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Effect of Foliar Humic Acid on Water Productivity: Biochemical Parameters and Biotic Stress on Geranium Yield

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Authors' contributions

This work was carried out in collaboration between both authors. Author RAD devised the idea and supervised the research work and helped in write-up of the manuscript. Author TN conducted the research trial and provided practical assistance. Each author equally aided in analysis, feedback, revising and endorsing the manuscript. Both authors read and approved the final manuscript.

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ABSTRACT

During the 2017/2018 and 2018/2019 seasons, a study was conducted on the effect of humic acid at 1.0, 1.5, and 2.0 ml L^{-1} and water productivity on essential oils and proline content, biotic stress caused by Cucumber Mosaic Virus (CMV) and yield of geranium plants. The study was conducted in El Kanater El Khairia of Qalubia Governorate. It was aimed at determining the appropriate concentration of humic acid that attains the highest water productivity (WP), the highest production of essential oils, and highest proline content as well as reducing the symptoms of CMV. Results indicate that the highest fresh yield was obtained with a foliar application of 2.0 ml L^{-1} humic acid and 120% evapotranspiration (ETo). Applied irrigation water was 15155, 12168, and 9334 m^3 ha^{-1} in the first growing season and 15218, 12298, and 9678 m^3 ha^{-1} in the second growing season with

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120, 100, and 80% ETo in both seasons. The highest average of WP 9.31 kg ha^{-1} both seasons was attained with 80% ETo and, 2.0 ml L^{-1} humic acid. While, the highest percentage of geranium essential oils and proline content, 68.16 and 3.73%, respectively were found with 2.0 ml L^{-1} humic. On the contrary, there was a significant reduction in CMV symptoms in plants treated with 2.0 ml L^{-1} humic acid compared to untreated controls. Thus, it is recommended that geraniums be irrigated with 80% ETo and application of 2.0 ml L^{-1} humic acid. Additionally, these treatments increased WP and resulted in the highest production of essential oils. It also increased the concentration of proline which acts as an endogenous osmoprotectants, against CMV.

Keywords: Water productivity; essential oils; proline; Cucumber Mosaic Virus (CMV); biotic stress.

1. INTRODUCTION

Ornamental plants are important export crops in Egypt. In 2020, the area planted was about 103,306 hectares (EAS) [1]. Geranium is planted on about 2,234 hectares producing 17,975 tons (EAS) [1]. Geranium is a perennial aromatic plant cultivated for the production of valuable volatile oils [2].

Humic acid (HA) is an organic substance which improves soil properties and plant growth and development. Numerous reports indicated that soil physical, chemical, and biological characteristics, namely, texture and water holding capacity are positively affected by HA [3,4]. HA resulted in increased drought resistance and enhanced crop production with reduced irrigation volumes [5]. Sustainable agriculture is used to increase the productivity of crops by using natural sources of nutrients instead of chemical fertilizer [6]. Although fertilizers are a vital factor that affects the production of geranium, it should be judiciously used to prevent oil degradation and environmental pollution [7].

Water is a limiting factor in geranium production. Biotic factors such as water deficit impact the yield and composition of essential oils [8]. Water productivity is one of the management practices used to achieve water conservation [9]. Abdel-Ghany and Abd El-Aleem [10] reported that sensitivity of the geranium to water deficit is of great interest to horticultural producers, in planning irrigation strategies. Sánchez-Blanco [11] indicated that deficit irrigation induces morphological and physiological responses in ornamental plants. However, irrigation and fertilization practices can result in producing quality plants with greater adaptation to the environment. One way to evaluate the impact of the application of different amounts of irrigation water is the calculation of water productivity. Water productivity increases with deficit irrigation compared to full irrigation [12].

Water productivity is calculated with different irrigation amounts. It is used to define the relationship between crop production and the applied water quantities [13]. Essential oil was increased with drought stress in two Salvia species and Sweet Basil [14,15].

