Growth, yield and volatile oil of *Pelargonium graveolens* as affected by spraying of moringa leaves extract under different irrigation intervals

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Background
Essential oil of *Pelargonium graveolens* plant (Geraniaceae family) is one of the most significant essential oils produced in Egypt for the domestic market and abroad. Plant extracts have been demonstrated to promote plant development by increasing the efficiency with which nutrients are used and by reducing the impact of different biotic or abiotic stresses on plants. Water regime is one of the great important factors that affect plant growth, oil production and the availability and supply of soil moisture not only governed the rate and type of growth but also commanded the availability of plant nutrients.
Objective
The aim of this work was to choose the most suitable irrigation intervals with the best concentration of moringa leaf extract to obtain strong growth characteristics and a high oil yield and quality of *Pelargonium graveolens* under drip irrigation system.
Materials and methods
This study was carried out in the Experimental Research Station of National Research Centre with a factorial experiment in complete block design contains 9 treatments which are the interaction of three irrigation treatments (every 2 days, 3 days and every 4 days) with three levels of moringa leaf extracts (MLE) as foliar application (0, 0.6 and 0.9%) for two cuts during the two successive seasons of 2020 and 2021.
Results and conclusion
The plants were irrigated every 4 days and sprayed with MLE at concentration 0.9% illustrated positive effect on growth parameters, chemical composition, herb yield per plant (g) and per ha. (ton) as well as essential oil yield. Regarding the effect on essential oil composition the GC-MS analysis revealed that MLE treatment improved the volatile oil constituents and showed that citronellol, α-eudesmol and cis-geraniol are the main components for essential oil of *Pelargonium graveolens* herb for two cuts.

Keywords:
pelargonium graveolens, irrigation, moringa leaves extract, essential oil, citronellol, geraniol, pigments and flavonoids

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Introduction

Originally from South Africa, the *Pelargonium graveolens* plant which commonly known geranium plant (Geraniaceae family) has been widely imported and farmed in several countries, including Algeria, Morocco, Madagascar, Réunion, Russia, China, Egypt, and Guinea. One of the most significant essential oils produced in Egypt for the domestic market and abroad is geranium (*Pelargonium graveolens*) oil and it has a particularly popular rose aroma [1,2]. Egypt and China currently produce the majority of the world's geranium oil, with small amounts also coming from a variety of East and South African origins. Egypt and China combined yearly output estimated to be between 280 and 350 tons, compared to a global total of between 350 and 400 tons [2]. The leaves are steam-distilled to produce the oil. It is one of the greatest skincare oils since it works well to clean oily skin and open skin pores. Other increasingly well-liked applications for geranium essential oil include the management of dysentery, hemorrhoids, inflammation, heavy menstrual flow, and even cancer [3]. Numerous cosmetic products, perfumes, and flavor use geranium oil. Egypt's climate is semi-arid and arid, with dry hot summers, mild winters, and little rainfall. Geranium oil is produced mostly in Beni-Suef, Upper Egypt, and

there is very little data on the influence of various planting locations on the essential quantity and chemical constitution of geranium oil, particularly in the newly reclaimed areas [4].

Plant extracts have been demonstrated to promote plant development by increasing the efficiency with which nutrients are used and by reducing the impact of different biotic or abiotic stresses on plants [5]. The nutritional and therapeutic benefits of the *Moringa oleifera* plant, a member of the Moringaceae family, are well recognized [6]. Due to the abundance of minerals, free amino acids, vitamins, phytohormones, and antioxidants found in moringa leaf extract (MLE), it has been categorized as one of the most important bio-stimulants [7]. MLE has been utilized as a natural growth stimulant and/or stress-reducer for many plant species, which is also economical and environmentally beneficial. The high levels of proteins, antioxidants (ascorbic acid, flavonoids, phenolics, and carotenoids), mineral ions (P, Ca, Fe, K, Cr, Cu, Mg, Mn, and Zn), amino acids, vitamins A and C, the B-complex, and plant hormones, particularly cytokinins (zeatin), make MLE more important as natural growth enhancer, it has low cost and helps plants adapt to various environmental factors [8].

One of the most critical subjects in all agricultural systems in many nations of the world is the problem of water deficiency. Concerns about the adverse effects of climate change in this region are growing and the planned expansions in the new reclaimed land areas are located in low fertility or sandy lands with a low water holding capacity for the plant use. The problem of water shortage in Egypt has led to the concern of those who control agriculture and its future [9].

Water regime is one of the great important factors that effect on growth and oil production, the availability and supply of soil moisture not only governed the rate and type of growth but also commanded the availability of plant nutrients. The aim of this work was to choose the most suitable irrigation intervals with the best concentration of moringa leaf extract to obtain strong growth characteristics and a high oil yield and quality of *Pelargonium graveolens* under drip irrigation system.

Materials and methods

This investigation was carried out in the Experimental Research Station of National Research Centre at Al-Nubaria region, Al Bahira Governorate, Egypt, 80 Km to East of Cairo and its location is latitude 30° 30' 1.4' N, and longitude 30° 19' 10.9' E. The cuttings were obtained from the Experimental Farm of the Medicinal and Aromatic Plants Research Department, Horticulture Research Institute, Agricultural Research Center, El-Kanater EI-Khaireya during the two successive seasons of 2020 and 2021 cultivated on 15th December in both experimental seasons. Cuttings of *Pelargonium* graveol*ens* L. (average 13 cm long) were planted at 1 ×15 m (15 m^2) experimental plot in hills on row. The distances between hills were 30 cm.

