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EFFECT OF HUMIC ACID AND SOME MICRO NUTRIENTS ON GROWTH, SEED YIELD AND OIL CONTENT OF *BORAGO OFFICINALIS* L. PLANT

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ABSTRACT: Borage (*Borago officinalis* L.) is a yearly herbaceous plant belonging to the *Boraginaceae* family and known as the bee plant or bee bread. Borage is a significant medicinal plant indigenous to the Mediterranean region and has become widespread in many other countries. A factorial experiment was executed to assess the impact of humic acid and micro nutrients on the growth characteristics, chemical composition, and oil production of borage plants. It was carried out at the Experimental Farm of the Horticulture Department, Faculty of Agriculture, Moshtohor, Benha University, through the two consecutive growing seasons of 2020/2021 and 2021/2022. This trial comprised 16 treatments which were the outcome of the combination between soil addition with humic acid at 0 (control), 2, 3 and 4 kg/fed, and foliar spray with water (control), Zn, Fe or Mn at 100 ppm for each one. Results indicated that the treatment of humic acid at 4 kg/fed + Fe at 100 ppm was significantly improved the growth characters including number of branches, fresh and dry weight of herb. The treatment of humic acid at 4 kg/fed + Fe at 100 ppm also produced the greatest values of total nitrogen, phosphorus, potassium and carbohydrate in both seasons. Meanwhile, the treatment of humic acid at 4 kg/fed + Zn at 100 ppm significantly improved the characters including plant height, fresh and dry weights of inflorescences, and seed yield in both seasons. The treatment of humic acid at 4 kg/fed + Zn at 100 ppm gave the highest fixed oil percentage followed by humic acid at 4 kg/fed + Fe at 100 ppm. Exactly 68 compounds were identified and accounted in the components of *Borago officinalis* fixed-seed oil samples of the second season when analyzed by GC-MS. Where the sample resulted from the treatment of humic acid (4 kg/fed) + Fe (100 ppm) recorded 33 compounds. Conversely, the sample resulted from the control treatment recorded 14 compounds.

Keywords: Borage, humic acid, micro nutrients, fatty acid

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INTRODUCTION

Borage (*Borago officinalis* L.) is an annual herbaceous plant belonging to the Boraginaceae family (Adamczyk-Szabela and Wolf, 2024). Also known as the bee plant or bee bread (El-Hafid *et al.*, 2002). The entire plant is covered with coarse, white, stiff bristles. Young leaves are edible or prepared like spinach, although this practice is principally common for plants grown in domestic gardens. The flowers are vibrant both blue and shaped like stars, with conspicuous black anthers forming a cone. The fruit consists of 4 dark brown to black nutlets (Seifzadeh *et al.*, 2020). Borage is a medicinal plant indigenous to the Mediterranean region and has become widespread in many other countries (El-

Rahman *et al.,* 2023). Though native to Europe, Asia Minor, and North Africa, it is cultivated worldwide, with major producers being the UK, Canada, and New Zealand (Galambosi *et al.,* 2014). Its therapeutic properties are esteemed both in modern pharmaceuticals and traditional healing practices. It serves as a potent anti-inflammatory agent, aiding in avoiding colds, bronchitis, and respiratory ailments (Bulgari *et al.,* 2017 and Montaner *et al.,* 2022). Additionally, borage reduces amount of cholesterol and assists in controlling the gut and cardiovascular issues (Gupta and Singh 2010 & Sheikhzadeh *et al.,* 2021). It is used for medicinal and culinary purposes, with recent cultivation focusing on oil production (Asadi-Samani *et al.,* 2014). The agricultural regions for this plant are not clearly outlined. Varieties with blue flowers are prevalent, while those with white flowers are primarily used for culinary purposes (Galambosi *et al.,* 2014). The leaves and flowers comprise multiple bioactive combinations, comprising mucilage, tannin, saponins, pyrrolizidine alkaloids, V.C, Ca, and K (Gupta and Singh, 2010). Additionally, borage seeds yield gamma-linolenic acid, a highly valued dietary supplement (Gilbertson *et al.,* 2014). The global trade volume of borage seeds ranges from 1000 to 2000 tonnes annually, with considerable yearly fluctuations (Galambosi *et al.,* 2014).

Relying exclusively on synthetic fertilizers in continuous intensive cropping systems does not effectively sustain long-term crop productivity. However, incorporating organic amendments alongside chemical fertilizers can significantly enhance soil's physical characteristics, preserve higher soil fertility levels, and result in improved crop yields (Bera *et al*., 2024). This strategy merges the quick nutrient supply offered by chemical fertilizers with the prolonged benefits of organic matter, such as better soil structure, increased water retention, and enhanced microbial activity (Elankavi *et al*., 2020). Among organic compounds, humic acid is one of the most influential molecules, significantly impacting various agronomic parameters and soil attributes (Ampong *et al*., 2022). Humic acid is predominantly formed from the breakdown of plant and animal matter and plays several essential roles in agricultural systems. These roles include enhancing the biological and physical properties of soil qualities by getting better soil texture, structure, microbial activity, and moisture retention (Nardi *et al*., 2021 and Shah *et al*., 2018). Moreover, humic acid functions as a chelating agent, increasing the accessibility of trace components in the soil and facilitating greater nutrient absorption by plants. It also helps mitigate the uptake of hazardous heavy metals by plants (Wu *et al*., 2017). The use of humic acid also boosts crop development by growing the levels of growth-regulating like cytokinin and auxin, which are essential for nutrient metabolism, stress adaptation, and photosynthetic performance (Canellas *et al*., 2020 and Jindo *et al*., 2020). Furthermore, humic acid positively influences plant cell membranes, improving mineral transport, enhancing protein synthesis, increasing enzyme activity, reducing the impact of harmful elements, and supporting a more robust microbial community (Khaled and Fawy, 2011).

Micro nutrients are vital trace elements that plants need in small amounts to achieve ideal development and reproduction. Nevertheless, these amounts are minimal, they are crucial for numerous biochemical and physiological functions. These elements play essential roles in processes such as enzyme activation, chlorophyll production, and nutrient assimilation, making them indispensable for the as a whole health and vigor of plants (Ahmed, 2024). Micronutrients are essential for sustaining the as a whole robustness and vigor of plants. They are integral to numerous physiological and biochemical functions, each contributing distinctively to the enhancement of plant health and efficiency (Aftab and Hakeem, 2020). These minor elements, usually present in low concentrations, are essential for the activation and support of enzymes that drive crucial metabolic pathways (Gomes *et al*., 2020).

Iron (Fe) is not merely a fundamental element; it is crucial for a multitude of enzymatic processes. Its involvement is essential for the optimal functioning of biological mechanisms such as photosynthesis, cellular respiration, and nitrogen fixation (Li *et al*., 2021). Decreased levels of iron can disrupt these systems, leading to reduced plant health (Herlihy *et al.*, 2020).

Similarly, zinc (Zn) is integral to various physiological processes, comprising nucleic acid synthesis and carbohydrate metabolism, making it indispensable for cellular activities (Balandrán-Valladares *et al*., 2021). Zinc (Zn) is actively engaged in the biosynthesis of auxins and phytohormones that control cell expansion, root architecture, and the regulation of flowering initiation (Balafrej *et al.,* 2020; Otiende *et al.*, 2021 and Tripathi *et al.,* 2022). Disruptions in zinc concentrations can thus produce cascading effects on plant developmental processes and overall growth trajectories (Suganya *et al.*, 2020).

Manganese (Mn) is crucial for the biosynthesis of compounds that maintain cellular structural stability. Additionally, it serves as a critical component in reinforcing plant antioxidant mechanisms, thereby safeguarding against potential environmental stresses (Ghorbani *et al.*, 2019 and Ye *et al.*, 2019).

The main aim of this work is to study the effect of humic acid and micro nutrients on the growth characteristics, chemical composition, and oil content of borage plants (*Borago officinalis* L.).

MATERIALS AND METHODS

A factorial experiment was performed to assess the role of humic acid and micro nutrients on the growth characteristics, chemical composition, and oil production of borage plants. It was carried out at the Experimental Farm of the Horticulture Department, Faculty of Agriculture, Moshtohor, Benha University, during the two consecutive growing seasons of 2020/2021 and 2021/2022.

