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INVESTIGATION OF THE EFFECTS OF HUMIC ACID AND SALT STRESS ON ESSENTIAL OIL CONTENT AND COMPOSITION IN *ARTEMISIA DRACUNCULUS* L. (TARRAGON)

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Abstract

In this study, the ameliorative roles of leonardite-derived liquid humic acid (HA) on growth parameters and essential oil yield and constituents of *Artemisia dracunculus* L. under salinity stress were examined. Salt stress, which is caused by the accumulation of salts in the rhizosphere after the evaporation of water in the soil due to reasons such as high temperature, is one of the most important abiotic stress factors that negatively affect plants in all aspects. Humic acids are natural substances that can alleviate the effects of abiotic stress factors on plants by making the soil suitable for plant survival in all aspects.

Salt stress caused a significant decrease in measured growth parameters (plant height, fresh weight of leaves and stems, dry weight of leaves and stems, number of leaves and leaf area). HA had a positive effect on growth parameters at 75 mM NaCl concentration, except for leaf number, but its effect was limited at 150 mM NaCl concentration.

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Essential oil yields (%) increased at 75 and 150 mM NaCl concentrations compared to humic acid treated groups. A total of 24 essential oil components were detected in the essential oil at ratios of 0.5% and above. The predominant components are elemycin, isoelemycin, methyl eugenol, phytol and sabinene. The relative percentages of the components differed between all experimental groups.

Key words: Essential oil component; Humic acid; Salt stress; Tarragon

Introduction

Tarragon (*Artemisia dracunculus* L.) is a perennial shrub in the family Asteraceae (Compositae). Many members of this family are rich in essential oils and consequently are important in pharmacy and medicine (Davis, 1982). Tarragon, which has an important place in Europe, especially in French cuisine, is also known and widely used in the south of Europe (Aglarova *et al*., 2008). Tarragon is a perennial, herbaceous species that grows linearly from 40 cm to 150 cm in length, with small yellowish flowers and forks towards the upper parts of the plant. The leaves are lanceolate, 2-8 cm long and 1-6 mm wide, alternate, entire or divided (Cronquist *et al*., 1995). Glandular hairs are biseriate and sparsely distributed on the leaf. Oil glands under the leaves are the primary source of essential oil, which gives the plant a pungent odor. Despite the great similarities between the glandular structures of French and Russian cultivars, their essential oil composition is markedly different (Obolskiy *et al*., 2011; Tomitaka *et al*., 1997). The essential oil content of tarragon varies between 0.15-3.1% (Obolskiy *et al*., 2011). Although this ratio is under the influence of genetic factors, it can be altered by many environmental factors or interventions.

Secondary metabolites are chemical compounds that plants do not need for normal growth and development but are produced in plants as by-products of cell metabolism (Bakır, 2020). The amount and composition of essential oils, which can be obtained by steam distillation from parts of plants rich in essential oils such as leaves, roots, stems, stems, fruits, seeds or stem bark (Kartal *et al*., 2021) and classified as secondary metabolites, may differ significantly depending on plant species, organ or different tissues of the same organ, growth and development period, different time of day in the same plant, as well as the environmental conditions (temperature, precipitation, soil texture, salinity, etc.) in which the plant grows (Baydar, 2019).

It has been reported that volatile compounds function as a defense system under abiotic stress conditions (Loreto *et al*., 2006) and have nematicidal, insecticidal and antioxidant activities as well as antimicrobial, antiviral and antifungal effects (Ntalli *et al*., 2010; Lang & Buchbauer, 2012). It has been reported that essential oils contribute to the plant's communication with its environment, facilitate reproduction, repel harmful species, confer antibacterial and antifungal properties in case of plant injury, as well as reducing water loss when found on the leaf surface (Price & Price, 2011).

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The composition and quality of essential oil have been reported to vary according to the way the plant grows, soil, climatic conditions, harvest time and post-harvest processes (drying, storage, etc.) (Tisserand & Young, 2013).

Salt stress, which affects a significant portion of agricultural production areas in the world, is one of the most important abiotic stress factors with a determining effect on plant growth and development and crop yield (Lal *et al*., 2021; Chourasia *et al*., 2021). Salinity stress is one of the problems seen in arid and semi-arid areas where temperature is high and rainfall is insufficient. In such regions, the evaporation of water from the soil with insufficient rainfall leads to salt accumulation in the upper soil layers and, thus around the root zone of plants (Dolarslan & Gul, 2012).