The NPK chemical fertilizers were 360 kg/ fad ammonium Nitrate (33.5% N), 300 kg/fad calcium super phosphate (15.5% P_2O_5) and 150 kg/ fad potassium sulphate (48% K_2O) supplement for all treatments at the two seasons, during soil preparation calcium super phosphate was add. The physical and chemical analyses of the used soil showed in (Table 1) and determined according to [10]. While, the calculated doses of N and K fertilizers were divided into fourth equal portions, the first portion was added on 1st February, second portion was added on 15th March, the third portion was added on 27th April (after the first cut) and the fourth portions 1st June.

The design of factorial experiment in complete block design with 9 treatments; consist of three irrigation treatments (every 2 days, 3 days and every 4 days for 4 h/day) with three levels of moringa leaf extract

Table 1 Physical and chemical properties of the experimental soil

Mechanical analysis of the samples taken from the experimental soil											
Soil depth		Clay %		Silt %			Sand %			Texture	
15 cm		14.94		30.00			54.28			Sandy loam	
30 cm		13.43		29.59			55.19			Sandy loam	
Chemical analysis of the samples taken from the experimental soil											
					Cations				Anions		
Soil depth	S,P%	$CaCo_3$%	pH	EC mmhos	Ca^+	M^+	Na^+	K^+	CO_3^-	HCO_3^-	Cl^-
15 cm	52.6	8.12	8.2	2.54	8.5	6	10.9	0.6	Nil	2.6	11
30 cm	51.9	7.75	8.8	2.96	10	7	12.3	0.6	Nil	3.85	9.5

(MLE) as foliar application (0, 0.6 and 0.9%) with three replicates. The plants were sprayed twice for each cut during every season (the first spray for first cut on 2nd February but the second time for first cut on 2nd March. In the second cut, the first spray was carried out on 12th may then the second time was after one month from the first sprayed). Two cuts were taken, the first cut was after three and half month from planting and the second cut was after three months from first cut during every season. Obtained results will be subjected to statistical analysis by using least significant

Table 2 Total phenols and total flavonoids content in moringa leaves extract

Total phenolic (mg/g Extract)	Total flavonoids (mg/g Extract)
54.25±2.39	13.62±1.45

Table 3 Effect of irrigation intervals and moringa leaves extract (MLE) on plant height (cm), number of branches and stem diameter(cm) of two cuts for *Pelargonium graveolens* plants during two seasons

Plant height (cm)								
Irrigation intervals (A)	1st Season				2nd Season			
	1st cut				1st cut			
	Moringa leaves extract (B)			Mean				Mean
	Control (0% MLE)	MLE 0.6%	MLE 0.9%		Control (0% MLE)	MLE 0.6%	MLE 0.9%	
2 days	34.67	40.67	45.50	40.28	37.00	41.33	47.00	41.78
3 days	39.00	42.33	47.33	42.89	42.67	43.50	52.67	46.28
4 days	45.67	48.33	52.33	48.78	47.00	49.50	56.67	51.06
Mean	39.78	43.78	48.39		42.22	44.78	52.11	
LSD 0.05	A: 2.28	B:2.28	A*B: 3.96		A: 1.12	B: 1.12	A*B: 1.94	
		2nd Cut				2nd Cut		
2 days	37.12	45.00	48.67	43.6	39.33	49.50	51.33	46.72
3 days	44.80	48.67	51.33	48.27	44.67	53.00	56.67	51.45
4 days	48.67	53.67	57.00	53.11	49.33	56.00	62.80	56.04
Mean	43.53	49.11	52.33		44.44	52.83	56.93	
LSD 0.05	A: 2.33	B: 2.33	A*B: 4.04		A: 3.16	B: 3.16	A*B: 5.47	
Irrigation intervals (A)	Stem diameter (cm)							
	1st Season				2nd Season			
	1st cut				1st cut			
	Moringa leaves extract (B)							Mean
2 days	1.05	1.26	1.35	1.22	1.10	1.28	1.35	1.24
3 days	1.39	1.42	1.50	1.44	1.41	1.43	1.48	1.44
4 days	1.42	1.57	1.78	1.59	1.44	1.60	1.75	1.60
Mean	1.29	1.42	1.54		1.32	1.44	1.53	
LSD 0.05	A: 0.053	B: 0.053	A*B: 0.092		A: 0.061	B: 0.061	A*B: 0.11	
		2nd Cut				2nd Cut		
2 days	1.12	1.38	1.44	1.31	1.14	1.40	1.48	1.34
3 days	1.44	1.48	1.56	1.49	1.47	1.52	1.60	1.53
4 days	1.45	1.66	1.84	1.65	1.49	1.71	1.91	1.70
Mean	1.34	1.51	1.61		1.367	1.54	1.66	
LSD 0.05	A: 0.036	B: 0.036	A*B: 0.063		A: 0.051	B: 0.051	A*B: 0.088	
Irrigation intervals (A)	Number of branches							
	1st Season				2nd Season			
	1st cut				1st cut			
	Moringa leaves extract (B)							Mean
2 days	2.00	3.33	6.00	3.78	2.33	4.00	5.67	4.00
3 days	2.67	4.00	6.67	4.45	2.33	4.67	6.67	4.56
4 days	3.33	5.67	7.33	5.44	4.00	6.00	7.67	5.89
Mean	2.67	4.33	6.67		2.89	4.89	6.67	
LSD 0.05	A: 1.15	B: 1.15	A*B: 1.98		A: 1.18	B: 1.18	A*B: 1.79	
		2nd Cut				2nd Cut		
2 days	3.67	4.00	6.67	4.78	3.33	6.33	6.67	5.44
3 days	4.33	6.67	8.00	6.33	5.00	7.00	9.00	7.00
4 days	5.00	7.33	9.67	7.33	7.00	8.67	10.33	8.67
Mean	4.33	6.00	8.11		5.11	7.33	8.67	
LSD 0.05	A: 1.09	B: 1.09	A*B: 1.90		A: 1.35	B: 1.35	A*B: 2.33	