Materials:

Borage seeds were directly sown in soil on the second of October 2020 and 2021 within plots measuring 1×1 meters. Each plot comprised 2 rows spaced 50 cm apart, with 50 cm between individual plants. Seeds of Borage were obtained from Horticulture Department Station, Faculty of Agriculture, Benha University. Fertilization involved the application of calcium superphosphate (15.5% P_2O_5) at a rate of 100 kg per feddan, ammonium sulfate (20.5% N) at 100 kg per feddan, and potassium sulfate (48% K_2O) at 50 kg per feddan (AzzEl-Din and Hendawy, 2010). Phosphorus was added during soil preparation, while nitrogen was applied in February and then in March, across both growing seasons. Potassium sulfate was added at three doses, the first one was added during soil preparation, the second one was added after two weeks from thinning, while the third dose was added after two weeks from the second one during two seasons.

The procedures outlined by Jackson *et al.* (1973) and Black *et al.* (1982) were utilized to assess the physical and chemical characteristics of the experimental soil. Table (1) summarizes the results of the soil analysis for both seasons. Furthermore, chemical analyses were conducted on the soil prior to the commencement of each season to evaluate factors such as organic matter content, calcium carbonate levels, available nitrogen, phosphorus, and potassium, as well as pH and electrical conductivity.

Layout of the experimental:

The experiment followed a randomized complete block design with three replications for each treatment, each treatment represented by three plots with four plants for each plot. This experiment included 16 treatments resulted from the combination between humic acid at addition (0, 2, 3 and 4 kg/fed, and spraying with water (control), Zn, Fe or Mn at 100 ppm for each one. Humic acid was added

Table 1. Chemical and physical characteristics of the experimental soil.

Parameters	2020/2021	2021/2022
	Mechanical Properties	
Coarse sand (%)	8.9	5.9
Fine sand (%)	13.8	12.2
Loam (%)	22.1	23.0
Clay (%)	55.2	59.0
Textural class	Clay loam	Clay loam
	Chemical Analysis	
Organic matter (%)	1.78	1.82
Calcium carbonate (%)	0.84	0.98
Available nitrogen (mg Kg^{-1})	0.67	0.73
Available phosphorus (mg kg^{-1})	0.43	0.39
Available potassium (mg kg^{-1})	198	209
pH water (1:1)	7.67	7.58
Electrical conductivity (dS/m)	0.95	0.75

as soil drench at three equal doses, the first one was done during soil preparation, the second one was conducted after one week from thinning, while the third one was carried out after two weeks from the second one during both seasons.

Three kinds of microelements, Zn EDTA (13%), Fe EDTA (13%) and Mn EDTA (13%) at 100 ppm were foliar sprayed early in the morning at three times, the first spray was carried out after one week from thinning and at three weeks intervals. Control plants were sprayed with distilled water.

Sampling:

Vegetative growth parameters were estimated just before flowering parameters were taken at full blooming in the two seasons. Besides, seed yield parameters were estimated at the end of the experiment. Chemical composition parameters were determined two weeks after the last spray treatments in the two seasons.

During each of the two growth seasons, the following traits were measured:

Growth, florescence and seed yield Parameters:

Plant height (cm), number of branches, vegetative fresh and dry weights (g/plant), inflorescences fresh and dry weights (g/plant), seed yield (kg/fed), fixed oil % and fixed oil yield (l/fed) were determined. In order to prevent seed loss during maturation, the seeds were harvested as soon as they started to ripen, let to dry, and then weighed.

Chemical Composition:

Leaf N%, P%, K% and total carbohydrate were determined according to Horneck and Miller (1998), Hucker and Catroux (1980), Horneck and Hanson (1998) and Herbert *et al.* (1971), respectively.

Extraction of fat, and determination of fatty acids of oil:

The AOAC (1984) techniques were followed in order to extract a fixed oil percentage from borage seed using hexane in a Soxcelt system HT apparatus.

Gas chromatography-mass spectrometry (GC/MS) analysis:

A GC (Agilent Technologies 7890A) with a mass-selective detector running on an HP-5ms capillary column (30 µm x 0.25 mm i.d. and 0.25 µm film thickness) was used at the Regional Center for Food and Feed (RCFF), ARC, Giza, Egypt to determine the methanolic extract. At a pace of 3 degrees Celsius per minute, the temperature was raised from 80 to 230 degrees. Helium was the carrier gas, flowing at a rate of 1 milliliter per minute. The process of bioactive chemical identification involved computer matching with the National Institute Standard and Technique database, as well as comparing the mass spectra and retention times of the compounds with those of genuine standards.

Statistical analysis:

Analysis of variance (ANOVA) was used to examine the values of all the data that were gathered as part of factorial investigations carried out in a complete randomized block design. $LSD_{5\%}$ test and Duncan multiple range test were used to differentiate means according to Snedecor and Cochran (1991).

RESULTS AND DISCUSSION

It is clear that treating *Borago officinalis* plants with humic acid and some micro nutrients increased vegetative growth, flowering, seed yield and chemical composition parameters compared with the control (without any addition).

Vegetative Characteristics:

Table (2) findings clearly show that the plant height was greatly affected by the utilization of humic acid and some micro nutrients. Results suggested that the plant height of borage was significantly ($P<0.05$) affected by zinc or Manganese or Iron in addition to humic acid at different levels. It was found that studied fertilization treatments progressively heightened the plant height of *Borago officinalis* L. plant when compared with control in both seasons. Nevertheless, the treatment of humic acid at 4 kg/fed + Zn at 100 ppm had the positive effect. These results agree with those obtained by Memon *et al.* (2014) on *Phlox Paniculata* plants, Mohamed and Ghatas (2020) on *Salvia hispanica*, Omar (2020) on caraway plants, Vafa *et al.* (2020) on summer savory plants, Zghair *et al.* (2021) on *Rosmarinus officinalis* plants, Tawfik (2022) on *Foeniculum vulgare*, Hoseini *et al.* (2023) on *Ocimum basilicum*, Kazemi *et al.* (2023) on *Physalis alkekengi* plant, Khosravi *et al.* (2023) on *Salvia officinalis* plants, Korani *et al.* (2023) on *Cichorium intybus*, Mubarak *et al.* (2023) on Japanese cabbage Plants.

The treatment of humic acid at 4 kg/fed + Fe at 100 ppm significantly improved the growth characters including number of branches, fresh and dry weights of herb. In this respect, the greatest number of branches were 23.04 and 24.29 in the first and second seasons respectively, when compared with control (12.92 and 13.12). The highest increment in fresh weight of herb was 1102 and 1410 g/plant, respectively in both seasons when compared with control (713.33 and 885 g/plant, respectively). As well as that dry weight of herb was 197.33 and 266 g/plant, respectively in both seasons when compared with untreated plants (control) (127 and 164.3 g/plant).

These results agree with those obtained by El-Gohary *et al.* (2014) on *Mentha piperita*, Azizi and Safaei (2017) on *Nigella sativa*, Dukpa *et al.* (2017) on *Ipomoea reptans*, Aghdasi *et al.* (2018) on *Vigena radiate*, Bastani *et al.* (2018) on tobacco plants, Ayobizadeh *et al.* (2019) on sesame cultivars, Cieschi *et al.* (2019) on *Glycine max*, Davoodi *et al.* (2020) on *Nigella sativa*, ¸Sim¸sek and Çelik (2021) on *Spinacia oleracea*, Hayati *et al.* (2022) on Nigella sativa, Turan *et al.* (2022) on *Spinacia oleracea*.

Chemical composition:

Total nitrogen percentage:

Data displayed in Table (3) suggested that, the total nitrogen percentage was profoundly impacted by the humic acid and some micro nutrients treatments; it was found that studied fertilization treatments progressively increased the total nitrogen percentage of *Borago officinalis* L. plant when compared with control in both seasons of study. However, the treatment of humic acid at 4 kg/fed + Fe at 100 ppm produced the maximum total nitrogen percentage in both seasons (2.727, 2.773) respectively, subsequently in descending order by utilizing the treatment of humic acid at 4 kg/fed + Zn at 100 ppm (2.693, 2.680), respectively in the

Table 2. Effect of humic acid and some micro nutrients on vegetative growth of *Borago officinalis* plants during 2020/2021 and 2021/2022 seasons.

