9, 41.7 and 14.7% for nitrogen in addition to 29.3, 24.3 and 13.9% for phosphorus and 25.5, 23.1 and 13.5% for potassium respectively. The corresponding increase, due to the same respective treatment, came

Table 7. Influence of gibberellic acid (GA_3) and liquorice root extract (LRE) on N, P and K % for the first cut (1st cut) of geranium plants during 2019/2020 and 2020/2021 seasons.

Liquorice roots extract (LRE) g/l	Gibberellic acid (GA_3)									
	Control (zero)	GA_3 100 ppm	GA_3 200 ppm	GA_3 300 ppm	Mean (LRE)	Control (zero)	GA_3 100 ppm	GA_3 200 ppm	GA_3 300 ppm	Mean (LRE)
	First season: 2019/2020					Second season: 2020/2021				
Nitrogen percentage (1st cut)										
Control	1.48	1.69	2.12	2.28	1.89	1.37	1.62	2.00	2.07	1.76
LRE eth.5	1.53	1.85	2.18	2.35	1.98	1.45	1.71	2.24	2.31	1.93
LRE eth.10	1.72	1.94	2.37	2.45	2.12	1.63	1.85	2.48	2.56	2.13
LRE aqu.5	1.67	1.89	2.34	2.37	2.07	1.53	1.78	2.41	2.48	2.05
LRE aqu.10	1.77	1.98	2.52	2.62	2.22	1.71	2.15	2.59	2.67	2.28
Mean (GA_3)	1.63	1.87	2.31	2.41		1.54	1.82	2.35	2.42	
L.S.D. 5%	GA: 0.19		LRE: 014	GA×LRE:0.28		GA: 0.18		LRE:0.11	GA×LRE: 0.22	
Phosphorus percentage (1st cut)										
Control	0.353	0.411	0.458	0.465	0.422	0.372	0.417	0.443	0.452	0.421
LRE eth.5	0.372	0.417	0.461	0.478	0.432	0.394	0.428	0.448	0.464	0.434
LRE eth.10	0.386	0.434	0.469	0.495	0.446	0.408	0.440	0.472	0.481	0.451
LRE aqu.5	0.364	0.427	0.468	0.482	0.435	0.398	0.435	0.457	0.473	0.441
LRE aqu.10	0.398	0.446	0.475	0.502	0.455	0.422	0.453	0.478	0.488	0.460
Mean (GA_3)	0.375	0.427	0.466	0.485		0.399	0.435	0.460	0.472	
L.S.D. 5%	GA:0.023		LRE:0.019	GA×LRE:0.038		GA:0.026		LRE:0.017	GA×LRE:0.034	
Potassium percentage (1st cut)										
Control	1.82	2.17	2.44	2.48	2.23	1.68	2.12	2.40	2.54	2.18
LRE eth.5	1.95	2.30	2.51	2.57	2.33	1.84	2.22	2.49	2.58	2.28
LRE eth.10	2.21	2.47	2.61	2.66	2.49	2.09	2.38	2.57	2.71	2.44
LRE aqu.5	2.14	2.34	2.58	2.63	2.42	1.96	2.26	2.59	2.61	2.35
LRE aqu.10	2.26	2.53	2.65	2.71	2.54	2.18	2.44	2.61	2.75	2.50
Mean (GA_3)	2.08	2.36	2.56	2.61		1.95	2.28	2.53	2.64	
L.S.D. 5%	GA: 0.15		LRE: 0.20	GA×LRE: 0.40		GA: 0.18		LRE: 0.22	GA×LRE: 0.44	

LRE eth.5: Liquorice root extract, ethanol at 5 g/l; LRE eth. 10: Liquorice root extract, ethanol at 10 g/l
LRE aqu.5: Liquorice root extract, aqueous at 5 g/l; LRE aqu.10: Liquorice root extract, aqueous at 10 g/l

to 57.1, 52.6 and 18.2% for N in addition to 18.2, 15.3 and 9% for P and 35.4, 29.7 and 19.9% for K, in the second season (1st cut), as illustrated in Table (7).