Geranium (Pelargonium spp.) is subjected to many biotic stresses, e.g., fungal, bacterial and viral diseases [16,17]. Of the more than 20 virus diseases found in pelargonium are beet curly top virus, cucumber mosaic virus (CMV), impatiens necrotic spot virus (INSV), tomato bushy stunt virus (TBSV), tomato rings pot virus, tomato spotted wilt virus (TSWV), tobacco mosaic virus (TMV), tobacco necrosis virus (TNV), pelargonium flower break virus (PFBV), and pelargonium line pattern virus; all can be transmitted to the next crop through dissemination procedures [18]. Viruses do not kill geranium, but can reduce vegetative growth and flower quality. For example, CMV which is transmitted by aphids severely reduces marketability by deforming blooms and causing foliar color breaks. The economic losses caused by these diseases are complicated to evaluate since infected plants are often symptomless and because both the cultivar and the environment in which the plants are growing can influence the severity of the symptoms. The problem is compounded by the different sources of stock plants and the fact that most geranium cultivars, especially those that are field grown, are virus-infected [19-21].

Proline is an important constituent that enhances biotic stress by affecting physiological and biochemical properties of plants [22-26]. Foliar application of humic acid enhances proline synthesis which results in increased systemic resistance to CMV in geranium [24-26].

This research was designed to find out the optimum concentration of humic acid and different amounts of applied water in order to achieve the highest levels of essential oils and the highest concentration of proline under local conditions in El Kanater El Khairia of Qalybia Governorate.

2. MATERIALS AND METHODS

The present study was conducted on naturally CMV-infected geranium plants to study the effect of foliar spraying with humic acid under different irrigation treatments to enhance vegetative growth, yield, essential oil content, and proline concentration during biotic stress. The experiment was performed during the 2017/2018 and 2018/2019 seasons at the Experimental Farm of Medicinal and Aromatic Plants Research Department in El Kanater El Khairiyia, Horticultural Research Institute, Agriculture Research Center in Egypt. The average meteorological values during the experimental period were obtained from the following: https://power.larc.nasa.gov/data- access-viewer/. Evapotranspiration (ETo, mm day^{-1}) was calculated using BISm model [27]. The values of ETo in 2017 for November and December were 2.94 and 2.60 (mm day^{-1}). As for 2018 ETo average values from January till December were (2.83, 3.46, 5.16, 6.54, 9.01, 9.46, 9.20, 8.50, 7.20, 5.82, 3.16 and 3.18 mm day^{-1}), respectively.

The physical and chemical analyses of the soil were determined according to methods reported by [28]. Soil texture results averages during the two growing seasons were as follows: 23.35% sand, 21.93% silt, 50.41% clay, and 1.43% organic matter. Soil chemical analysis averages during the two growing seasons were as follows: pH (7.35), salinity (EC 0.63 dS m^{-1}), and total nitrogen (35.78 ppm), available phosphorus (27.66 ppm), available potassium (0.93 ppm). Soil moisture constants used according to [29] are presented in Table 1.

2.1 Experimental Design

The experimental design was spilt plot with three replicates, three irrigation amounts were assigned to the main plots and four foliar applications of humic acid were assigned to the sub-plots as followed:

- Three irrigation treatments:

a) Application of 120% ETo (full irrigation, FI control);
b) Application of 100% ETo (deficit irrigation, DI_1) and;
c) Application of 80% ETo (deficit irrigation, DI_2).

- Four applications of humic acid:

a) CMV-infected geranium plants without application of humic acid (H1= control);
b) Foliar applications of 1.0 cm/L humic acid (H2= 1.0 cm/L);
c) Foliar applications of 1.5 cm/L humic acids (H3= 1.5 cm/L) and;
d) Foliar applications of 2.0 cm/L humic acid (H4= 2.0 cm/L).