Humic acid treatments	Micronutrient treatments									
	0 (Control)	Zn 100 ppm	Fe 100 ppm	Mn 100 ppm	Mean	0 (Control)	Zn 100 ppm	Fe 100 ppm	Mn 100 ppm	Mean
	Plant Height (cm)					No. of branches/ plant				
	First season									
0 (Control)	81.79^{I}	84.27^{FG}	83.72^{GH}	82.91^{H}	83.17^{D}	12.92^{I}	13.75^{I}	15.52^{FG}	14.91^{GH}	14.28^{D}
2 kg/fed	84.41^{FG}	88.05^{E}	85.24^{F}	84.98^{F}	85.67^{C}	14.64^{H}	16.28^{F}	17.79^{E}	16.33^{F}	16.26^{C}
3 kg/fed	90.61^{D}	97.04^{B}	94.05^{C}	93.04^{C}	93.69^{B}	16.21^{F}	18.04^{E}	22.01^{B}	20.56^{C}	19.21^{B}
4 kg/fed	93.24^{C}	104.85^{A}	96.04^{B}	94.03^{C}	97.04^{A}	17.58^{E}	19.24^{D}	23.04^{A}	21.84^{B}	20.43^{A}
Mean	87.51^{D}	93.55^{A}	89.76^{B}	88.74^{C}		15.34^{D}	16.83^{C}	19.59^{A}	18.41^{B}	
$LSD_{0.05}$	A: 0.5356	B: 0.6634	A×B: 1.071			A: 0.4313	B: 0.5471	A×B: 0.8675		
	Second season									
0 (Control)	85.36^{J}	92.30^{FG}	89.96^{HI}	89.03^{I}	89.16^{D}	13.12^{K}	15.02^{J}	17.09^{GH}	16.14^{HI}	15.34^{D}
2 kg/fed	91.08^{GH}	97.02^{DE}	93.75^{F}	90.88^{GH}	93.18^{C}	15.65^{IJ}	15.87^{IJ}	19.06^{CDE}	18.05^{EFG}	17.16^{C}
3 kg/fed	96.21^{E}	106.70^{B}	103.22^{C}	97.98^{D}	101.03^{B}	17.18^{FG}	18.28^{DE}	23.43^{A}	19.66^{C}	19.64^{B}
4 kg/fed	103.47^{C}	112.09^{A}	108.21^{B}	104.63^{C}	107.10^{A}	18.14^{EF}	19.31^{CD}	24.29^{A}	20.85^{B}	20.65^{A}
Mean	94.03^{D}	102.03^{A}	98.79^{B}	95.63^{C}		16.02^{D}	17.12^{C}	20.97^{A}	18.68^{B}	
$LSD_{0.05}$	A: 0.2664	B: 0.8726	A×B: 1.686			A: 0.5173	B: 0.5977	A×B: 1.035		
	Fresh weight of herb/plant (g)					Dry weight of herb/ plant (g)				
	First season									
0 (Control)	713.33^{M}	801.67^{I}	792.67^{J}	763.67^{L}	767.84^{D}	127.00^{L}	145.00^{I}	141.67^{J}	136.00^{K}	137.42^{D}
2 kg/fed	782.00^{K}	892.67^{F}	898.33^{F}	817.67^{H}	847.67^{C}	140.67J	161.00^{F}	161.33^{F}	146.00^{I}	152.25^{C}
3 kg/fed	871.00^{G}	983.33^{C}	986.33^{C}	937.00^{E}	944.42^{B}	155.00^{H}	174.67^{D}	175.00^{D}	167.00^{E}	167.92^{B}
4 kg/fed	892.00^{F}	1072.67^{B}	1102.00^{A}	963.00^{D}	1007.42^{A}	158.33^{G}	195.00^{B}	197.33^{A}	184.67^{C}	183.83^{A}
Mean	814.58^{D}	937.59^{B}	944.83^{A}	870.34^{C}		145.25^{C}	168.92^{A}	168.83^{A}	158.42^{B}	
$LSD_{0.05}$	A: 3.535	B: 3.957	A×B: 7.070			A: 1.130	B: 1.698	A×B: 2.260		
	Second season									
0 (Control)	885^{O}	963^{K}	943^{L}	914.67^{N}	926.42^{D}	164.3^{I}	181.7^{G}	186.3^{F}	173.7^{H}	176.5^{D}
2 kg/fed	924.33^{M}	1109.33^{H}	1083^{I}	984.33^{J}	1025.25^{C}	175.7^{H}	209.7^{D}	204^{E}	185.3^{FG}	193.68^{C}
3 kg/fed	1080.33^{I}	1311^{C}	1293.67^{D}	1117.67^{G}	1200.67^{B}	204.3^{E}	247.3^{B}	246^{B}	211.7^{D}	227.33^{B}
4 kg/fed	1124.33^{F}	1383.67^{B}	1410^{A}	1217^{E}	1283.75^{A}	211.7^{D}	262.3^{A}	266^{A}	233.3^{C}	243.33^{A}
Mean	1003.50^{D}	1191.75^{A}	1182.42^{B}	1058.42^{C}		189^{C}	225.25^{A}	225.58^{A}	201^{B}	
$LSD_{0.05}$	A: 2.887	B: 6.158	A×B: 5.773			A: 1.877	B: 2.622	A×B: 3.755		

Table 3. Effect of humic acid and some micro nutrients on chemical composition of *Borago officinalis* plants during 2020/2021 and 2021/2022 seasons.

Humic acid treatments	Micro nutrient treatments									
	0 (Control)	Zn 100 ppm	Fe 100 ppm	Mn 100 ppm	Mean	0 (Control)	Zn 100 ppm	Fe 100 ppm	Mn 100 ppm	Mean
			N %					**P %**		
					First season					
0 (Control)	2.143^{N}	2.210^{L}	2.237^{K}	2.180^{M}	2.193^{D}	0.222^{H}	0.219^{H}	0.227^{GH}	0.218^{H}	0.222^{D}
2 kg/fed	2.327^{J}	2.377^{I}	2.417^{H}	2.497^{G}	2.405^{C}	0.232^{FGH}	0.247^{CDEF}	0.241^{DEFG}	0.239^{EFG}	0.240^{C}
3 kg/fed	2.571^{F}	2.617^{C}	2.587^{EF}	2.593^{DE}	2.592^{B}	0.252^{BCDE}	0.259^{ABC}	0.263^{ABC}	0.258^{ABCD}	0.258^{B}
4 kg/fed	2.617^{C}	2.693^{B}	2.727^{A}	2.610^{CD}	2.662^{A}	0.265^{AB}	0.269^{AB}	0.272^{A}	0.267^{AB}	0.268^{A}
Mean	2.415^{C}	2.474^{B}	2.492^{A}	2.470^{B}		0.2428^{A}	0.2485^{A}	0.2508^{A}	0.2457^{A}	
LSD$_{0.05}$	A: 0.008426		B: 0.009989	A×B: 0.01685		A: 0.008426		B: 0.009989	A×B: 0.01685	
					Second season					
0 (Control)	2.197^{L}	2.283^{H}	2.257^{I}	2.237^{JK}	2.244^{D}	0.208^{F}	0.212^{F}	0.220^{EF}	0.213^{F}	0.213^{C}
2 kg/fed	2.250^{IJ}	2.230^{K}	2.343^{G}	2.290^{H}	2.278^{C}	0.219^{EF}	0.231^{DE}	0.239^{CD}	0.219^{EF}	0.227^{B}
3 kg/fed	2.483^{F}	2.567^{E}	2.627^{C}	2.597^{D}	2.569^{B}	0.243^{BCD}	0.242^{BCD}	0.257^{AB}	0.253^{ABC}	0.248^{A}
4 kg/fed	2.587^{D}	2.680^{B}	2.773^{A}	2.563^{E}	2.651^{A}	0.250^{BC}	0.257^{AB}	0.268^{A}	0.250^{BC}	0.256^{A}
Mean	2.379^{D}	2.440^{B}	2.500^{A}	2.422^{C}		0.230^{B}	0.236^{B}	0.246^{A}	0.234^{B}	
LSD$_{0.05}$	A: 0.008426		B: 0.009989	A×B: 0.01685				A: 0.008426	B: 0.009989	
			K %					**Total Carbohydrate %**		
					First season					
0 (Control)	1.340^{K}	1.387^{J}	1.410^{I}	1.347^{K}	1.371^{D}	14.87^{L}	15.27^{K}	15.77^{J}	14.93^{L}	15.21^{D}
2 kg/fed	1.390^{J}	1.487^{G}	1.587^{D}	1.463^{H}	1.482^{C}	15.90^{L}	16.87^{H}	17.07^{G}	16.37^{I}	16.55^{C}
3 kg/fed	1.463^{H}	1.517^{F}	1.670^{B}	1.533^{EF}	1.546^{B}	17.17^{FG}	17.93^{D}	18.13^{C}	17.27^{F}	17.63^{B}
4 kg/fed	1.527^{EF}	1.637^{C}	1.720^{A}	1.543^{E}	1.607^{A}	17.67^{E}	18.40^{B}	18.77^{A}	18.10^{C}	18.24^{A}
Mean	1.430^{D}	1.507^{B}	1.597^{A}	1.472^{C}		16.40^{D}	17.12^{B}	17.44^{A}	16.67^{C}	
LSD$_{0.05}$	A: 0.008426		B: 0.009989	A×B: 0.01685		A: 0.07050		B: 0.1094	A×B: 0.1410	
					Second season					
0 (Control)	1.513^{DE}	1.463^{EF}	1.480^{EF}	1.433^{F}	1.472^{C}	15.33^{L}	15.97^{J}	16.33^{HI}	15.63^{K}	15.82^{D}
2 kg/fed	1.463^{EF}	1.513^{DE}	1.500^{EF}	1.470^{EF}	1.487^{C}	16.23^{I}	16.77^{G}	17.27^{F}	16.43^{H}	16.68^{C}
3 kg/fed	1.523^{CDE}	1.580^{BCD}	1.623^{AB}	1.597^{BC}	1.581^{B}	17.80^{E}	18.27^{D}	18.93^{B}	18.10^{D}	18.28^{B}
4 kg/fed	1.590^{BC}	1.633^{AB}	1.687^{A}	1.623^{AB}	1.633^{A}	18.10^{D}	18.27^{D}	19.20^{A}	18.47^{C}	18.51^{A}
Mean	1.522^{B}	1.547^{AB}	1.573^{A}	1.531^{B}		16.87^{D}	17.32^{B}	17.93^{A}	17.16^{C}	
LSD$_{0.05}$	A: 0.03768		B: 0.04467	A×B: 0.07536		A: 0.08426		B: 0.08358	A×B: 0.1685	