Table 4 Effect of irrigation intervals and moringa leaves extract (MLE) on aerial part fresh weight (g/plant) and fresh herb yield (ton/ha.) of two cuts for *Pelargonium graveolens* plants during two seasons

Irrigation intervals (A)	Aerial part fresh weight (g/plant)							
	1st Season				2nd Season			
	1st cut				1st cut			
	Moringa leaves extract (B)			Mean				Mean
	Control (0% MLE)	MLE 0.6%	MLE 0.9%		Control (0% MLE)	MLE 0.6%	MLE 0.9%	
2 days	517.62	620.67	776.90	638.40	528.14	642.22	788.09	652.82
3 days	577.94	724.18	878.35	726.82	590.00	729.24	889.81	736.35
4 days	620.08	851.92	992.06	821.35	643.53	863.45	1009.70	838.89
Mean	571.88	732.26	882.44		587.22	744.97	895.87	
LSD 0.05	A: 4.94	B: 4.94	A*B: 8.56		A: 6.27	B: 6.27	A*B: 10.69	
		2nd Cut				2nd Cut		
2 days	536.48	652.76	802.82	664.02	557.65	673.42	824.30	685.12
3 days	611.27	760.00	923.61	764.96	620.98	774.75	946.33	780.69
4 days	686.29	922.73	1076.02	895.01	695.50	961.38	1104.00	920.29
Mean	611.35	778.50	934.15		624.71	803.18	958.21	
LSD 0.05	A: 4.62	B: 4.62	A*B: 8.01		A:6.25	B: 6.25	A*B: 10.83	

Irrigation intervals (A)	Fresh herb yield (ton/ha.)							
	1st Season				2nd Season			
	1st cut				1st cut			
	Moringa leaves extract (B)							Mean
2 days	17.25	20.69	25.90	21.28	17.60	21.41	26.27	21.76
3 days	19.26	24.14	29.28	24.23	19.67	24.31	29.66	24.55
4 days	20.67	28.40	33.07	27.38	21.45	28.78	33.66	27.96
Mean	19.06	24.41	29.42		19.57	24.83	29.86	
LSD 0.05	A: 2.77	B: 2.77	A*B: 4.80		A: 1.71	B: 1.71	A*B: 2.96	
		2nd Cut				2nd Cut		
2 days	17.88	21.76	26.76	22.13	18.59	22.45	27.48	22.84
3 days	20.38	25.33	30.79	25.50	20.70	25.82	31.54	26.02
4 days	22.88	30.79	35.87	29.85	23.18	32.05	36.80	30.68
Mean	20.38	25.96	31.14		20.82	26.77	31.94	
LSD 0.05	A: 1.19	B: 1.19	A*B: 2.06		A: 2.09	B: 2.09	A*B: 3.62	

Table 5 Effect of irrigation intervals and moringa leaves extract (MLE) on root length (cm), root fresh and dry weight (g/plant) of *Pelargonium graveolens* plants at end of each season

Irrigation intervals (A)	Root length (cm)							
	1st Season				2nd Season			
	Moringa leaves extract (B)							Mean
	Control (0% MLE)	MLE 0.6%	MLE 0.9%	Mean	Control (0% MLE)	MLE 0.6%	MLE 0.9%	
2 days	34.67	36.33	38.50	36.5	35.33	38.67	40.67	38.22
3 days	36.00	39.33	42.33	39.22	35.67	39.67	44.00	39.78
4 days	39.67	43.67	47.00	43.45	41.67	44.33	48.18	44.73
Mean	36.78	39.78	42.61		37.56	40.89	44.28	
LSD 0.05	A: 2.45	B: 2.45	A*B: 4.24		A:2.14	B: 2.14	A*B: 3.70	
Root fresh weight (g/plant)								
Irrigation intervals (A)	1st Season				2nd Season			
	Moringa leaves extract (B)							Mean
2 days	31.13	35.75	40.62	35.83	33.62	41.49	42.50	39.20
3 days	34.22	37.69	45.80	39.24	36.65	38.90	49.62	41.72
4 days	42.23	46.72	50.34	46.43	45.60	47.39	50.77	47.92
Mean	35.86	40.05	45.59		38.62	42.59	47.63	
LSD 0.05	A: 1.31	B: 1.31	A*B: 2.26		A: 2.13	B: 2.13	A*B: 3.69	
Root dry weight (g/plant)								
Irrigation intervals (A)	1st Season				2nd Season			

(*Continued*)

Table 5 (*Continued*)

	Root length (cm)							
Irrigation intervals (A)	1st Season				2nd Season			
	Moringa leaves extract (B)							Mean
2 days	10.39	12.38	14.35	12.37	10.85	14.56	15.36	13.59
3 days	11.67	13.23	17.18	14.03	12.39	13.27	18.48	14.71
4 days	15.35	17.87	19.46	17.56	16.75	17.54	19.63	17.97
Mean	12.47	14.49	17.00		13.33	15.12	17.82	
LSD $_{0.05}$	A: 0.75	B: 0.75	A*B:1.30		A:0.80	B: 0.80	A*B: 1.39	