Humic acid treatments were sprayed three times, 15, 45 and 75 days after planting. Geranium was planted on the 1th of November in both seasons. Each plot included 3 rows with distance of 60 cm between rows and 25 cm between plants within the rows. The plot area was 4.5 m^2 (1.80 × 2.5), included 27 plant/plot. Cattle manure (36 m^3/ha) and calcium super phosphate (15.5% P_2O_5) at the rate of 600 kg/ha were added during land preparation; two weeks before planting. Whereas, ammonium sulphate (20.5%N) at 960 kg/ha, and potassium sulphate (48% K_2O) at 240 kg/ha were added in three equal doses. The first dose was applied 45 day after planting, the second dose applied after one month after the first dose and the third dose after the first cut. Geranium plants were harvested twice by cutting the vegetative parts, 10-15 cm above the soil surface. The first cut and second cut (harvest) were done on 20th May and 15th October at the first season, respectively. In the second season, the first and second cut (harvest) was done on 15th May and 5th October, respectively.

2.2 The Following Parameters were Measured

2.2.1 The total fresh weight (ton ha^{-1})

The weight of the harvested plants is then recorded in tonnes per hectare (ton/ha). which is calculated by dividing the total weight of the plants by the area of land from which the plants were harvested.

2.2.2 Essential oil percentage (%)

Essential oil percentage (%) was determined in fresh plants of the two cuts according to the method described by [30]. In addition, essential oil samples of the 2nd cut during the 2nd season were subjected to gas-liquid chromatography (GLC) according to the methods of [31,32].

Table 1. Soil moisture parameters of the experimental site

	Soil moisture constants						
Depth	**Field capacity (FC)**		**Wilting point (WP)**		**Available water (AW)**		**Bulk density (BD) Mg/m^3**
	% weight	**Cm**	**% weight**	**cm**	**% weight**	**cm**	
0-15	38.9	6.94	18.2	3.25	20.7	3.69	1.19
15-30	36.5	6.57	17.1	3.11	19.4	3.49	1.20
30-45	33.9	6.46	16.5	3.14	17.4	3.31	1.27
45-60	32.8	6.84	16.4	3.42	16.4	3.42	1.39
Total		26.81		12.92		13.91	

2.2.3 Chemical analysis of proline contents

Chemical analysis of proline contents in dry leaves was determined according to Bates et al. [33].

2.2.4 Water relations

Soil moisture content was gravimetrically determined in soil samples taken from consecutive depths of 15 cm down to 60 cm. Soil samples were collected just before each irrigation, and 48 hours after irrigation to calculate the following:

2.2.4.1 Amount of applied irrigation water (AIW):

A submerged flow orifice with fixed dimension was used to measure the amount of water applied, according to Michael [34] as follows:

$$Q = CA\sqrt{2gh}$$

Where:

Q = discharge through orifice, (1/sec); C = coefficient of discharge, (0.61); A= cross-sectional area of the orifice, cm^2; G = acceleration due to gravity, (981 cm/sec.^{2}); H = pressure head, causing discharge through the orifice, (cm).

2.2.4.2 Crop water productivity (WP)

WP is defined as crop yield per unit of applied irrigation water, which determines the efficient use of applied irrigation water Zhang [35] and is given as follows:

$$WP = \frac{Yield\ (ton/ha)}{Seasonal\ AIW\ (m3\ water\ applied/ha)}$$

2.2.5 Effect of different treatments of humic acid on CMV concentration

Enzyme-Linked Immunosorbent Assay (ELISA) was used to detect the concentration of CMV in naturally infected geranium plants according to the method described by Zehnder et al. [36]. Leaves that showed viral-like symptoms (mosaic, chlorosis, and mottling) were collected from the top of the geranium plants to detect virus infection. 200 ml of CMV-specific immunoglobulin G (IgG) at a concentration of 1 mg ml-1 were diluted in coating buffer pH 9.6 and incubated in the microtitre plate at 4°C overnight. The wells were washed three times with washing buffer pH 7.4 [phosphate buffer saline (0.15 M NaCl) containing 0.1% tween 20 and 0.01% sodium azide]. 200 ml of each sample was diluted 1 to 20 (w v-1) in extraction buffer (0.01 M PBS pH 7.4 containing 0.05% Tween-20, 2% polyvinyl pyrrolidine, M.wt. 40,000) and then incubated at 4°C overnight. The plate was washed three times with washing buffer (PBS-T). 200 ml of IgG alkaline phosphate conjugate diluted at 1/100 in conjugate buffer pH 7.0 (phosphate buffer saline, bovine serum albumin (BSA) 1%, Tween 0.25%) was added to each well and incubated for 3 hours at 37°C. The conjugate was removed and the plate was washed three times with washing buffer (PBS-T). 200 ml of the freshly prepared substrate (P-nitro phenyl phosphate in substrate buffer (10% di ethanol amine, NaNO3 0.01%) at a concentration of 0.75 mg ml-1 was added to each well. The reaction was readied spectrophotometrically at 405 nm after incubation at 37°C for 30 and/or 60 minutes using vnusken ELISA reader. The reaction was stopped by adding 50 ml of 3 M NaOH. The absorbance was measured at a wave length of 405 nm using a Sunrise™ TECAN, Switzerland micro plate reader. The ELISA values were considered positive for more than twice of healthy plant values. The ELISA experiment was conducted three times and three replicates (two leaves for each replicate) were used for each test.

2.2.6 Statistical analysis

All collected data were analyzed with analysis of variance (ANOVA) with Tukey's test ($p < 0.05$) procedure using MSTAT-C Statistical Software Package [37]. Differences between means were compared by using Duncan multiple range tests at 0.05 [38].

3. RESULTS AND DISCUSSION

3.1 Effect of Humic Acid and Irrigation amount on Geranium Fresh Yield

The results in Table (2) indicated that there were significant relationships between irrigation treatments, spraying with humic acid and their interaction in both seasons. The results also revealed that application of full irrigation (120% ETo) gave the highest value of geranium fresh yield with humic acid 2.0 cm/L, namely 110.9 ton/ha average over the two growing seasons, compared to no application of humic acid, which attained 67.3 ton/ha. Similar trends were obtained under deficit irrigation treatments in both growing seasons. The table also showed that spraying geranium plants with humic acid 2.0 cm/L under application of 100% or 80% ETo produced fresh yield higher than the value obtained under full irrigation without spraying with humic acid, namely 98.7 and 91.3 ton/ha average over the two growing seasons. This result implied that foliar application humic acid help geranium plants to withstand the effect of water deficiency and maintain reasonable yield.

Similar results were obtained by [39 & 40] who found that herb fresh weight and volatile oil yield of *Pelargonium graveolens* plants were gradually increased with increasing the amounts of the applied irrigation water. Furthermore, [41] indicated that drought stress had a significant effect on the decrease of most of the studied characteristics of aromatic geraniums. The promoting effects of humic acid may be attributed to its role of improving photosynthesis and consequently increasing of the secondary metabolites production [42]. Zaghloul et al. [43] indicated that spraying *Thujaorientalis* plants with humic acid increased its growth compared with no sprayed plants due to the direct effect of humic acid on solubilization and transport of nutrients.

3.2 Effect of Humic Acid and Irrigation on Geranium Essential Oil Yield (liter/ha) and Essential Oil Percentage (%)

3.2.1 The essential oil yield (liter/ha)

Table 3 indicated significant relationships between irrigation treatments, spraying with humic acid and their interaction in both growing seasons. Application of full irrigation (120% ETo) and spraying with 2.0 cm/L humic acid gave the highest value of geranium oil yield, namely 60.93 liter/ha average over the two growing seasons, compared to no application of humic acid, which attained 29.02 liter/ha. Furthermore, under deficit irrigation treatments, application of 2.0 cm/L humic acid gave the highest value under irrigation 80% ETo namely, 64.33 liter/ha average over the two growing seasons, compared to no application of humic acid, which attained 26.14 liter/ha averaged over the two growing seasons(Table 3). This result is in agreement with the findings of [44] who reported that the highest essential oil yield was obtained from plants irrigated every 5 days and fertilized with 1.2 g N/pot and sprayed with 1% K-humate. Also, [45,46] reported that as fresh herb yield decreased under low water application, the oil yield was decreased.