both seasons, when compared with control. The lowest value of this parameter was acquired by the treatment of control (2.143, 2.197) respectively, in both seasons.

Total phosphorus percentage:

Data displayed in Table (3) demonstrated that, the total phosphorus percentage was positively affected by the humic acid and some micro nutrients treatments, it was found that studied fertilization treatments progressively increased the total phosphorus percentage of *Borago officinalis* L. plant when compared with control in both seasons. The treatment of humic acid at 4 kg/fed + Fe at 100 ppm produced the maximum total phosphorus in both seasons (0.272,0.268), respectively, descending order by using the treatment of humic acid at 4 kg/fed + Zn at 100 ppm (0.269, 0.257), respectively at the first and second seasons, when compared with control. The least values of this parameter were listed by control (0.222 and 0.208), respectively, in both seasons.

Total potassium percentage:

Data presented in Table (3) indicated that, the total potassium percentage was greatly affected by the humic acid and some micro nutrients treatments; it was found that studied fertilization treatments progressively increased the total potassium percentage of *Borago officinalis* L. plant when compared with control in both seasons of study. However, the treatment of humic acid at 4 kg/fed + Fe at 100 ppm produced the maximum total potassium in both seasons (1.720, 1.687), respectively, followed in descending order by using the treatment of humic acid at 4 kg/fed + Zn at 100 ppm (1.637, 1.633), respectively at the first and second seasons, when compared with control. The lowest value of this parameter was gained by using the treatment of control (1.340, 1.513), respectively, in both seasons.

Total Carbohydrate percentage:

Data offered in Table (3) demonstrated that, the total carbohydrate percentage was enormously affected by the humic acid and some micro nutrient treatments; it was found that studied fertilization treatments progressively increased the total carbohydrate percentage of *Borago officinalis* L. plant when compared with control in both seasons. The treatment of humic acid at 4 kg/fed + Fe at 100 ppm produced the maximum total carbohydrate in both seasons (18.77 and 19.20, respectively), subsequently in a descending sequence by utilizing the treatment of humic acid at 4 kg/fed + Zn at 100 ppm (18.40 and 18.27, respectively in the first and second seasons), when compared with control. The lowest value of this parameter was gained by using the treatment of control (14.87 and 15.33, respectively, in both seasons).

Flowering growth and seeds yield:

From the results listed in Table (4) it is evident that the treatment of humic acid at 4 kg/fed + Zn at 100 ppm significantly improved the characteristics including fresh as well as dry weight of inflorescences, and seed yield in both seasons. The highest increment in fresh weight of inflorescences was 247 and 252 g/plant, respectively in both seasons when compared with control (183.33 and 232 g/plant, respectively). As well as, dry weight of inflorescences was 37.57 and 40.27 g/plant, respectively in both seasons when compared with control (27.20 and 28.93 g/plant). Additionally, in both seasons, it generally showed a greater and statistically significant increase in seed output per faddan when compared to the other ones under examination. It produced 378 and 387 kg/fed respectively, when compared with untreated plants (control) (286 and 369 kg/fed in the first and second seasons, respectively).

Fixed oil percentage and Fixed oil yield/fed (l):

According to the data in Table (5), utilizing humic acid and some micro nutrients treatments had a more significant effect on the fixed oil percentage of borage seeds than the control in both seasons. The treatment of humic acid at 4 kg/fed + Zn at 100 ppm gave the highest fixed oil percentage at 28.57 and 26.90% followed (in descending order) by

Table 4. Effect of humic acid and some micro nutrients on flowering growth and seeds yield of *Borago officinalis* plants during 2020/2021 and 2021/2022 seasons.

Humic acid treatments	Micro nutrient treatments														
	0 (Control)	Zn 100 ppm	Fe 100 ppm	Mn 100 ppm	Mean	0 (Control)	Zn 100 ppm	Fe 100 ppm	Mn 100 ppm	Mean	0 (Control)	Zn 100 ppm	Fe 100 ppm	Mn 100 ppm	Mean
	Fresh W. of flower/plant (g)					Dry W. of flower/plant (g)					Seed yield/ fed (kg)				
								First season							
0 (Control)	183.3^{L}	196.0^{HI}	191.3^{JK}	189.0^{K}	189.9^{D}	27.2^{J}	29.6^{G}	28.4^{HI}	28.1^{I}	28.3^{D}	286^{H}	297^{FG}	293^{GH}	290^{GH}	292^{C}
2 kg/fed	193.3^{IJ}	206.7^{G}	197.0^{H}	194.0^{IJ}	197.7^{C}	28.1^{I}	31.4^{F}	29.4^{G}	28.8^{H}	29.4^{C}	292^{GH}	321^{E}	318^{E}	304^{F}	309^{B}
3 kg/fed	213.0^{E}	233.0^{B}	212.3^{EF}	209.7^{F}	217.0^{B}	31.4^{F}	34.8^{B}	31.4^{F}	31.7^{F}	32.3^{B}	356^{CD}	364^{B}	359^{BCD}	352^{D}	358^{A}
4 kg/fed	217.0^{D}	247.0^{A}	228.0^{C}	217.3^{D}	227.3^{A}	32.9^{D}	37.6^{A}	33.9^{C}	32.4^{E}	34.2^{A}	352^{D}	378^{A}	364^{B}	361^{BC}	364^{A}
Mean	201.67^{C}	220.67^{A}	207.17^{B}	202.5^{C}		29.9^{D}	33.3^{A}	30.8^{B}	30.2^{C}		322^{D}	340^{A}	333.5^{B}	326.75^{C}	
$LSD_{0.05}$	A: 1.4		B: 1.9	A×B: 2.9		A: 0.3		B: 0.3	A×B: 0.5		A: 3.8		B: 6.5	A×B: 7.7	
								Second season							
0 (Control)	185.3^{K}	198.7^{I}	196.7^{I}	192.7^{J}	193.3^{D}	28.9^{J}	31.6^{H}	31.2^{HI}	30.5^{I}	30.6^{D}	294^{K}	312^{H}	308^{I}	302^{J}	304^{D}
2 kg/fed	195.7^{IJ}	216.0^{G}	217.7^{G}	207.3^{H}	209.2^{C}	31.4^{H}	34.3^{F}	34.6^{F}	33.2^{G}	33.4^{C}	326^{G}	341^{E}	337^{F}	326^{G}	333^{C}
3 kg/fed	224.0^{F}	237.7^{C}	231.7^{D}	228.3^{E}	230.4^{B}	35.7^{E}	38.3^{C}	36.5^{DE}	36.3^{DE}	36.7^{B}	358^{D}	372^{BC}	369^{C}	361^{D}	365^{B}
4 kg/fed	232.0^{D}	252.0^{A}	245.7^{B}	237.0^{C}	241.7^{A}	37.0^{D}	40.3^{A}	39.3^{B}	38.6^{BC}	38.8^{A}	369^{C}	387^{A}	375^{B}	371^{C}	376^{A}
Mean	209.2^{D}	226.1^{A}	222.9^{B}	216.3^{C}		33.3^{D}	36.1^{A}	35.4^{B}	34.7^{C}		337^{D}	353^{A}	347^{B}	340^{C}	
$LSD_{0.05}$	A: 1.5		B: 2.7	A×B: 3.0		A: 0.4		B: 0.4	A×B: 0.8		A: 1.9		B: 3.4	A×B: 3.8	

Table 5. Effect of humic acid and some micro nutrients on fixed oil % and fixed oil yield/fed (l) of *Borago officinalis* plants during 2020/2021 and 2021/2022 seasons.