Table 6 Effect of irrigation intervals and moringa leaves extract (MLE) on chlorophyll a, b and carotenoids (mg. g^{-1} F.W.) of two cuts for *Pelargonium graveolens* plants during two seasons

	Chlorophyll a (mg. g^{-1} F.W.)							
	1st Season				2nd Season			
Irrigation intervals (A)	1st Cut				1st Cut			
	Moringa leaves extract (B)							Mean
	Control (0% MLE)	MLE 0.6%	MLE 0.9%	Mean	Control (0% MLE)	MLE 0.6%	MLE 0.9%	
2 days	0.73	1.00	1.05	0.93	0.93	1.02	1.15	1.03
3 days	0.89	1.17	1.26	1.11	0.97	1.28	1.37	1.21
4 days	1.08	1.23	1.37	1.23	1.14	1.36	1.53	1.34
Mean	0.90	1.13	1.23		1.01	1.22	1.35	
LSD $_{0.05}$	A: 0.041	B: 0.041	A*B: 0.071		A: 0.038	B: 0.038	A*B: 0.067	
		2nd Cut				2nd Cut		
2 days	0.72	0.94	0.97	0.88	0.78	0.89	0.99	0.89
3 days	0.77	1.00	1.10	0.96	0.93	1.19	1.27	1.13
4 days	0.99	1.05	1.15	1.06	1.17	1.29	1.32	1.26
Mean	0.83	1.00	1.07		0.96	1.12	1.19	
LSD $_{0.05}$	A: 0.045	B: 0.045	A*B: 0.078		A: 0.039	B: 0.039	A*B: 0.068	
	Chlorophyll b (mg. g^{-1} F.W.)							
Irrigation intervals (A)	1st Season				2nd Season			
	1st cut				1st cut			
	Moringa leaves extract (B)							Mean
2 days	0.25	0.30	0.32	0.29	0.29	0.38	0.42	0.36
3 days	0.29	0.37	0.40	0.35	0.34	0.51	0.54	0.46
4 days	0.35	0.43	0.46	0.41	0.43	0.52	0.56	0.50
Mean	0.30	0.37	0.39		0.35	0.47	0.51	
LSD $_{0.05}$	A: 0.036	B: 0.036	A*B: 0.062		A: 0.037	B:0.037	A*B:0.065	
		2nd Cut				2nd Cut		
2 days	0.19	0.21	0.25	0.22	0.20	0.22	0.26	0.23
3 days	0.22	0.28	0.31	0.26	0.23	0.31	0.36	0.30
4 days	0.24	0.29	0.33	0.27	0.28	0.32	0.40	0.33
Mean	0.22	0.25	0.28		0.24	0.28	0.34	
LSD $_{0.05}$	A: 0.037	B: 0.037	A*B: 0.064		A: 0.036	B: 0.036	A*B: 0.063	
	Carotenoids (mg. g^{-1} F.W.)							
Irrigation intervals (A)	1st Season				2nd Season			
	1st cut				1st cut			
	Moringa leaves extract (B)							Mean
2 days	0.45	0.58	0.66	0.56	0.64	0.69	0.76	0.70
3 days	0.59	0.67	0.74	0.67	0.67	0.80	0.86	0.78
4 days	0.63	0.70	0.78	0.70	0.72	0.83	0.95	0.83
Mean	0.56	0.65	0.73		0.68	0.77	0.86	
LSD $_{0.05}$	A: 0.041	B: 0.041	A*B: 0.070		A: 0.038	B: 0.038	A*B:0.067	
		2nd Cut				2nd Cut		
2 days	0.31	0.35	0.37	0.34	0.49	0.55	0.59	0.54
3 days	0.39	0.42	0.47	0.43	0.51	0.62	0.71	0.61
4 days	0.39	0.45	0.50	0.45	0.56	0.68	0.78	0.67
Mean	0.36	0.41	0.45		0.52	0.62	0.69	
LSD $_{0.05}$	A: 0.040	B: 0.040	A*B: 0.069		A: 0.047	B: 0.047	A*B: 0.081	

Table 7 Effect of irrigation intervals and moringa leaves extract (MLE) on total sugars, total phenols and total flavonoids content (mg. g^{-1} F.W.) of *Pelargonium graveolens* plants for first cut during two seasons

Total sugars content (mg. g^{-1} F.W.)								
Irrigation intervals (A)	1st Season				2nd Season			
	Moringa leaves extract (B)			Mean				Mean
	Control (0% MLE)	MLE 0.6%	MLE 0.9%		Control (0% MLE)	MLE 0.6%	MLE 0.9%	
2 days	6.76	8.66	10.24	8.55	7.21	8.29	10.68	8.73
3 days	10.96	11.89	12.36	11.74	12.28	12.76	13.18	12.74
4 days	11.37	13.31	14.94	13.21	15.29	15.92	16.40	15.87
Mean	9.70	11.29	12.51		11.59	12.32	13.42	
LSD $_{0.05}$	A: 1.24	B: 1.24	A*B: 1.58		A: 0.88	B:0.88	A*B: 1.53	
Irrigation intervals (A)	Total phenols (mg. g^{-1} F.W.)							
	1st Season				2nd Season			
	Moringa leaves extract (B)							Mean
2 days	9.17	9.25	10.04	9.49	10.60	10.98	11.45	11.01
3 days	11.36	11.88	12.43	11.89	12.06	12.50	12.83	12.46
4 days	11.63	13.13	13.69	12.82	12.87	13.15	13.40	13.14
Mean	10.72	11.42	12.05		11.84	12.21	12.56	
LSD $_{0.05}$	A: 0.94	B: 0.94	A*B: 1.62		A: 0.58	B: 0.58	A*B: 1.00	
Total flavonoids (mg. g^{-1} F.W.)								
Irrigation intervals (A)	1st Season				2nd Season			
2 days	4.95	5.39	7.46	5.93	6.15	9.25	9.38	8.26
3 days	6.40	7.67	7.72	7.26	6.76	9.83	10.22	8.94
4 days	6.93	7.71	8.43	7.69	7.24	10.25	10.79	9.43
Mean	6.09	6.92	7.87		6.72	9.78	10.13	
LSD $_{0.05}$	A: 1.02	B: 1.02	A*B: 1.77		A: 0.76	B: 0.76	A*B: 1.32	