Table 2. Geranium yield (ton/ha) as affected by interaction between irrigation treatments and humic acid in both growing seasons

Treatments	2017/2018				2018/2019			
	FI	DI1	DI2	Mean	FI	DI1	DI2	Mean
H1(Control)	63.50	54.67	47.89	55.35	71.1	60.3	53.8	61.73
H2(1.0 cm/L)	82.69	72.17	64.60	73.15	88.4	75.6	70.8	78.27
H3(1.5 cm/L)	88.13	77.27	70.13	78.51	94	82.6	75.9	84.17
H4(2.0 cm/L)	106.43	94.80	86.79	96.01	115.3	102.6	95.6	104.50
Mean	85.2	74.7	67.4	75.76	92.2	80.3	74.0	82.17
LSD at 5 %								
Irrigation (I)	0.71				0.16			
Humic acid (H)	0.43				0.28			
I X H	0.88				0.49			

FI: Irrigation 120% ETo; DI1: Irrigation 100%ETo; DI2: Irrigation 80% ETo

Table 3. Essential oil yield (liter/ha) as affected by interaction between irrigation treatments and humic acid in both growing seasons

Treatments	2017/2018				2018/2019			
	FI	DI1	DI2	Mean	FI	DI1	DI2	Mean
H1 (Control)	28.38	26.95	25.53	26.95	29.65	28.16	26.74	28.18
H2 (1.0 cm/L)	38.86	36.81	36.63	37.43	38.63	39.84	41.77	40.08
H3(1.5 cm/L)	43.80	43.81	43.69	43.77	45.78	45.68	47.59	46.35
H4(2.0 cm/L)	59.60	58.11	60.49	59.40	62.26	60.84	68.16	63.76
Mean	42.66	41.42	41.59	41.89	44.08	43.63	46.07	44.59
LSD at 5 %								
Irrigation (I)	0.13				0.75			
Humic A (H)	0.34				0.56			
I X H	0.6				0.98			

FI: Irrigation 120%; DI1: Irrigation 100%; DI2: Irrigation 80 %of evapotranspiration (ETo).

Table 4. Essential oil percentage (%) at affected by interaction between irrigation treatments and humic acid in both growing seasons

Treatments	2017/2018				2018/2019			
	FI	DI1	DI2	Mean	FI	DI1	DI2	Mean
H1 (Control)	0.45	0.49	0.53	0.49	0.42	0.47	0.50	0.46
H2 (1.0 cm/L)	0.47	0.51	0.57	0.52	0.44	0.53	0.59	0.52
H3(1.5 cm/L)	0.50	0.57	0.62	0.56	0.49	0.55	0.63	0.56
H4(2.0 cm/L)	0.56	0.61	0.70	0.62	0.54	0.59	0.71	0.62
Mean	0.49	0.55	0.61	0.55	0.47	0.54	0.61	0.54
LSD at 5 %								
Irrigation (I)	0.00				0.01			
Humic A (H)	0.01				0.01			
I X H	NS				0.02			

FI: Irrigation 120%; DI1: Irrigation 100%; DI2: Irrigation 80 %of evapotranspiration (ETo)

3.2.2 Percentage of essential oil of geranium

The results in Table 4 indicated significant relationships between irrigation treatments, spraying with humic acid and their interaction in the first growing seasons and between irrigation treatments, spraying with humic acid in the second season on geranium essential oil percentage. The results also showed that application of full irrigation decreased geranium essential oil percentage under all humic acid treatments in both growing seasons. The highest value of geranium essential oil percentage was found under application of 80% ETo and spraying with 2.0 cm/L humic acid namely 0.71% average over the two growing seasons.

In this context, [43] reported that humate application lead to increase oil content in Thujaorientalis plants. Said-Al Ahl et al. [44] stated that foliar application of K- humate promoted growth and possessed the best oil percentage in oregano plants.