Concerning liquorice root extract (LRE) treatments, the four used ones, ethanolic liquorice root extract (LRE eth.) at 5, 10 (g/l) and aqueous liquorice root extract (LRE aqu.) at 5 and 10 g/l treatments caused an increase in total NPK percent, in both seasons in the first cut, over those of control plants as shown in Table (7). The differences were significant for all NPK percentages of geranium plants by liquorice root extract applications except for the lowest dose of ethanolic extract at 5 g/l. The highest values being given by the LRE aqu treatment at 10 g/l followed by LRE eth at 10 g/l, while LRE aqu at 5 g/l, gave the significantly least values. The significantly doses of aqueous LRE and ethanolic LRE at 10 g/l then LRE aqu. at 5 g/l treatments increased total NPK% in the first season by 17.5, 12.2 and 9.5% for N% in addition to 7.8, 5.7 and 3% for P% and 13.9, 11.7 and 8.5% for K% respectively in the 1st cut, also in the second season 29.5, 21.0 and 16.5% for N% in addition to 9.3, 7.1 and 4.8% for P% and 14.7, 11.9 and 7.8% in the same cut, in comparison with those of control plants.

Presented data in Table (7) indicated that total N, P and K % were significantly increased by the interaction between gibberellic acid treatments and liquorice root extract, in the 1st cut of both seasons. The highest overall value for the three parameters was obtained when geranium plants were sprayed with the high dose of GA_3 at 300 ppm in combination with aqueous LRE at 10 g/l treatment. However, from the practical, economical and environmental point of view, no significant differences were existed, in both seasons for the three NPK %, between solely GA_3 at 300 ppm treatment and that of GA_3 at 200 ppm treatment as illustrated in Table (7).

Volatile oil components:

Data listed in Table (8), showed the presence of 20 components in the volatile oil of geranium from two cuts in the 2nd season for some treatments such as 1st cut (control zero comparison with GA_3 200 ppm and LRE aqu. 10 g/l) and 2nd cut (control comparison with GA_3 200 ppm and LRE aqu. 10 g/l). Fig. (1), pointed out that the major components of geranium volatile oil were citronellol, geraniol, citronellyl formate, 10-epi-ç-eudesmol, L-linalool, l-menthone and rose oxide.

Antimicrobial activity:

The in depth use of antibiotics is commonly observed via way of means of the presence of resistant lines of microorganisms. The sight of the resistance of microorganism to drugs, the look for herbal compounds having antibacterial interest is a pressing call for to address the dangerous results of these pathogenic microorganisms. Accordingly, in this study four geranium oil samples had been examined in inhibition microorganism's Gram-positive B. *cereus*, *L. monocytogenes* and *S. aureus*, and Gram-negative microorganism *E. coli*, *S. boydii*, and *S. typhi* and fungal microorganisms *Aspergillus niger* and *Candida albicans*. The maximum antimicrobial interest via way of means of stopping the growth of the examined isolates in comparison with the opposite geranium oil samples "control 1st cut (A), control 2nd cut (B) and GA_3 200 ppm x LRE aqu.10 g/l, 2nd cut (D)". The most powerful antimicrobial activity of the sample "1st cut (GA_3 200 ppm × LRE aqu. 10 g/l)" (C) has recorded opposition to *S. boydii* pressure with inhibition sector of 30 mm, while the decrease sports had been in opposite to the *Candida albicans* and *S. typhi* lines with inhibition zone of 5 mm. The antimicrobial activities are recorded in Figs. (2 and 3).

DISCUSSION

Medicinal plants are important sources of various bioactive compounds and also the nutrient molecules for the well-being of various organisms (Narayanankutty, 2021 and Narayanankutty *et al*., 2021c). Plants are rich suppliers of various chemicals,

Table 8. Chemical constituent percentages of geranium volatile oil for some treatments of two cuts in the second season (2020/2021).