differences (LSD) at 5% level according to method described by [11].

The vegetative growth [plant height, stem diameter, number of branches and aerial fresh weights (g plant^{-1} and ton ha^{-1})] were recorded after first and second cuts for each season, while (the root length, root fresh and dry weights) were measured at the end of the seasons. Photosynthetic pigments in leaves (chlorophyll a, chlorophyll b and total carotenoids) were determined according to [12], total sugars content (mg. g^{-1} F.W.) was determined according to [13], total phenolics was determined according to [14] total flavonoids (mg. g^{-1} F.W) was determined according to [15]. The essential oil percentage and oil yield (ml plant^{-1} and L ha^{-1}) were recorded and the main constituents of the essential oil were determined by Gas chromatography–mass spectrometry (GC-MS).

Preparation of ethanolic *Moringa oleifera* extract

Moringa oleifera dried leaves were obtained from National Research Centre in Giza, Egypt, and crudely powdered. A weight of 500 g of moringa leaves powder were macerated in 2.5 liter of 70% ethyl alcohol, and kept in tightly sealed vessels at room temperature for three weeks in the dark, then the mixture was filtered. The extraction of the residue was repeated 3 times in the same manner until a clear colorless supernatant extraction liquid was obtained. The extracted liquid was filtered and concentrated using rotary evaporator under reduced pressure at 50°C until the solvent was completely removed. The extract was stored at 4°C until used. The plant extract was tested for the total phenols content and total flavonoids and shown in (Table 2).

Gas chromatography–mass spectrometry analysis (GC-MS)

The GC-MS analysis of the essential oil samples was carried out using gas chromatography-mass spectrometry instrument stands at the Department of Medicinal and Aromatic Plants Research, National Research Center as reported by [16].

Results and discussion

Growth, fresh herb and yield parameters

The traits subjected of the study were for the shoots of *Pelargonium graveolens* plants in two cuts for each season, while the roots traits were measured at the end for each season. The results presented in (Tables 3–5) detected that the different irrigation intervals on the vegetative growth characteristics, as the arrival of irrigation intervals to irrigation every 4

Table 8 Effect of irrigation intervals and moringa leaves extract (MLE) on essential oil (%) of two cuts for *Pelargonium graveolens* plants during two seasons

Essential oil (%)								
	1st Season				2nd Season			
Irrigation intervals (A)	1st cut				1st cut			
	Moringa leaves extract (B)			Mean				Mean
	Control (0% MLE)	MLE 0.6%	MLE 0.9%		Control (0% MLE)	MLE 0.6%	MLE 0.9%	
2 days	0.49	0.52	0.59	0.53	0.54	0.55	0.63	**0.57**
3 days	0.55	0.60	0.61	0.59	0.59	0.62	0.64	**0.62**
4 days	0.66	0.78	0.84	0.76	0.69	0.82	0.90	**0.80**
Mean	0.57	0.63	0.68		0.61	0.66	0.72	
LSD 0.05	A: 0.038	B: 0.038	A*B: 0.067		A: 0.034	B: 0.034	A*B: 0.059	
	2nd Cut				2nd Cut			
2 days	0.41	0.42	0.52	0.45	0.43	0.44	0.53	**0.47**
3 days	0.48	0.52	0.50	0.50	0.51	0.55	0.54	**0.53**
4 days	0.57	0.69	0.75	0.67	0.60	0.76	0.83	0.73
Mean	0.49	0.54	0.59		0.51	0.58	0.63	
LSD 0.05	A: 0.040	B: 0.040	A*B: 0.069		A: 0.039	B: 0.039	A*B: 0.067	
Irrigation intervals (A)	Essential oil yield (ml/ plant)							
	1st Season				2nd Season			
	1st cut				1st cut			
	Moringa leaves extract (B)			Mean				Mean
2 days	2.54	3.20	4.58	3.44	2.83	3.53	4.93	3.76
3 days	3.18	4.31	5.31	**4.27**	3.48	4.48	5.69	**4.55**
4 days	4.06	6.64	8.28	**6.33**	4.41	7.04	9.04	**6.83**
Mean	3.26	4.72	6.06		**3.57**	**5.02**	**6.55**	
LSD 0.05	A: 0.36	B: 0.36	A*B: 0.61		**A: 0.37**	**B: 0.37**	**A*B: 0.64**	
	2nd Cut				**2nd Cut**			
2 days	2.17	2.74	4.17	**3.03**	2.40	2.96	4.37	**3.24**
3 days	2.90	3.95	4.62	**3.82**	3.14	4.26	5.06	**4.15**
4 days	3.88	6.37	8.07	**6.11**	4.14	7.31	9.16	**6.87**
Mean	2.98	4.35	5.62		**3.23**	**4.84**	**6.20**	
LSD 0.05	A: 0.56	B: 0.56	A*B: 0.97		A: 0.55	B: 0.55	A*B: 0.95	
Irrigation intervals (A)	Essential oil yield (l/ ha.)							
	1st Season				2nd Season			
	1st cut				1st cut			
	Moringa leaves extract (B)							Mean
2 days	84.54	106.55	152.79	114.63	94.18	117.74	164.18	125.37
3 days	105.95	143.63	177.13	142.24	116.03	149.49	189.82	151.78
4 days	135.38	221.50	276.12	211.00	146.94	234.57	301.22	227.58
Mean	108.62	157.23	202.01		119.05	167.27	218.41	
LSD 0.05	A: 5.42	B: 5.42	A*B: 9.39		A: 3.72	B: 3.72	A*B: 6.44	
	2nd Cut				2nd Cut			
2 days	72.42	91.39	139.15	100.99	79.93	98.77	145.62	108.11
3 days	96.78	131.73	153.93	127.48	104.53	142.04	168.78	138.45
4 days	129.25	212.23	269.00	203.49	137.94	243.55	305.44	228.98
Mean	99.48	145.12	187.36		107.467	161.45	206.61	
LSD 0.05	A: 4.14	B: 4.14	A*B: 7.18		A: 3.45	B: 3.45	A*B: 5.98	