The response to salt stress varies according to the species and genotype of the plant, the salt concentration in the growing medium, the duration of exposure to stress and the stress magnitude, the developmental stage of the plant as well as environmental conditions including temperature, light and soil structural characteristics (Marschner, 1995). It has been stated that salt stress causes disorders in vascular tissue differentiation and development due to decreased root and stem length, leaf area and weight, decreased cell number and mitotic activity in root and stem (Burssens *et al*., 2000).

Humic substances are heterogeneous organic substances that occur spontaneously in nature, vary in color from yellow to black, contain various functional groups in their structure, and are resistant to decomposition and degradation. Although humic acids can be found in lignite and peat deposits, soil, animal manure and seas, the highest rate is found in leonardite (Jakson, 1994).

In studies, it has been determined that humic acids show their positive effects on plants by rendering the physical, chemical and microbiological qualities of soil fit for plant life (Liu *et al*., 2019; Saidimoradi *et al*., 2019; Bano *et al*., 2022). There are studies reporting that humic acid application reduces stress-induced decreases in essential oil content and the ratio of some essential oil components in salt-stressed plants (Mostafa, 2015; Zaremanesh *et al*., 2021; El-Gohary *et al*., 2023).

In the present study, the essential oil composition of tarragon seedlings subjected to two different salt stresses was determined by Gas Chromatography Mass Spectrometry. Oil content was compared between the seedlings in pots treated with two salt concentrations and humic acid and the control tarragon seedlings.

Material and Methods

Plant material: Russian tarragon, which is one of the two widely cultivated tarragon varieties and can be produced from seed, was used. Seeds were obtained from the seed supplier Kings Seeds Company (Monks Farm, Kelvedon, Colchester, Essex, United Kingdom).

Experimental design and treatments: All germination and cultivation processes were carried out in the plant growth room with controlled conditions in the Plant Physiology Research Laboratory in the Department of Biology, Faculty of Science, Marmara University.

A total of 45 plants, 9 plants in each experimental group, were used to examine the growth parameters. For essential oil analysis, a total of 130 plants, 26 plants in each experimental group, were harvested for drying. Tarragon seedlings were treated with three different salt stress factors (0, 75 and 150 mM NaCl) and the other two groups were treated with HA (10 ml/l) together with salt. The dose of HA applied was determined according to the recommendation indicated on the label of the commercial product provided. Thus, the experimental groups were determined as C = control; S1 = 75 mM NaCl, S2 = 150 mM NaCl, S1 + HA = 75 mM NaCl + humic acid, S2 + HA = 150 mM NaCl + humic acid. In the study, NaCl with 99.5% purity (Merck®, Darmstadt, Germany) and leonardite-derived liquid commercial HA obtained from Turkish Coal Enterprises (TKİ) (Ankara, Turkey) were used. HA used in the experiments is a product obtained by physical and chemical treatment of solid natural leonardite with potassium hydroxide (KOH). The content of liquid HA is given (Table 1).

Table 1. Properties of liquid humic acid.

Content of liquid humic substance	Amount (%*w*/*w*)
Total organic matter	5
Total humic acid + Fulvic acid	12
Water soluble potassium oxide (K_2O)	1.8
pH	
10.5–12.5	

Cultivation conditions of plants: Washed river sand and LECAT® (Söğüt Toprak Madencilik Sanayi Co. Inc., Söğüt, Bilecik, Turkey) brand expanded clay particles with a grain size of 0–3 mm were used to germinate the seeds and grow the plants. The river sand was soaked in distilled water overnight for sterilization, then washed several times and a 2:1 sand-clay mixture was used. The conditions of the plant growth room were 23 ±2°C and 4000–4200 lux light intensity and 14/10 h day/night light cycle. Nutrient solutions used for plant growth were prepared by dissolving mineral nutrients in distilled water according to Hoagland & Arnon (1950). Tarragon seeds were germinated in 450 mL plastic pots by giving only 30 mL distilled water for 14 days. Starting from the 15th day, Hoagland's solution was given for 39 days, 40 mL for the first 13 days, 50 mL for the next 13 days and 60 mL for the last 13 days. On day 40, 45 plants for the measurement of growth parameters and 130 plants for essential oil analysis were randomly selected among the germinated ones and transferred to drained plastic pots containing 1,750 g of sand-clay mixture in which they would be grown individually.