Humic acid treatments	Micro nutrient treatments									
	0 (Control)	Zn 100 ppm	Fe 100 ppm	Mn 100 ppm	Mean	0 (Control)	Zn 100 ppm	Fe 100 ppm	Mn 100 ppm	Mean
	Fixed oil %					Fixed oil yield/fed (l)				
	First season									
0 (Control)	24.60^{K}	25.80^{HI}	25.93^{GH}	25.63^{I}	25.49^{D}	70.43^{P}	76.60^{L}	75.93^{M}	74.07^{N}	74.26^{D}
2 kg/fed	25.17^{J}	26.30^{E}	26.10^{FG}	25.97^{GH}	25.89^{C}	73.33^{O}	84.40^{I}	83.07^{J}	78.73^{K}	79.88^{C}
3 kg/fed	25.97^{GH}	27.80^{C}	27.33^{D}	27.47^{D}	27.14^{B}	89.67^{H}	101.3^{C}	98.03^{E}	96.43^{F}	96.36^{B}
4 kg/fed	26.23^{EF}	28.57^{A}	28.13^{B}	27.93^{C}	27.72^{A}	92.23^{G}	107.8^{A}	102.4^{B}	100.8^{D}	100.81^{A}
Mean	25.49^{D}	27.12^{A}	26.87^{B}	26.75^{C}		81.42^{D}	92.53^{A}	89.85^{B}	87.51^{C}	
$LSD_{0.05}$	A: 0.0843		B: 0.1548	A×B: 0.1685		A: 0.1032		B: 0.07064	A×B: 0.2064	
	Second season									
0 (Control)	23.97^{K}	24.97^{H}	24.67^{I}	24.47^{J}	24.52^{D}	70.40^{O}	77.73^{L}	75.87^{M}	73.77^{N}	74.44^{D}
2 kg/fed	24.67^{I}	25.33^{F}	25.17^{G}	25.30^{FG}	25.12^{C}	80.13^{K}	86.53^{H}	84.70^{I}	83.37^{J}	83.68^{C}
3 kg/fed	25.30^{FG}	26.43^{C}	26.50^{C}	26.27^{D}	26.13^{B}	90.70^{G}	98.33^{C}	97.90^{D}	94.70^{F}	95.41^{B}
4 kg/fed	25.77^{E}	26.90^{A}	26.73^{B}	26.50^{C}	26.48^{A}	95.37^{E}	103.4A	100.2^{B}	98.07^{D}	99.26^{A}
Mean	24.93^{D}	25.91^{A}	25.77^{B}	25.63^{C}		84.15^{D}	91.50^{A}	89.67^{B}	87.48^{C}	
$LSD_{0.05}$	A: 0.0705		B: 0.1094	A×B: 0.1410		A: 0.0923		B: 0.1139	A×B: 0.1846	

humic acid at 4 kg/fed + Fe at 100 ppm at 28.13 and 26.73%. On the other hand, the control is the lowest levels of this factor during both seasons (24.60 and 23.97%).

Also, the maximum and significant increases in fixed oil yield/fed (l) were obtained by the treatment of humic acid at 4 kg/fed + Zn at 100 ppm which gave the highest yield at 107.8 and 103.4 l followed (in descending order) by humic acid at 4 kg/fed + Fe at 100 ppm at 102.4 and 100.2 l. On the other hand, the control yielded the lowest levels of this factor during both seasons (70.43 and 70.40 l) during the first and second seasons.

Main Components of the *Borago Officinalis* L. seed-oil as analyzed and identified by GC-MS:

The main components of *Borago Officinalis* fixed-seed oil (as identified by GC-MS) when affected by humic acid (4 kg/fed) as soil application and foliar spray with Zn, Fe, or Mn at 100 ppm concentration in the second season (2021/2022) are presented in Table (6) and Figs. (1, 2, 3, 4 and 5). While admitting that the result data in Table (6) were not subjected to statistical analysis, still there were clear indicators in the general trends of the obtained results which will be highlighted and stressed in the paragraphs. Exactly 68 compounds were identified and accounted in the components of *Borago Officinalis* fixed-seed oil samples of the second season when analyzed by GC-MS. For the fixed-seed oil resulting from treatment of humic acid (4 kg/fed) + Zn (100 ppm), the number of main compounds identified in plenty were 21 compounds, i.e., 11,13-Eicosadienoic acid methyl ester (2.95%), 1-Decanol (4.63%), 1-Nonyne (1.86 %), 1-Octadecyne (1.16 %), 2-Undecenal (2.65 %), 6,9,12-Octadecatrienoic acid, methyl ester (1.02 %), 7,10-Octadecadienoic acid, methyl ester (41.1%), 8,11,14-Docosatrienoic acid, methyl ester (0.83%), 9,12-Octadecadienoic acid (1.13%), 9-Octadecyne (0.8 %), Camphor (0.89%), cis-11-Eicosenoic acid (7.39 %), Dodecane (1.48 %), Erucic acid

Table 6. Main Components of the *Borago Officinalis* L.seed-oil as analyzed and identified by GC-MS when affected by Humic acid (4 kg/fed) as soil application and foliar spray with Zn, Fe, or Mn at 100 ppm concentration.

Components	Control		Humic acid (4 kg/fed) + Zn (100 ppm)		Humic acid (4 kg/fed) + Fe (100 ppm)		Humic acid (4 kg/fed) + Mn (100 ppm)		Humic acid (4 kg/fed)	
	RT (min)	Area sum %	RT (min)	Area sum %	RT (min)	Area sum %	RT (min)	Area sum %	RT (min)	Area sum %
11,13-Eicosadienoic acid, methyl ester	17.752	3.81	17.7	2.95	3.3	2.5			17.768	2.19
1-Decanol	5.847	3.14	5.7	4.63	5.7	6.23	5.7	1.1	5.712	4.55
1-Decyne	9.275	0.5			9.2	1.94				
1-Docosanol							14.4	1.65		
1-Dodecene					8.9	0.74				
1-Eicosanol							7.7	1.25		
1-Hexadecanol, 2-methyl-									9.2	1.52
1-Nonyne			7.7	1.86						
1-Octadecyne			11	1.16	10.8	2.03				
1-Octanol					3.5	4.37				
1-Tetradecanol					9	0.81	7.2	0.98		
1-Undecen-10-al					11	2.2				
2(10)-Pinene					13.8	6.17	13.8	2.12		
2-Decenal, (E)-										
2-Dodecenal, (E)-					11.1	0.97			7.1	2.12
2-Myristynoic acid							10.8	0.79		
2-Undecenal	9.821	1.84	9.8	2.65	9.8	3.65	9.8	1.22	9.821	1.49
2-Undecenal, E-									11	1.32
3,5-Octadiene, 4,5-diethyl-					11.4	3.01				
3-Pinanol					7	0.84				
6,8-Dimethoxy-4-methyl-4H-					12.7	2.32	12.6	1.56		
6,9,12-Octadecatrienoic acid, methyl ester			17.6	1.02						
7,10-Octadecadienoic acid, methyl ester	18.359	49.07	18.8	41.1			18.65	35.66	18.576	42.41
7-Hexadecyne					9.5	0.87	9.5	1.82		
7-Tetradecene					7.1	3.11				
8,11,14-Docosatrienoic acid, methyl ester	19.458	1.62	19.4	0.83			19.3	1.18	19.376	2.65
9,12-Octadecadienoic acid(Z,Z)-			12.3	1.13						
9-0ctadecenoic acid (Z)-							15.5	0.94		
9-0ctadecenoic acid (Z)-,							4.4	2.38		
9-Octadecyne	10.214	0.62	10.2	0.8	10.2	8.66	10.2	1.22	10.218	0.63
Benzyl oxy tridecanoic acid			3.4	1.72						
Camphor	7.811	1.21	10.4	0.89	10.5	7.11	10.5	1.91	10.489	1.38
cis-11-Eicosenoic acid	20.532	3.91	20.5	7.39			20.6	6.44	20.586	4.9
cis-7-Hexadecenoic acid							9	0.94		
Cyclododecene					9.4	1.35				
Cyclohexane, 1,1,3-trimethyl-					3.9	2.7				
Dodecane			7.1	1.48						
Erucic acid	23.12	1.47	23	1.65			23	2.55	23.047	2.13
Heneicosane					12.4	1.51				
Heptanoic acid					6.2	2.61				
Hexadecanoic acid, methyl ester							15.2	0.49		
Isopropyl linoleate							17.2	2.64		
Methoprene									21.4	1.22
Methyl ɣ-linolenate			13.2	1.87	13.3	5.28			13.302	0.71
Myristic acid							15.1	0.66		
Myristic acid, methyl ester	16.353	0.67	16.3	1.11					16.362	1.43

Continued

Table 6. Continued.