days gave the highest values for all characteristics in terms of plant height, stem diameter, number of branches, aerial part fresh weight, fresh herb yield, root length and root fresh and dry weights. This result agreed with [17] who observed that water excess treatment altered the chemical characteristics of the soil for plant development by lowering the oxygen content in the soil and lowering the degree of nutrient absorption, resulting in a reduction in plant growth and root growth.

The data presented in the same Tables pointed that moringa leaves extract (MLE) treatment at rate of 0.9% appeared significantly increment in all measured

Table 9 The main constituents of essential oil for fresh herb of *Pelargonium graveolens* affected by irrigation intervals and moringa leaf extract at first cut

		Components %								
		Irrigation every 2 day			Irrigation every 3 day			Irrigation every 4 day		
RT	Components	Control	MLE 0.6%	MLE0.9%	Control	MLE 0.6%	MLE 0.9%	Control	MLE0.6%	MLE0.9%
4.27	α-Pinene	1.22	0.95	0.77	0.85	0.30	trace	1.47	1.45	0.68
5.98	α –Myrcene	trace	trace	trace	trace	0.41	trace	trace	0.27	trace
10.57	á-Linalool	4.08	6.71	2.69	4.70	4.44	6.5	6.35	8.12	6.75
10.91	Rose oxide	0.29	0.38	0.25	0.48	0.40	0.28	0.33	0.50	0.31
12.96	Isomenthone	6.14	9.36	3.79	7.35	5.93	8.88	7.10	9.49	7.73
14.40	α-Terpineol	trace	0.45	trace	0.35	0.32	0.36	0.47	0.57	0.34
17.66	Citronellol	38.61	40.28	46.31	32.51	41.50	43.88	50.37	55.40	53.10
18.17	Cis-Geraniol	15.96	13.75	22.67	21.71	13.30	9.20	6.35	5.96	7.19
18.68	Geraniol formate	3.64	1.73	2.40	2.58	4.21	0.40	0.35	0.48	0.30
20.40	Citronellol acetate	0.39	0.50	0.18	0.29	0.41	0.28	Trace	0.32	0.26
21.40	(–)-β-Bourbonene	0.87	0.92	0.47	0.60	1.15	0.91	1.02	0.89	0.71
21.68	2,6-Octadienol,3 dimethyl acetate	0.43	trace	0.30	0.45	0.72	0.75	0.58	0.90	0.60
22.93	Isocaryophyllene	0.68	0.30	0.32	0.43	0.79	0.32	0.76	0.52	0.54
24.46	Humulene	0.64	0.75	0.18	0.24	0.41	0.25	0.61	0.26	0.21
25.32	Geranyl propionate	1.32	1.47	0.40	0.73	0.88	1.49	1.70	1.25	0.78
25.63	Germacrene D	0.30	0.33	0.90	0.93	1.32	1.88	0.35	0.67	1.46
27.10	Cadina-1(10),4-diene	0.48	0.55	0.23	0.32	0.50	0.38	0.51	0.29	0.25
27.42	cis-Calamene	0.28	0.40	0.19	0.32	0.38	0.53	0.3	0.32	0.38
28.63	Geraniol butyrate	0.63	0.49	0.21	0.59	0.84	0.3	0.42	0.44	0.24
30.44	Phenylethyl tiglate	3.01	3.57	2.21	3.18	3.39	4.16	3.37	3.51	3.42
32.10	α-Eudesmol	18.20	14.42	13.63	18.53	14.97	16.73	15.64	7.29	12.34
33.15	β-Eudesmol	0.97	0.90	0.66	1.05	1.25	0.96	0.31	0.32	0.86
34.21	Geranyl tiglate	1.14	1.61	0.73	1.08	1.84	1.50	1.45	0.66	1.24
Oxygenated compounds	94.81	95.62	96.43	95.58	94.40	95.67	94.79	95.21	95.46	
Non oxygenated compounds	4.47	4.20	3.06	3.69	5.26	4.27	5.02	4.67	4.23	
Total compounds	99.28	99.82	99.49	99.27	99.66	99.94	99.81	99.88	99.69	

parameters. It has been reported that MLE contains zeatin, dihydrozeatin and isopentyladenine which are endogenous cytokinins [18].