No.	Constituents	Control (1st cut)	GA_3 200 ppm & LRE aqu. 10 g/l (1st cut)	Control (2nd cut)	GA_3 200 ppm & LRE aqu. 10 g/l (2nd cut)
1.	Citronellol	39.11	42.09	29.15	33.35
2.	Citronellyl formate	9.02	10.41	8.77	10.32
3.	10-epi-ç-eudesmol	8.65	9.43	11.05	13.35
4.	Geraniol	7.55	6.32	14.67	17.42
5.	L-linalool	5.68	7.87	3.66	2.82
6.	l-menthone	7.15	7.44	4.65	5.90
7.	Rose oxide	1.95	1.93	0.39	0.47
8.	à bourbonene	0.56	0.49	0.38	0.45
9.	à-citral	0.18	0.27	0.36	0.44
10.	à-pinene	0.33	0.38	0.17	0.22
11.	Aristolenepoxide	0.54	0.75	0.28	0.41
12.	Aromadendrene	0.41	0.34	0.01	0.11
13.	ë-cadinene	0.37	0.41	0.31	0.26
14.	Eudesm-4(14)-en-11-ol	0.73	0.62	0.82	1.01
15.	Geranyl formate	0.53	0.61	4.02	3.19
16.	Germacrene-D	0.78	0.90	0.53	0.46
17.	Cadina-1,3,5-triene	0.21	0.26	0.16	0.23
18.	Caryophyllene	0.38	0.57	0.29	0.36
19.	Cis-rose oxide	0.56	0.59	0.13	0.20
20.	(-)-aristolene	0.48	0.54	0.43	0.62

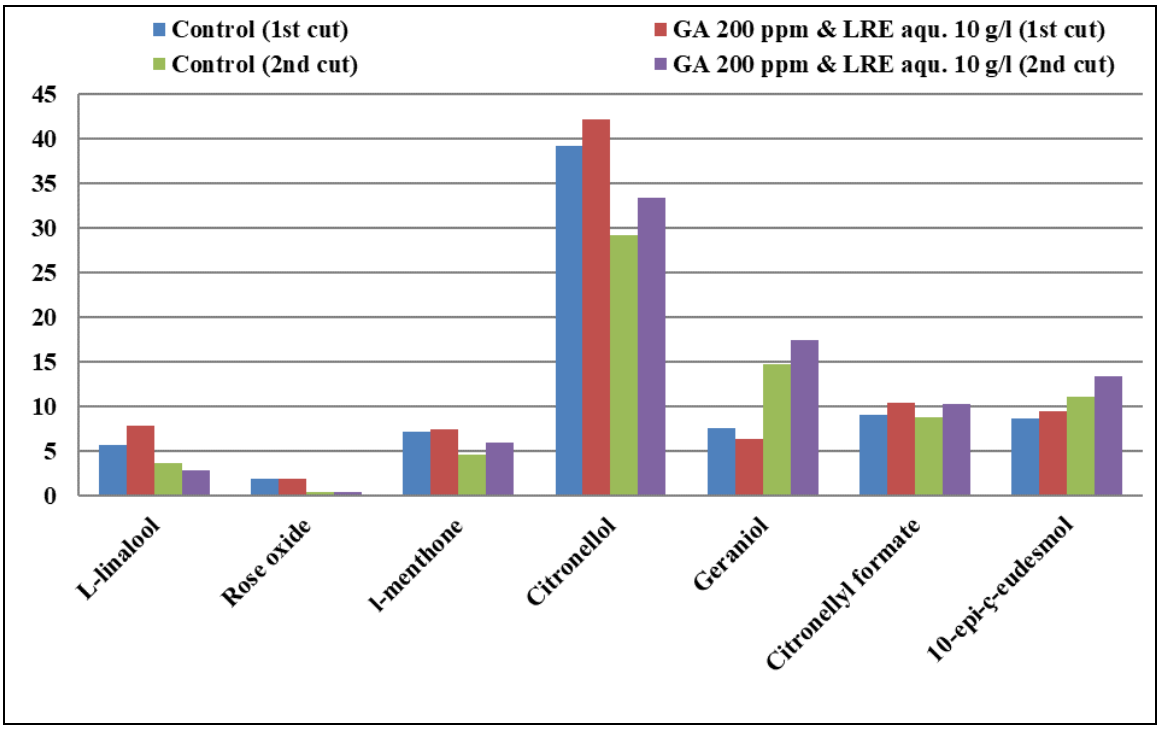

Fig. 1. The major components of geranium volatile oil for some treatments of two cuts in the second season (2020/2021).