The pots have a height of 18 cm, a mouth width of 10.8 cm, a base width of 9 cm, a capacity of 1.4 liters and a volume of 0.16 m^3. In order to prevent the loss of sand-clay mixture through the drainage holes of the pots, two layers of blotting paper were placed on the bottom of the pots and then filled with the mixture.

After the transfer, Hoagland nutrient solution continued to be given to the plants for another 21 days. After 21 days, the experimental groups were; control group (K) irrigated with Hoagland nutrient solution only, Salt 1 group (S1) irrigated with Hoagland nutrient solution containing 75 mM NaCl, Salt 2 group (S2) irrigated with

Hoagland nutrient solution containing 150 mM NaCl, Salt 1 + Humic Acid group (S1 + HA) irrigated with humic acid solution added to Hoagland nutrient solution containing 75 mM NaCl and Salt 2 + Humic Acid group (S2 + HA) irrigated with humic acid solution added to Hoagland nutrient solution containing 150 mM NaCl.

After the experimental groups were established, the plants were watered every other day. The solutions specific to the groups of plants were given to the growing media for 63 days for the plants grown for the measurement of growth parameters and 167 days for the plants grown for essential oil analysis. All irrigations were done at the same time of the day during the experiment.

Measuring plant growth parameters: From day 135, the harvested plants were cut just above the soil level with a razor blade. Above-ground plant height (cm), root, stem and leaf fresh and dry weights (g), leaf number and leaf area (cm^2) were determined. Fresh weights, number of leaves and leaf area were determined on the day of harvest, while dry weights were determined after each of the plant parts separated into roots, stems and leaves were placed in separate envelopes and dried in an oven set at 80 °C for 48 hours. Leaf area (cm^2) was calculated using ImageJ (version 1.54c) image-processing software after taking four samples of mature leaves of each plant.

Essential oil amount and component analysis: A total of 130 harvested plants were dried at room temperature, in an adequate and regularly ventilated environment, under shade conditions and on a clean surface without damaging the integrity of the above-ground parts. During the drying period, the plants were turned upside down at regular intervals to ensure homogeneous and healthy drying. The dried plants were cut into small pieces and transferred to glass jars covered with aluminum foil. After the jars were tightly closed, they were placed in a desiccator and kept in the desiccator until the day of analysis. Water distillation was employed to extract plant essential oils in a Clevenger apparatus for 3 hours. Essential oil quantity (ml) and component analyses were carried out at Anadolu University Plant, Drug and Scientific Research Application and Research Center (AÜBİBAM). In the essential oil component analysis, Gas Chromatography/ Mass Spectrometry method was used to identify the components present at 0.5% and above and Gas Chromatography method was used to determine their relative percentages.

Sample preparation: The sample prepared with hexane (10% v/v) was injected into the system as 1 µL with a 40:1 split ratio.

Gas chromatography (GC) conditions: System: Agilent 7890B GC System; Column: Agilent HP-Innowax (60 m x 0.25 mm inner diameter x 0.25 µm film thickness); Detector: Flame Ionization Detector (FID); Injection temperature: 250°C; Detector temperature: 250°C; Temperature program: 60°C (10 min), 4°C/min. 220°C (10 min) 1°C/min 240°C, Total 80 min; Carrier gas: Helium (0.7 mL/min).

Gas chromatography/Mass spectrometry (GC/MS) conditions: System: Agilent 7890B GC 5977B Mass Selective Detector System; Column: Agilent HPInnowax (60 m, 0.25 mm inner diameter, 0.25 m film thickness); Injection temperature: 250°C; Ion source temperature: 230°C; Ionization mode: EI; Electron energy: 70 ev; Mass range: 35- 450 m/z; Temperature program: 60°C (10 min), 4°C/min. 220°C (10 min) 1°C/min 240°C, Total 80 min; Carrier gas: Helium (0.7 mL/min); Identifications: Wiley 9-Nist 11 Mass Spectral Database.

Statistical analysis

Germinated tarragon plants were randomly placed in each experimental group in the growing medium. Statistical analyses were undertaken in SPSS (22.0 for Windows). The Kruskal-Wallis test was used for statistical comparison of replicates of control and experimental groups. This test determines whether the values of the parameters are significant or not. The significance level was accepted as 95% ($p<0.05$). Standard errors were added to the obtained averages.