Components	Control		Humic acid (4 kg/fed) + Zn (100 ppm)		Humic acid (4 kg/fed) + Fe (100 ppm)		Humic acid (4 kg/fed) + Mn (100 ppm)		Humic acid (4 kg/fed)	
	RT (min)	Area sum %	RT (min)	Area sum %	RT (min)	Area sum %	RT (min)	Area sum %	RT (min)	Area sum %
Myristoleic acid					7.6	0.8				
Myrtenoic acid, butyl ester					14.5	4.89				
Neopentane					8.5	1.63				
n-Hexadecanoic acid	16.792	21.12	16.9	16.79			17	10.58	16.895	17.53
Nonane					4.8	1.02			3.5	1.5
Octanoic acid	8.648	2.41			8.7	1.63				
Oleic Acid							11.7	0.52	17.3	0.65
Oxiraneoctanoic acid, 3-6ctyl-, cis-							12.3	0.91		
o-Xylene					4.4	4.33			4.4	1.73
Palmitic acid, 2-(tetradecyloxy)ethyl ester									15.8	1.07
Palmitoleic acid							11.9	0.46		
Pentadecanoic acid			15.8	1.57			16.2	13.56		
Phytol							12.1	2.15		
Pinolenic acid					15.7	9.85				
p-Xylene					4.3	1.65				
Rescinnamine									15.4	0.47
Retinal									12.1	0.52
Tetradecanoic acid	14.939	4.98	14.9	1.8					14.967	2.63
Tridecanedial							13.3	0.85		
α-Humulene			13.6	5.62					13.643	3.25
nonanal					7.7	1.65	6.8	1.46		
1-Decene					5.5	1.57				

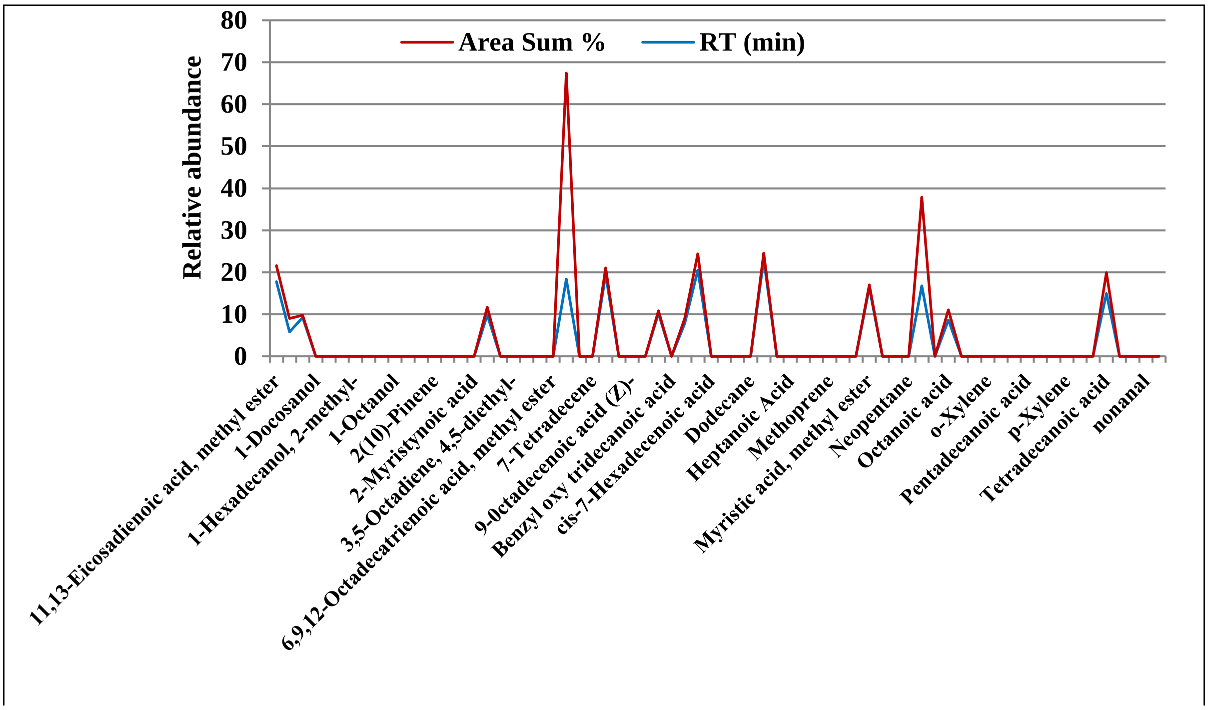

Fig. 1. Chart of GC-mass chromatogram of *Borago Officinalis* L. seed-oil from the plants treated with only water (Control) during the second season (2021/2022).

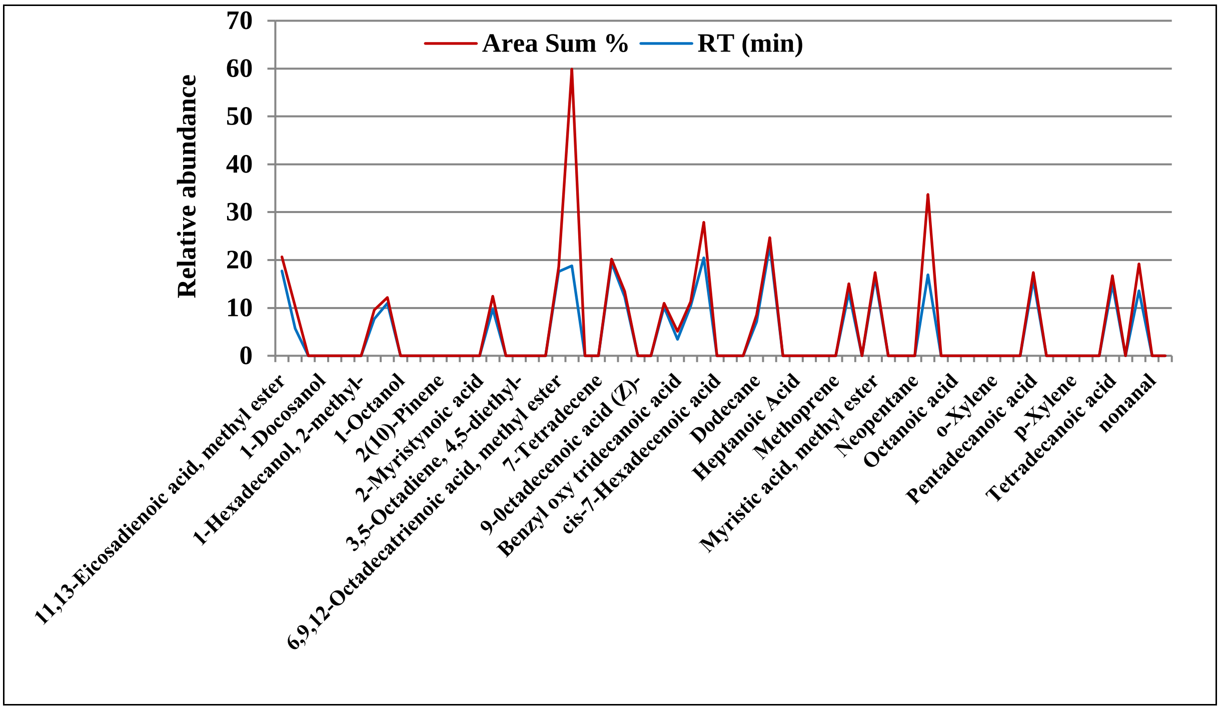

Fig. 2. Chart of GC-mass chromatogram of *Borago Officinalis* L. seed oil from the plants treated with humic acid (4 kg/fed) + Zn (100 ppm) during the second season (2021/2022).