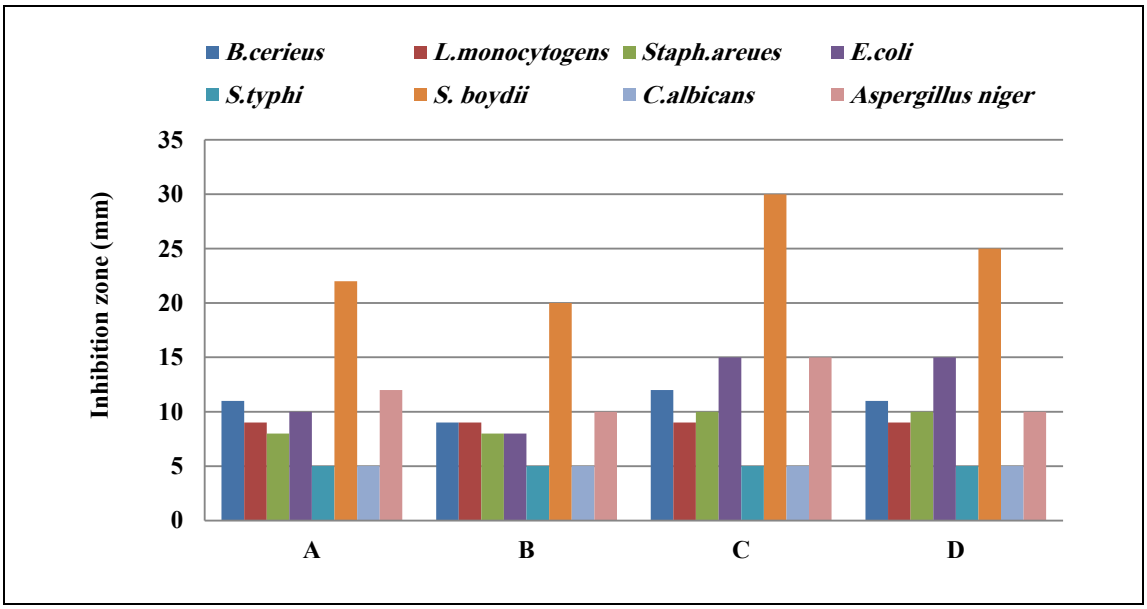

Fig. 2. The inhibition zone (mm) of the different oil samples against different pathogenic microorganisms.