3.2.3 Effect of irrigation and humic acid on proline content

Significant relationships between irrigation treatments, spraying with humic acid and their interaction in both growing seasons on proline contents in geranium tissues were found (Table 5). The results also indicated that the highest contents of proline in geranium plants was found under application of 80%ETo and application of 2.0 cm/L humic acid namely, 3.72 mg/100 g proline average over two growing seasons, compared to no application of humic acid, which attained 3.01 mg/100 g proline average over the two growing seasons. Whereas, the lowest value namely, 2.75 mg/100 g proline was obtained under irrigation with 120% ETo and application of 2.0 cm/L humic acid average over the two seasons. It was reported that proline play a role as osmotic preservation, free radicals scavenger, and second role in maintaining cellular stability and induction of systemic acquired resistance against biotic stresses [47].

Table 5. Proline content (mg/100 g) at affected by interaction between irrigation treatments and humic acid in both growing seasons

Treatments	2017/2018				2018/2019			
	FI	**DI1**	**DI2**	**Mean**	**FI**	**DI1**	**DI2**	**Mean**
H1 (Control)	2.07	2.74	3.03	2.61	2.12	2.72	2.98	2.61
H2 (1.0 cm/L)	2.29	2.73	3.07	2.7	2.3	2.86	3.03	2.73
H3(1.5 cm/L)	2.47	2.95	3.25	2.89	2.55	3.02	3.15	2.91
H4(2.0 cm/L)	2.69	3.01	3.73	3.14	2.81	3.3	3.70	3.27
Mean	2.38	2.86	3.27	2.84	2.45	2.98	3.22	2.88
LSD 5%								
Irrigation (I)	0.08				0.10			
Humic (H)	0.11				0.06			
I X H	0.19				0.18			

FI: Irrigation 120%; DI1: Irrigation 100%; DI2: Irrigation 80 %of evapotranspiration (ETo)

Table 6. Effect of irrigation treatment on the amounts of applied irrigation water (AIW, m^3/ha) and percentage of saved water (IWS %) for geranium plants in the two growing seasons

Irrigation treatments	AIW (m^3/ha)	IWS%
2017/2018		
FI	15155	-
DI_1	12168	20
DI_2	9334	38
2018/2019		
FI	15218	-
DI_1	12298	19
DI_2	9678	36

FI: Irrigation 120%; DI1: Irrigation 100%; DI2: Irrigation 80 % of evapotranspiration (ETo)

3.2.4 Water requirements for geranium plants

3.2.4.1 Applied irrigation water to geranium

The results in Table 6 indicated that the amount of applied irrigation water for geranium plants 15155, 12168 and 9334 m^3/ha in first growing season and were 15218, 12298, and 9678 m^3/ha in second growing season under 120, 100, and 80 ETo, respectively. Application of 100% ETo resulted in 20% water saving, whereas application of 80% ETo saved 38% of the applied irrigation water, compared to 120% ETo average over the two seasons.

3.2.4.2 Geranium yield losses under deficit irrigation and humic acid treatments

The results in Table 7 showed that geranium yield losses were lower in the first season, compared to its counterpart values in the second season which can be attributed to climate variability between the two seasons. The lowest values of geranium yield reduction percentage under 100% and 80% ETo were 11 and 17%, respectively under application of 2.0 cm/L humic acid averaged over the two growing seasons. Furthermore, application of 2.0 cm/L humic acid resulted in lower yield losses under both deficit irrigation treatments, compared to yield loss under application of 120% ETo and spraying with 2.0 cm/L humic acid.

3.2.4.3 Water productivity (WP) to geranium

Table 8 showed that the highest values of WP were attained under irrigation with 80% ETo, namely 9.31 and 9.88 kg/ha in both growing seasons under application humic acid with 2.0 cm/L. While, the lowest values were found under irrigation 120% ETo with no application of humic acid namely 4.19 and 4.67 kg/ha in the both growing seasons.