Results

Changes in growth parameters: As expected, all plant growth parameters were negatively affected by both salt stress levels. The effect of humic acid, which was applied to have a curative effect against salt stress, was variable. The negative effect of NaCl on growth parameters except leaf area was higher in 150 mM NaCl treated groups. NaCl treatment of tarragon seedlings at 75 and 150 mM concentrations caused a 17.86% and 31.48% decrease in plant height, respectively. Similar results were observed in root, stem and leaf fresh and dry weights. Root fresh weight decreased by 26.67%, stem fresh weight by 43.07% and leaf fresh weight by 49.14% at 75 mM NaCl concentration. At 150 mM NaCl concentration, the rate of decrease in the same parameters was 43.65% for root fresh weight, 54.83% for stem fresh weight and 59.99% for leaf fresh weight. These losses in dry weights were 43.27% and 39.76% in the root, 44.48% and 51.62% in the stem, and 43.05% and 47.74% in the leaf for 75 and 150 mM concentrations, respectively. NaCl treatments also caused decreases in leaf area and leaf number. The decrease in leaf area was 37.58% in the 75 mM NaCl group and 28.26% in the 150 mM NaCl group. Decreases in leaf number were realized as 31.04% and 47.03%.

With the addition of HA, 75 mM NaCl-treated plants showed a 3.67% increase in height in comparison to plants treated with 75 mM NaCl alone. Similar increases were obtained in root (2.33%), stem (2.48%) and leaf (15.26%) fresh weights. With the addition of HA, plants treated with 75 mM NaCl showed an increase of 15.46% in root, 10.52% in stem, 17.52% in leaf and 34.57% in leaf area, while leaf number decreased by 9.90% compared to plants treated with 75 mM NaCl alone. It was observed that the effects of HA application on plant growth parameters negatively affected by 150 mM NaCl application were different. With the addition of HA, the height (3.05%), root fresh weight (1.39%), stem fresh and dry weight (18.66% and 23.49%, respectively) and number of leaves (15.44%) of 150 mM NaCl-treated plants decreased, whereas leaf fresh and dry weight (15.06% and 1.87%, respectively), stem dry weight (4.85%) and leaf area (24.46%) increased (Tables 2 and 3).

Table 2. Effects of different levels of salt stress (75 mM and 150 mM) and humic acid (HA) application on fresh and dry weights of tarragon plants.

	Root fresh weight (g)	Shoot fresh weight (g)	Leaf fresh weight (g)	Root dry weight (g)	Shoot dry weight (g)	Leaf dry weight (g)
C	1,402 ± 0,193	1,625 ± 0,120	4,497 ± 0,434	0,171 ± 0,031	0,308 ± 0,037	0,511 ± 0,049
S1	1,028 ± 0,144	0,925 ± 0,078	2,287 ± 0,102*	0,097 ± 0,009	0,171 ± 0,017	0,291 ± 0,020
S2	0,790 ± 0,207	0,734 ± 0,103*	1,799 ± 0,263	0,103 ± 0,024	0,149 ± 0,028*	0,267 ± 0,044*
S1+HA	1,052 ± 0,118	0,948 ± 0,123	2,636 ± 0,180	0,112 ± 0,020	0,189 ± 0,032	0,342 ± 0,031
S2+HA	0,779 ± 0,113	0,597 ± 0,031*	2,070 ± 0,110*	0,108 ± 0,017	0,114 ± 0,007*	0,272 ± 0,016*

C = Control; S1 = 75 mM NaCl; S2 = 150 mM NaCl; S1 + HA = 75 mM NaCl + Humic acid; S2 + HA = 150 mM NaCl + Humic acid. * = significantly different from the control group. Error bars in columns indicate ± standard error

Table 3. Effects of different levels of salt stress (75 mM and 150 mM) and humic acid (HA) application on plant height, leaf number and leaf area of tarragon plants.