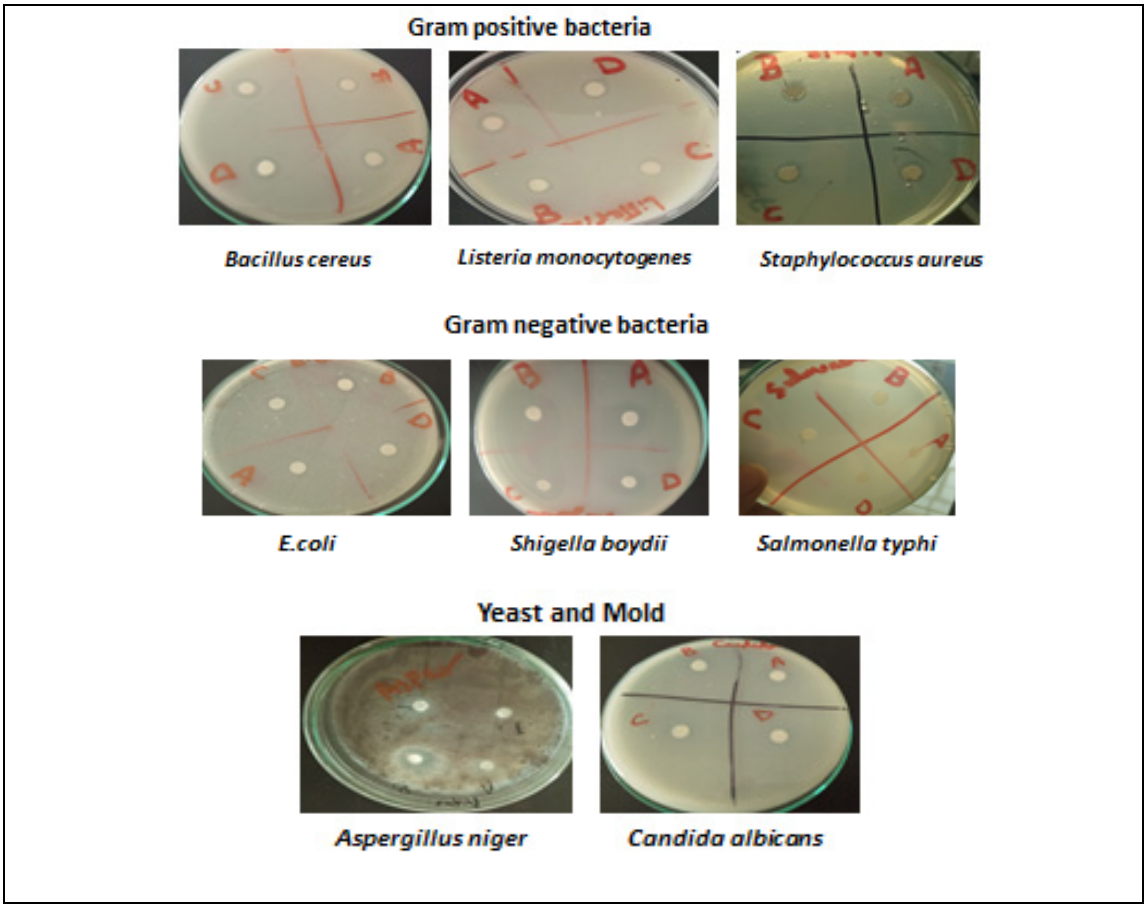

Fig. 3. The inhibition zone (mm) of the different oil samples against different pathogenic microorganisms. Samples (A) control (water) 1st cut; (B) control (water) 2nd cut; (C) 1st cut (GA_3 200 ppm × LRE aqu. 10 g/l) and (D) 2nd cut (GA_3 200 ppm × LRE aqu.10 g/l).

including phenols, flavonoids, alkaloids, phenolic acids, tannins, saponins, anthocyanins, lignans, carbohydrates, carotenoids, and isoflavones, according to a previous study (Rasoulpour *et al*., 2020). Androutsopoulou *et al.,* 2021 suggested that essential oils and extracts of rose geranium (*Pelargonium graveolens*) and petals of rose (*Rosa damascena*) were completely characterized in phrases of composition, safety, antimicrobial, and antiviral properties. They had been analyzed in opposite to *Escherichia coli, Salmonella enterica serovar Typhimurium, Staphylococcus aureus* and *Aspergillus niger*.

Gibberellic acid is one of the most important endogenous or exogenous plant hormones or plant growth regulators (George *et al*., 2008). It is stimulating, noticeably diligent effect on the vegetative growth characteristics under investigation may be related to how it affects cell growth and division. The use of GA_3 as a plant regulator to promote cell division and cell elongation that favorably influence the characteristics of vegetative growth is well known. It has an impact on numerous mechanisms of plant growth, including stem elongation by promoting cell division and elongation, flowering, fruit development, and breaking dormancy (Neil and Reece, 2002). Previous studies have found that GA_3 has beneficial effects on growth and yield parameters, such as, plant height, number of branches/plant and herb fresh weight per plant and per feddan were declared by Sorour and El-Shanhorey (2016) on *Dracaena marginata*, Atteya and El Gendy (2018) on Tagetes, Abdel-Hamid (2020) on basil, Gabr *et al*. (2021) on globe artichoke and Ali *et al*. (2021) on sorghum. Additionally, GA_3's mode of action (positive influence) may also be attributed to an increase in auxin biosynthesis (Sastry and Muir, 1965), or by a decrease in IAA-oxidase activity, which slows down the breakdown of auxin, as suggested by Kogl and Elema (1960). Furthermore, due to gibberellin's impact on plant height, the interaction between the fresh and dry weights is likely to intensify.

Due to its mechanism of action, the GA_3 foliar spray enhanced the activation of the shoots growth while also subtly reducing the plants need for absorbed carbohydrates. The increment of plants fresh and dry weights as available carbohydrates are digested and allocated to the development of vegetative characters as shown by (Soliman *et al*., 2019). The efficiency of gibberellic acid in increasing the photosynthetic pigments contents and total carbohydrates over control treatments recorded in the present study was also detected by many researchers. Examples are Eid and Abou-Leila (2006) on croton, Mohamed (2011) on *Conocarpus erectus,* Zang *et al*., (2016) on blueberry, Atteya and El Gendy (2018) on Tagetes and Arefnezhad *et al*. (2021) on barberry plants. Davies (2013) asserts that the GA_3 mode of action affects the starch, fructan, and sucrose hydrolytic enzymes. The increased amount of carbohydrates in leaves may be attributable to gibberellic acid's role in improving photosynthesis (Chen and Cheng, 2004) by increasing total chlorophyll (Al-Rawi *et al*., 2016). According to Arteca (2013), the application of gibberellin raises the ultra-structural morphogenesis of plastids and enhances the number and size of chloroplasts, which in turn increases the chlorophyll concentrations in leaves. the greater chlorophyll content may be attributed to the increased assimilate and water synthesis and translocation by gibberellins and cytokinins (CPPU), which inhibit chlorophyll degradation in leaves (Ries *et al*., 1977), It might be because these growth regulators have some sort of anti-senescence property (Sekhar *et al*., 2018). The efficiency of photosynthetic processes typically rises as chlorophyll concentration does. GA_3 stimulates photosynthesis and plays a significant function in the chloroplast membrane (Janowska and Jerzy, 2003).