Regarding the effect of interaction between irrigation intervals and moringa leaves extract, it was deduced that the plants irrigated every 4 days and sprayed with MLE at 0.9% produced the highest mean values of the selected traits.

Chemical composition parameters

The data presented in Tables 6 and 7 illustrated that plants irrigated every 4 days gave the highest values of all chemical compositions were estimated including photosynthetic pigments (chlorophyll a, b and carotenoids) in two cuts for each season, as well as the rest of chemical composition (total sugars, total phenols and flavonoids) which were determined in shoots at the end of each season as compared to other irrigation treatment Our results in the same line with [9] who supposed that decrease irrigation numbers from three times a week to twice a week significantly increased content of chlorophyll a,b and carotenoids for calendula plant.

The treatment MLE at concentration of 0.9% enhanced the content of photosynthetic pigments in fresh leaves of *P. graveolens* plants in both cuts for both seasons, and total sugars, total phenols and total flavonoids content in shoots in both seasons as compared to plants sprayed with distilled water. Increase in values of chemical composition parameters by concentration of MLE could be explained by that leaves of *Moringa oleifera* contains proteins, vitamins (such as A, B_1, B_2, B_3, ascorbic acid and E), β carotene, amino acids, phenolic compounds, sugars and minerals (such as calcium, magnesium, sodium, iron, phosphorus and potassium) and several flavonoid pigments so, foliar application promoting growth, yield and pigments content crops [19–21].

Table 10 The main constituents of essential oil for fresh herb of *Pelargonium graveolens* affected by irrigation intervals and moringa leaf extract at second cut

RT	Components	Components %								
		Irrigation every 2 day			Irrigation every 3 day			Irrigation every 4 day		
		Control	M 0.6%	M 0.9%	Control	M 0.6%	M 0.9%	Control	M 0.6%	M 0.9%
4.27	α-Pinene	0.68	1.06	0.83	0.74	0.87	0.53	0.84	1.00	0.79
10.57	á-Linalool	3.04	3.00	2.57	3.35	6.40	2.77	2.95	4.94	2.45
10.91	Rose oxide	0.68	0.66	0.43	0.45	1.11	0.50	trace	trace	0.56
12.96	Isomenthone	trace	0.51	0.30	trace	0.31	0.60	trace	trace	0.36
14.40	α-Terpineol	7.59	7.94	7.65	7.61	9.81	6.61	6.02	8.75	5.29
17.66	Citronellol	43.72	48.38	58.06	54.33	55.13	60.34	49.26	51.28	54.05
18.17	cis-Geraniol	6.04	3.85	3.38	2.53	6.04	4.11	6.40	4.62	8.38
18.68	Geraniol formate	0.32	0.30	0.24	0.30	0.31	0.25	2.87	0.35	2.70
20.40	Citronellol acetate	1.03	0.90	0.78	0.57	0.59	0.67	0.27	0.98	0.75
21.40	(–)-β-Bourbonene	0.48	0.53	0.51	0.41	0.48	0.50	0.35	0.64	0.38
21.68	2,6-Octadienol,3 dimethyl acetate	0.78	0.60	0.48	0.45	trace	0.40	0.81	0.80	0.42
22.93	Isocaryophyllene	0.37	0.32	0.26	trace	0.29	trace	0.55	0.30	trace
24.46	Humulene	0.91	0.97	0.97	0.68	0.55	1.02	1.09	1.14	1.03
25.32	Geranyl propionate	1.51	1.67	1.12	1.49	0.69	1.04	1.59	1.88	1.06
25.63	Germacrene D	trace	0.36	0.36	trace	0.23	0.23	0.42	0.27	0.34
27.10	Cadina-1(10),4-diene	0.48	0.47	0.37	0.40	0.29	0.30	0.66	0.49	0.28
27.42	cis-Calamene	0.45	0.37	0.25	0.33	0.23	0.25	trace	trace	Trace
28.63	Geraniol butyrate	1.30	1.56	1.31	0.52	0.29	1.16	1.46	1.75	1.03
30.44	Phenylethyl tiglate	4.43	4.68	2.80	3.45	2.70	3.83	3.40	3.78	3.66
32.10	α-Eudesmol	23.21	18.65	14.50	19.38	12.28	13.08	18.03	14.36	14.26
33.15	β-Eudesmol	0.45	1.20	1.05	1.07	0.39	0.73	0.86	0.78	0.90
34.21	Geranyl tiglate	1.88	1.69	1.32	1.47	0.50	0.91	1.66	1.68	1.05
Oxygenated compounds	95.98	95.59	95.99	96.97	96.55	97.00	95.58	95.95	96.92	
Non oxygenated compounds	3.37	4.08	3.55	2.56	2.94	2.83	3.91	3.84	2.82	
Total compounds	99.35	99.67	99.54	99.53	99.49	99.83	99.49	99.79	99.74	

So, it is a good source of natural antioxidants [22], calcium and potassium which play essential roles in crop growth and development through osmoregulation, enzynme activation, photosynthesis and various other physiological processes [23,24]. So, moringa leaves extract spraying treatment increase the nutraceutical properties of *Pelargonium graveolens* herb.