3.2.5 Effect of different treatment of humic acid on CMV concentration

Cucumber Mosaic Virus accumulation (biotic stress) in systemically naturally infected geranium plants was determined by ELISA (Table 9). The results declared that CMV Concentration decreased significantly in plants treated with humic acid compared to control (C). The most pronounced effect was achieved by

Table 7. Geranium yield losses (YR%) as a result application of deficit irrigation treatments under foliar applications of humic acid in both growing seasons

Humic treatments	Fresh yield (ton/ha)			YR%	
	FI	DI1	DI2	DI1	DI2
2017/2018					
H1 (Control)	63.5	54.7	47.9	14	25
H2 (1.0 cm/L)	82.7	72.2	64.6	13	22
H3(1.5 cm/L)	88.1	77.3	70.3	12	20
H4(2.0 cm/L)	106.4	94.8	86.9	11	18
2018/2019					
H1 (Control)	71.1	60.3	53.8	15	24
H2 (1.0 cm/L)	88.4	75.6	70.8	14	20
H3(1.5 cm/L)	94	82.6	75.9	12	19
H4(2.0 cm/L)	115.3	102.6	95.6	11	17

FI: Irrigation 120%; DI1: Irrigation 100%; DI2: Irrigation 80 % of evapotranspiration (ETo)

Table 8. Water productivity (WP, kg/ha) for geranium plants under different irrigation treatments and humic acid application in two growing seasons

Treatments	FI	DI1	DI2	FI	DI1	DI2
2017/2018				**2018/2019**		
H1 (Control)	4.19	4.50	5.13	4.67	4.90	5.56
H2 (1.0 cm/L)	5.46	5.93	6.92	5.81	6.15	7.32
H3 (1.5 cm/L)	5.81	6.35	7.53	6.18	6.72	7.84
H4 (2.0 cm/L)	7.02	7.79	9.31	7.58	8.34	9.88

FI: Irrigation 120%; DI1: Irrigation 100%; DI2: Irrigation 80 % of evapotranspiration (ETo)

Table 9. Effect of different treatment of humic acid on CMV Concentration (nm) in both growing seasons

Treatments	Virus Concentration (405 nm)	
	2017/2018	2018/2019
H1 (Control)	2.42 a	3.54 a
H2 (1.0 cm/L)	1.89 b	2.02 b
H3(1.5 cm/L)	1.01c	1.56 c
H4(2.0 cm/L)	0.48 d	0..69 d

Means (±SE standard error) followed by different letters (a, b, c, d) are significantly different from each other as indicated by Tukey's test ($p < 0.05$)

applying foliar applications of (2.0 cm /L Humic acid). The highest percentage of CMV Concentration in infected untreated plants was (2.42 and 3.54) in both growing seasons. However, the results showed negative significant correlation between virus concentration and spraying with humic acid in both growing seasons on geranium plants. It was found that under foliar applications of 2.0 cm /L humic acid, virus concentration was decreased to (0.48 and 0.69 nm) over two growing seasons respectively. It was reported that humic acid play a role in decreasing virus concentration, thus induce of systemic acquired resistance against biotic stresses [47-50].

4. CONCLUSIONS

The results of this research indicated that application of 120% under spraying with 2.0 cm/L humic acid to geranium increase its fresh yield. However, application of 80% ETo under spraying with 2.0 cm/L humic acid attained the highest values of geranium essential oil, water productivity and proline production. Whereas, pronounced decrease in CMV Concentration. Therefore, it is recommended to irrigate geranium plants with 80% ETo under spraying with 2.0 cm/L humic acid to conserve irrigation water, increase the productivity of water unit and may be a hopeful strategy to overcome the biotic stresses by triggering the antioxidant defense system to induce systemic acquired resistance.

5. SIGNIFICANCE OF STUDY

The novelty of our work entitled "Effect of foliar humic acids on water productivity, biochemical parameters and biotic stress in Geranium yield" highlighted on application of humic acid on geranium plants to improve essential oil, water productivity under surface irrigation and proline content production to increase biotic stress tolerance and reduce CMV Concentration that may be a hopeful strategy to overcome the biotic stresses by triggering the antioxidant defense system to induce systemic acquired resistance

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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