Gibberellic acid treatments applied via foliar application greatly enhanced the percentages of total nitrogen, phosphorus

and potassium in geraniums. The positive impact of gibberellic acid on the nutrient content of the leaves could be attributed the given that phytochrome effects chlorophyll, it is probable that this effect was caused by an interaction between gibberellin and phytochrome (Mathis *et al*., 1989). This discovery could also be described by the function of GA_3, which raises N content in leaves and helps produce chlorophyll molecules, along with some other nutrients (like Mg) that could indirectly enhance the feature of the supplied molecule. Furthermore, it may delay the loss of protein, RNA, and chlorophyll that results from the gradual oxidation of these substances and increasing composition, which would otherwise cause senescence (delay ageing) (Alwan, 2014). This result was comparable to the results achieved by Eid and Abou-Leila (2006) on croton, Shah *et al*. (2006) on black cumin, Atteya and El Gendy (2018) on Tagetes and Thuc *et al*. (2021) on black sesame.

Volatile oil productivity of geranium plants was significantly augmented due to foliar application of GA_3 at 200 and 300 ppm over those untreated plants. It might be because gibberellin effectively enhances plant performance and some vegetation features, which in turn positively reflects on volatile oil through the rejuvenation of the efficiency of the enzymes, particularly enzyme nitrate reductase and enhances photosynthesis (Shah, 2007). Li *et al*. (2007) and Hazzoumi *et al.* (2014) reported that monoterpenes of *Ocimum basilicum* and *O. gratissimum* are highly influenced by plant growth regulators treatments due to the genes regulation which cause an increase in enzyme numbers related to the metabolic pathways of these compounds. This regulation is due to the change in the enzyme catalytic of these reactions. The role of gibberellic acid in augmenting volatile oil parameters were reported by Almehemdi *et al*. (2011) on caraway, Amiri *et al*. (2011) and Elsayed *et al*. (2021) on chamomile, Abdel-Hamid (2020) on basil. In the current study, the highest citronellol content was obtained in 1st cut while the lowest contents were obtained in 2nd cut. However, the highest geraniol content was obtained in 2nd cut while the lowest values were obtained in 1st cut, the results existed in agreement with Abd El-Wahab, (2016) on geranium plant

All vegetative growth and yield characters (plant height, number of branches/plant and herb fresh weight per plant and per feddan), oil productivity (volatile oil percentage and yield per plant and per feddan), Total chlorophyll and carbohydrates and NPK % were positively increased due to use liquorice roots extract treatments comparing with control treatment, it may due to that liquorice root contains more than 100 various compounds, some of them accumulated in large amounts, most important of them are triterpene saponins (including glycyrrhizin), phenolic compounds, mevalonic acid, amino acid (asparagin), polysaccharide (glucose, fructose, sucrose, maltose) lignins, vitamins such as B1, B2, B3, B6, C and E, Biotin, folic acid and pantothenic acid which play an important role in improving the growth of the plants (Ross, 2001 and Arystanova *et al*., 2001). Glycyrrhizic acid is first synthesized from mevalonic acid which has similar effect to GA_3 in reducing complex compounds to simple ones utilized by plants to build new proteins necessary for growth (Babilie *et al*., 2015). In addition, magnesium (main element in liquorice) plays a role in increasing foliage growth, cell division, and biological plant activities (Moses *et al*., 2002). Liquorice root contains some macro nutrients and micro nutrients such as N, Cu, Zn, Mn, Mg (Morsi *et al*., 2008), Ca, K, Na (Al-Bachir *et al*., 2004) and it is very rich in Fe contents > 4000 µg/g (Ansari *et al*., 2004). For instance, N plays several roles in plant growth which is necessary for formation of amino acids, the building blocks of protein, essential for plant cell division, vital for plant growth, directly involved in photosynthesis, necessary component of vitamins, aids in production and use of carbohydrates and affects energy reactions in the plant. As for micro-elements