The plants irrigated every 4 days and sprayed with MLE at concentration of 0.9% showed the highest content of photosynthetic pigments, total sugars, total phenols and flavonoids as compared with other treatments, where the lowest values were obtained from the plants irrigated every 2 days and sprayed with distilled water.

Essential oil percentage and yield (ml/plant and l/ha.)

The mean values indicated that first cut was the best cut for essential oil % and essential oil yield (ml/plant and l/ha.) in both seasons (Table 8). In the same time, irrigation every 4 days gave highest essential oil % and essential oil yield (ml/plant and l/ha.) for two cuts in the both seasons.

Sprayed moringa leaves extract also influenced on essential oil yield (ml/plant and l/ha) and percentage. By raising MLE concentration from 0.6% to 0.9%, they increased, so the highest yield of essential oil was determined from Pelargonium graveolens aerial herb sprayed with MLE 0.9%.

Spraying moringa leaves extract at various concentrations and irrigation intervals had a significant interaction effect, where irrigation every 4 days and 0.9% of moringa leaves extract treatments gives the highest essential oil percentage and essential oil yield (ml/plant and l/ha.) for *Pelargonium graveolens* plants at both cuts and two investigated seasons. The increased in the essential oil percentage and oil yield (ml/plant and l/ha.) for *p. graveolens* plants sprayed with different level of MLE probably attributed to the highest energy in synthesis biochemical metabolites as product from sprayed MLE. These findings are in agreed with the results of [25,26] who found that MLE is rich in macro and micro nutrients, antioxidants, amino acids, and phytohormones. Additionally, salicylic acid and jasmonic acid are also

detected in MLE so, MLE has shown to be a strong bio-stimulant for improving essential oil production of *Pelargonium graveolens* plants.

Essential oil composition

The essential oil of *Pelargonium graveolens* is one of the most universally essential oils used in the perfumery, flavoring and cosmetic industries [27,28]. The essential oil of *P. graveolens* from the aerial parts was obtained by hydro distillation and analyzed by gas chromatography- mass spectrometry.

Twenty-three to twenty-two compounds were identified for the first and second cuts; respectively, the former compounds were detected in percentages represented in Tables 9 and 10. The total identified compounds ranged from 99.27 to 99.88% from the separated compounds.

The identified compounds can be classified into 2 main classes:

Oxygenated compounds: α-linalool, rose oxide, isomenthone, α-terpineol, citronellol, cis-geraniol, geraniol formate, citronellol acetate, 2,6-octadienol, 3 dimethyl acetate, geranyl propionate, geraniol butyrate, phenylethyl tiglate, α-eudesmol, β-eudesmol and geranyl tiglate, and their percentage ranged from 94.40% in the first cut to 97.00% in the second cut.

Non oxygenated compounds: α-pinene, α-myrcene, (–)-β-bourbonene, humulene, germacrene D, cadina-1(10) 4-diene and cis-calamene and their percentage ranged from 2.56% in the second cut to 5.02% in the first cut. This agreed with [29].

The major compound was found to be citronellol in all treatments and the highest citronellol percentage (55.40%) was found in essential oil of pelargonium plants which irrigated every 4 days with spraying of MLE (0.6%) in the first cut. Where in the second cut, the highest citronellol percentage (60.43%) was found in essential oil of plants with the treatment of irrigation every 3 days with spraying of (MLE 0.9%).

Cis-geraniol was identified as the second main component in essential oil of *P. graveolens* plants in all treatments. The highest value (22.67%) was found in the essential oil of plants irrigated every 2 days and sprayed with MLE 0.9%, but the lowest percentage (5.96) of cis geraniol was found in volatile oil of *P. graveolens* which irrigated every 4 days and sprayed with MLE 0.6% in the first cut. While, in the second cut α-Eudesmol was the second main compound was identified in the essential oil of *Pelargonium graveolens* plants with all treatments. the maximum amount of α-Eudesmol (23.21%) was found in the essential oil of plants irrigated every 2 days without spraying, but minimum amount α-Eudesmol (12.28%) was found in the essential oil of plants irrigated every 3 days with sprayed MLE 0.6%.Generally, MLE treatments improved the volatile oil constituents. The results showed that foliar spraying with MLE in concentration of 0.6% and irrigation interval of 3 or 4 days gave the highest concentrations for almost identified compounds.

Generally, the identified compounds can be classified into 2 main classes:

Oxygenated compounds: α-linalool, rose oxide, isomenthone, α-terpineol, citronellol, cis-geraniol, geraniol formate, citronellol acetate, 2,6-octadienol, 3 dimethyl acetate, geranyl propionate, geraniol butyrate, phenylethyl tiglate, α-eudesmol, β-eudesmol and geranyl tiglate, and their percentage ranged from 94.40% in the first cut to 97.00% in the second cut.

Non oxygenated compounds: α-pinene, α-myrcene, (–)-β-bourbonene, humulene, germacrene D, cadina-1 (10), 4-diene and cis-calamene and their percentage ranged from 2.56% in the second cut to 5.02% in the first cut. This agreed with [29].

Conclusion

It could be concluded that, growth of geranium plant was positively increased when irrigated every 4 days and sprayed with different concentrations of moringa leaves extract. The biomass values were stimulated with these treatments, in addition to essential oil yield which increased. The essential oil components were also improved compared to control. It could be recommended that applying foliar spray with *Moringa oleifera* leaves extract at 0.9% concentration with generally resulted in the highest values for fresh herb yield, essential oil yield and essential oil components percentages.

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Conflicts of interest

There are no conflicts of interest.

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