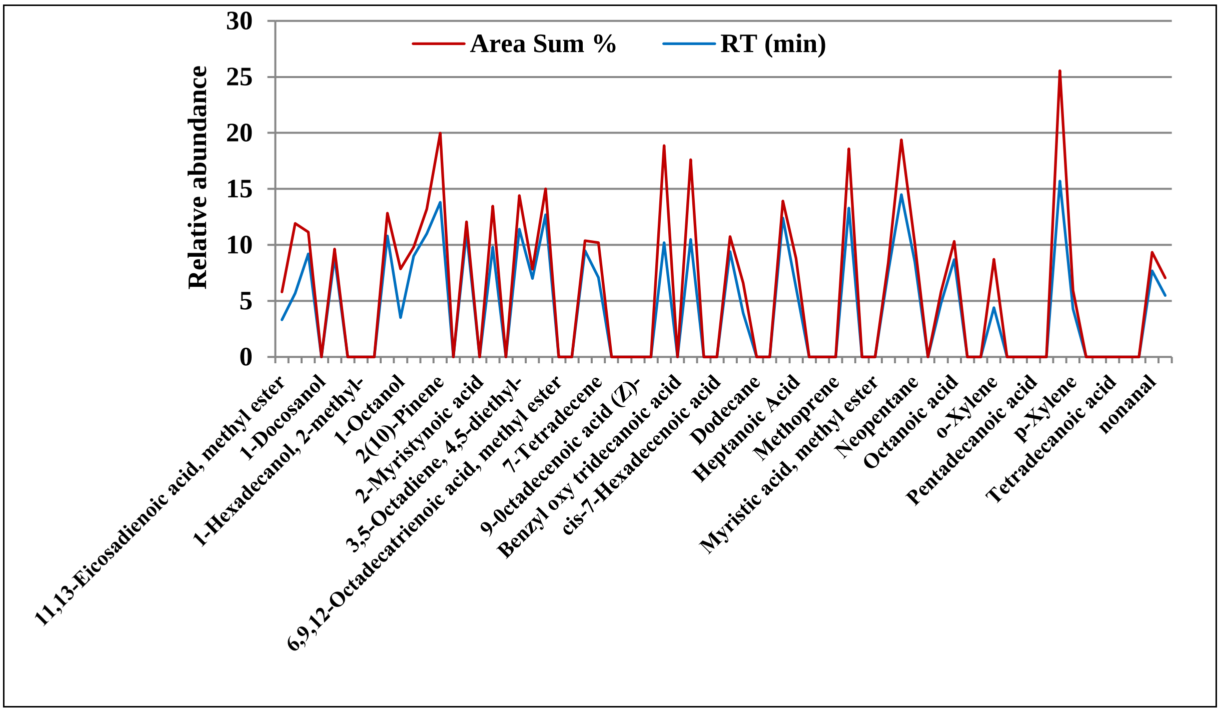

Fig. 3. Chart of GC-mass chromatogram of *Borago Officinalis* L. seed oil from the plants treated with humic acid (4 kg/fed) + Fe (100 ppm) during the second season (2021/2022).

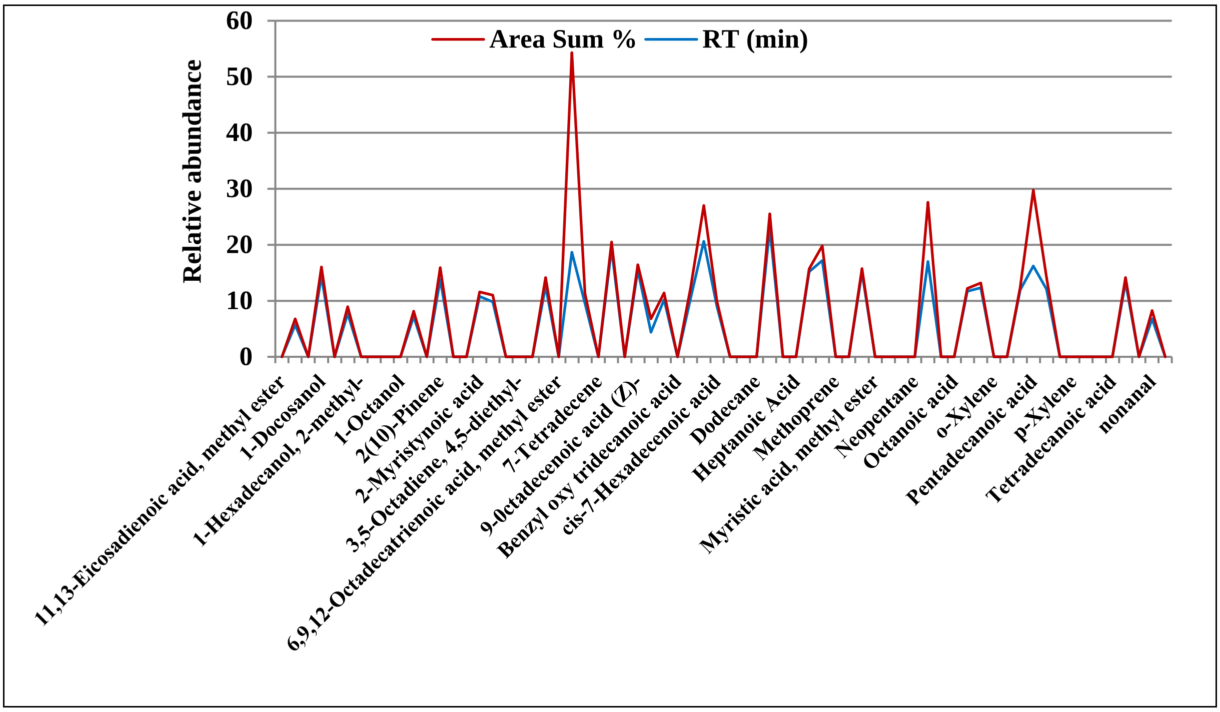

Fig. 4. Chart of GC-mass chromatogram of *Borago Officinalis* L. seed oil from the plants treated with humic acid (4 kg/fed) + Mn (100 ppm) during the second season (2021/2022).

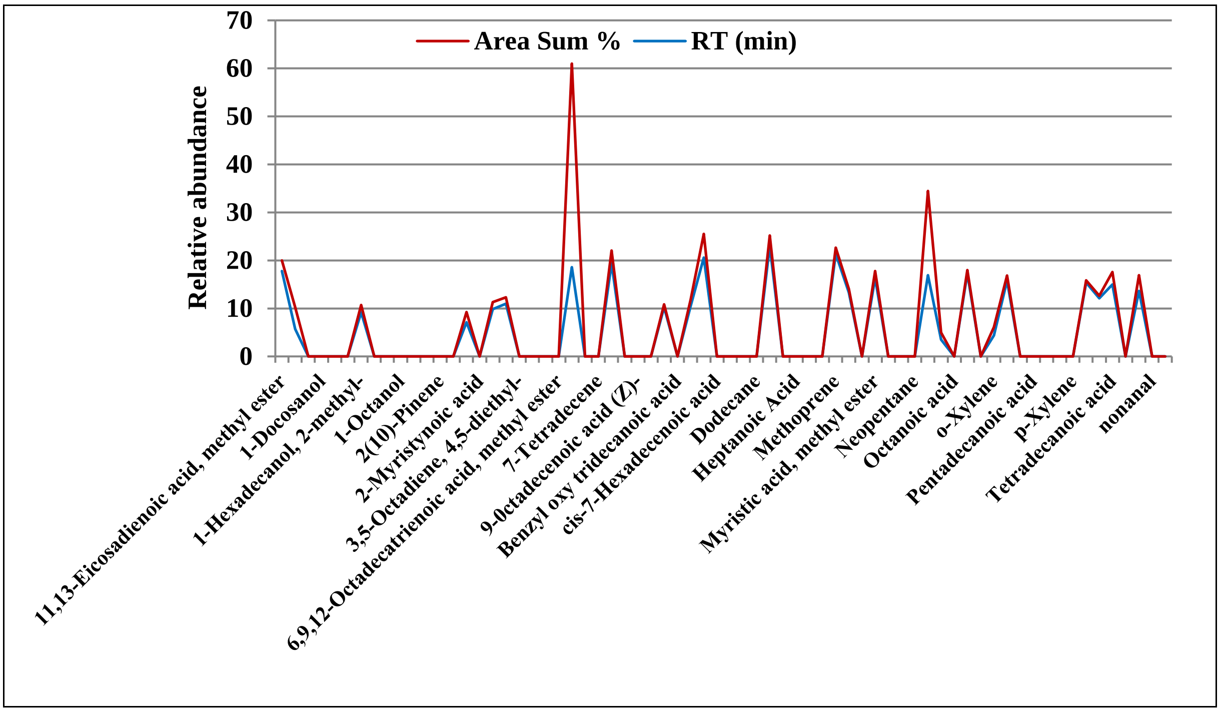

Fig. 5. Chart of GC-mass chromatogram of *Borago Officinalis* L. seed oil from the plants treated with humic acid (4 kg/fed) during the second season (2021/2022).