such as Cu, Zn, Mn and Mg in ethanol or water extract of liquorice contained these elements, for example, Mg plays a brisk role in the chlorophyll molecules and in many enzyme activities and is required for crops to capture the sun's energy for growth and production. While iron have very important role in many plant enzyme systems including the formation of chlorophyll (Barker and Pilbeam, 2006). In harmony with these findings concerning the promoting effect of liquorice extract on the above mentioned characters were those disclosed by Almehemdi *et al*. (2011) on caraway, Al-Mahdawe (2015) on calendula, El-Alakmy (2016) on *Mentha longifolia,* Abdallah *et al*. (2016) and Abd El-Azim, *et al*. (2017) on fennel, Rady *et al*., (2019) on bean, Massoud *et al*. (2019) on caraway, Salih *et al*. (2021) on myrtus and Abou El-Ghait *et al*. (2021) on *Trachyspermum ammi* plants.

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تأثير الرش بحمض الجبريليك ومستخلص جذور العرقسوس على النمو وإنتاجية محصول الزيت الطيار ومضادات الميكروبات في نباتات العتر البلدي

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تم تنفيذ هذا العمل خلال الموسمين المتتاليين (٢٠١٩/٢٠٢٠ و ٢٠٢٠/٢٠٢١) في المزرعة التجريبية بمحطة بحوث سدس، التابعة لمركز البحوث الزراعية، محافظة بني سويف، بهدف دراسة تأثير الرش الورقي لحمض الجبريليك (GA_3 عند ١٠٠ و ٢٠٠ و ٣٠٠ جزء في المليون)، ورش مستخلصين من جذور العرقسوس (المائي بمعدل ٥ و ١٠ جم / لتر والإيثانولي عند ٥ و ١٠ جم/لتر) ومعاملات التفاعل بينهما، على النمو الخضري (طول النبات، عدد الأفرع، الوزن الطازج للعشب لكل من النبات و الفدان) وإنتاجية الزيت الطيار (النسبة المئوية للزيت، محصول الزيت الطيار لكل من النبات والفدان)، الكلوروفيل الكلي والنسبة المئوية للكربوهيدرات الكلية، النسبة المئوية للنيتروجين والفوسفور والبوتاسيوم، بالإضافة إلى النشاط المضاد للميكروبات لنبات العتر. أوضحت النتائج المتحصل عليها أن أفضل صفات النمو الخضري وإنتاجية الزيت الطيار والكلوروفيل الكلي والكربوهيدرات الكلية وNPK تم الحصول عليها نتيجة استخدام كل من التركيز العالي والمتوسط من حمض الجبريلك (٢٠٠ و٣٠٠ جزء في المليون) مع عدم وجود فروق معنوية بين التركيزين. أما فيما يتعلق بمعاملات مستخلص العرقسوس، تم زيادة كل صفات النمو الخضري وإنتاج الزيت والمكونات الكيميائية بشكل كبير بسبب المعدل العالي من المستخلص المائي للعرقسوس عند تركيز ١٠ جم/لتر تليها المستخلص الإيثانولي للعرقسوس عند ١٠ جم/لتر، بينما المستخلص المائي للعرقسوس عند تركيز ٥ جم/لتر أعطت اقل القيم معنوية. وفيما يتعلق بمعاملات التداخل بين العاملين، أعطى حمض الجبريلين أعلى قيم للنمو وللمحصول وتركيب كيميائي عند ٢٠٠ أو ٣٠٠ جزء في المليون بالاشتراك مع مستخلص جذور العرقسوس المائي عند تركيز ١٠ جم/لتر. كما تم تسجيل أقوى نشاط مضاد للميكروبات لنفس معاملة التداخل السابقة في كلا الحشتين لنباتات العتر البلدي. يمكن أن ينصح من وجهة النظر الاقتصادية والبيئية، معاملة نباتات العتر البلدي بالرش الورقي بحمض الجبريلك بتركيز ٢٠٠ جزء في المليون بالاضافة الى المستخلص المائي لجذور العرقسوس بتركيز ١٠ جم/لتر وذلك بغرض تحسين إنتاجية الزيت الطيار والنشاط المضاد للميكروبات.