(1.65%), Methyl ɣ-linolenate (1.87%), Myristic acid (1.11 %), methyl ester, n-Hexadecanoic acid (16.79 %), Pentadecanoic acid (1.57 %), Tetradecanoic acid (1.8 %) and α-Humulene (5.62%).

While the sample resulted from the treatment of humic acid (4 kg/fed) + Fe (100 ppm) recorded 33 compounds, i.e., 11,13-eicosadienoic acid, methyl ester (2.5%), 1-Decanol (6.23%), 1-Decyne (1.94%), 1-Dodecene (0.74%), 1-Octadecyne (2.03%), 1-Octanol (4.37%), 1-Tetradecanol (0.81%), 1-Undecen-10-al (2.2%), 2 (10)-Pinene (6.17%), 2-Dodecenal, (E)- (0.97%), 2-Undecenal (3.65%), 3,5-Octadiene, 4,5-diethyl- (3.01%), 3-Pinanol (0.84%), 6,8-Dimethoxy-4-methyl-4H-chromene (2.32%), 7-Hexadecyne (0.87%), 7-Tetradecene (3.11%), 9-Octadecyne (8.66%), Camphor (7.11%), Cyclododecene (1.35%), Cyclohexane, 1,1,3-trimethyl (2.7%), nonanal (1.51%), 1-Decene (2.61%), Methyl ɣ-linolenate (5.28%), Myristoleic acid (0.8%), Myrtenoic acid, butyl ester (4.89%), Neopentane (1.63%), Nonane (1.02%), Octanoic acid (1.63%), o-Xylene (4.33%), Pinolenic acid (9.85%), p-Xylene (1.65%), Heneicosane (1.65%) and Heptanoic Acid (1.57%). The sample resulted from the treatment of humic acid (4 kg/fed) +Mn (100 ppm) recorded 26 compounds, i.e., 1-Decanol (1.1%),1-Docosanol (1.65%),:1-Eicosanol (1.25%), 1-Tetradecanol (0.98%), 2(10)-Pinene (2.12%),2-Myristynoic acid (0.79%), 2-Undecenal (1.22%), 6,8-Dimethoxy-4-methyl-4H-chromene (1.56 %), 7,10-Octadecadienoic acid, methyl ester (35.66%), 7-Hexadecyne (1.82%), 8,11,14-Docosatrienoic acid, methyl ester (1.18%), 9-0ctadecenoic acid (Z)- (0.94%), 9-0ctadecenoic acid (Z)-, phenylmethyl ester (2.38%), 9-Octadecyne (1.22%), Camphor (1.91%), cis-11-Eicosenoic acid (6.44%), cis-7-Hexadecenoic acid (0.94%), Erucic acid (2.55%), Hexadecanoic acid, methyl ester (0.49%), Isopropyl linoleate (2.64%), Myristic acid (0.66%), n-Hexadecanoic acid (10.58%), Oleic Acid (0.52%), Oxiraneoctanoic acid, 3-6ctyl-, cis- (0.91%), Palmitoleic acid (0.46%), Pentadecanoic acid (13.56%), Phytol (2.15%), Tridecanedial (0.85%) and Nonanal (1.46%).

Furthermore, the sample resulted from the treatment of humic acid (4 kg/fed) recorded 25 compounds, i.e., 11,13-Eicosadienoic acid, methyl ester (2.19 %), 1-Decanol(4.55 %), 1-Hexadecanol, 2-methyl-(1.52 %), 2-Dodecenal, (E)-(2.12 %), 2-Undecenal(1.49 %), 2-Undecenal, E-(1.32 %), 7,10-Octadecadienoic acid, methyl ester(42.41 %), 8,11,14-Docosatrienoic acid, methyl ester(2.65 %), 9-Octadecyne(0.63 %), Camphor(1.38%), cis-11-Eicosenoic acid(4.9 %), Erucic acid (2.13%), Methoprene (1.22%), Methyl ɣ-linolenate (0.71%), Myristic acid, methyl ester(1.43%), n-Hexadecanoic acid (17.53%), Nonane (1.5%), Oleic Acid (0.65%), o-Xylene (1.73%), Palmitic acid, 2-(tetradecyloxy) ethyl ester (1.07%), Rescinnamine (0.47%), Retinal (0.52 %), Tetradecanoic acid (2.63%) and α-Humulene (3.25%). On the other hand, the sample resulted from the control treatment recorded 14 compounds only, i.e., 11,13-Eicosadienoic acid, methyl ester (3.81%), 1-Decanol (3.14%), 1-Decyne (0.5%), 2-Undecenal (1.84%), 7,10-Octadecadienoic acid, methyl ester (49.07%), 8,11,14-Docosatrienoic acid, methyl ester (1.62%), 9-Octadecyne (0.62%), Camphor (1.21%), cis-11-Eicosenoic acid (3.91%), Erucic acid (1.47%), Myristic acid, methyl ester (0.67%), n-Hexadecanoic acid (21.12%), Octanoic acid (2.41%) and Tetradecanoic acid (4.98%).

The main compounds identified in plenty in almost all cases were 11.13-Eicosadienoic acid, methyl ester, 1-Decanol, 2-Undecenal, 9-Octadecyne, Benzyl oxy tridecanoic acid, Camphor and cis-11-Eicosenoic acid. Lastly, only one component viz. 1-Nonyne appeared in the seed oil sample resulting from the treatment of humic acid (4 kg/fed) + Zn (100 ppm).

CONCLUSION

Adding humic acid at 4 kg/fed before sowing as soil application then foliar spraying the plants with Fe or Zn at 100 ppm for 4 times is the best for the growth, flowering characteristics, chemical composition, and oil production of borage plants.

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تأثير حمض الهيوميك وبعض العناصر الغذائية الصغرى على نمو وإنتاجية البذور ومحتوى الزيت في نبات خبز النحل

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يعتبر خبزالنحل (*Borago officinalis* L.) نباتًا عشبياً حولياً ينتمي إلى الفصيلة البوراجينية ويعرف باسم نبات النحل وهو نبات طبي مهم أصلي في منطقة البحر الأبيض المتوسط وانتشر على نطاق واسع في العديد من البلدان الأخرى. أجريت تجربة بهدف تقييم تأثير حمض الهيوميك والعناصر الغذائية الصغرى على خصائص النمو والتركيب الكيميائي وإنتاج الزيت في نباتات خبزالنحل. أجريت في المزرعة التجريبية لقسم البساتين، كلية الزراعة، مشتهر، جامعة بنها، خلال موسمي النمو المتتاليين ٢٠٢١/٢٠٢٠ و٢٠٢٢/٢٠٢١. تضمنت هذه التجربة ١٦ معاملة ناتجة عن التفاعل بين إضافة حامض الهيوميك للتربة بمعدل صفر (الكنترول) و٢ و٣ و٤ كجم/فدان والرش الورقي بالماء (الكنترول) أو الزنك أو الحديد أو المنجنيز بمعدل ١٠٠ جزء في المليون لكل منها. أشارت النتائج إلى أن معاملة حمض الهيوميك بمعدل ٤ كجم/فدان + حديد بمعدل ١٠٠ جزء في المليون أدت إلى تحسين كبير في خصائص النمو بما في ذلك عدد الفروع والوزن الطازج والجاف للنبات. كما أنتجت معاملة حمض الهيوميك بمعدل ٤ كجم/فدان + حديد بمعدل ١٠٠ جزء في المليون أقصى قيم للنيتروجين الكلي والفوسفور والبوتاسيوم والكربوهيدرات في كلا الموسمين. وفي الوقت نفسه، أدت معاملة حمض الهيوميك بمعدل ٤

كجم/فدان + زنك بمعدل ١٠٠ جزء في المليون إلى تحسين كبير في بعض الصفات بما في ذلك طول النبات والوزن الطازج والجاف للنورات وإنتاج البذور في كلا الموسمين. أعطت معاملة حمض الهيوميك بمعدل ٤ كجم/فدان + زنك بمعدل ١٠٠ جزء في المليون أعلى نسبة ثابتة للزيت يليها معاملة حمض الهيوميك بمعدل ٤ كجم/فدان + حديد بمعدل ١٠٠ جزء في المليون. تم ظهور ٦٨ مركباً في مكونات عينات زيت البذور أثناء تحليل العينات على جهاز GC-MS . حيث سجلت العينة الناتجة عن معاملة حمض الهيوميك (٤ كجم/فدان) + حديد (١٠٠ جزء في المليون) ٣٣ مركباً، ومن ناحية أخرى سجلت العينة الناتجة عن معاملة الكنترول ١٤ مركباً.