	Plant height (cm)	Number of leaves	Leaf area (cm^2)
C	65,111 ± 5,514	66,714 ± 4,843	3,17 ± 0,455
S1	53,478 ± 2,049	46,000 ± 2,733	1,98 ± 0,188
S2	44,611 ± 3,434*	35,333 ± 1,675*	2,28 ± 0,304
S1+HA	55,444 ± 5,111	41,444 ± 2,409	2,67 ± 0,209
S2+HA	43,250 ± 2,685*	29,875 ± 1,245*	2,83 ± 0,234

C = Control; S1 = 75 mM NaCl; S2 = 150 mM NaCl; S1 + HA = 75 mM NaCl + Humic acid; S2 + HA = 150 mM NaCl + Humic acid. * = significantly different from the control group. Error bars in columns indicate ± standard error

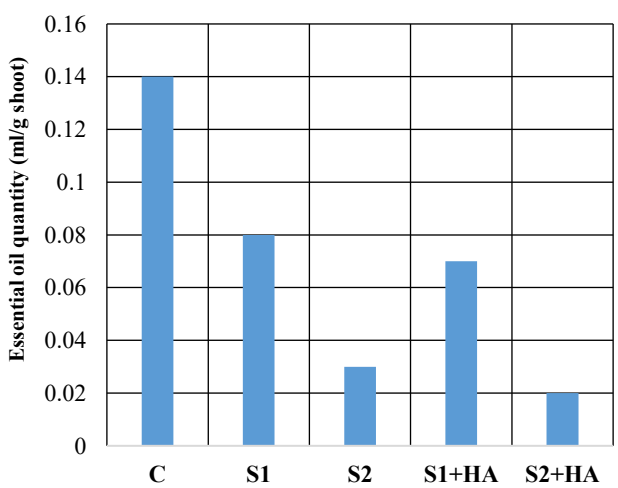

Fig. 1. Essential oil quantity in shoots of tarragon seedlings (ml). C = Control; S1 = 75 mM NaCl; S2 = 150 mM NaCl; S1 + HA = 75 mM NaCl + Humic acid; S2 + HA = 150 mM NaCl + Humic acid.

Essential oil quantity: For essential oil extraction from the dried plant parts and analysis of essential oil components, 40 g samples from the control group, 20 g samples from the T1 experimental group, 20 g samples from the T1 + HA experimental group, 13 g samples from the T2 experimental group and 13 g samples from the T2 + HA experimental group were used. From these quantities of dry materials to be subjected to analysis, 0.14 ml of essential oil was obtained from the control group, 0.08 ml from the T1 group, 0.07 ml from the T1 + HA group, 0.03 ml from the T2 group, and 0.02 ml from the T2 + HA group (Fig. 1). The results obtained are in agreement with the results obtained in the growth parameters of the plants in the groups exposed to salt only, while they contradict the results obtained in the same groups where the ameliorative effect of humic acid against salt stress was observed.

Analysis of essential oil components: The number of components detected in control and experimental groups and the relative percentages of major and minor components differed between the groups. As a result of GC-MS analysis, a total of 24 essential oil components were detected at 0.5% and above. The major components detected in the experimental groups were sabinene, methyl eugenol, elemicin, isoelemycin and phytol. The proportion of major components among all detectable components was 78.4% in control, 80.8% in S1, 78.2% in S2, 71.8% in S1+HA, and 78.1% in S2+HA. Although significant differences were found in the proportion of major components between the groups, these components were detected in all experimental groups. In contrast to all growth parameters that were negatively affected by salt stress conditions, many essential oil components were found to increase in the salt-containing groups.

Among the major components, isoelemycin, methyl eugenol and phytol showed an increase in S1 and S2 groups, while elemycin showed a slight increase only in the S2 group. On the other hand, only sabinene among the major components decreased in S1 and S2 groups. Especially in the S2 group, there was an 89.3% decrease in sabinene compared to the control. Isoelemycin, which is positively affected by salt stress, increased by 64.6% and 51.7%, and methyl eugenol by 96.2% and 23.3% in S1 and S2 groups, respectively, compared to the control. All detectable components and their relative percentages are given (Table 4) according to the experimental groups.

Discussion

Plant height decline due to salt stress was also found in studies conducted with some plant species. The results obtained from the studies on 60 and 120 mM NaCl in *Artemisia dracunculus* L. (Mohammadi *et al*., 2023), watermelon (Yetişir & Uygur, 2009) and Filiz 99 cultivars of faba bean (Bulut & Akıncı, 2010) are consistent with the results obtained in our study. On the other hand, NaCl applied at concentrations of 50 and 100 mM increased the plant height of *Artemisia dracunculus* compared to the control group, contradicting the findings of our study (Hassanpouraghdam *et al*., 2022). HA, when applied together with 75 mM NaCl concentration, increased plant height compared to plants treated with 75 mM NaCl alone. This result is similar to the findings of studies in quinoa (Rekaby *et al*., 2023), wheat (Osman *et al*., 2017) and bean (Meganid *et al*., 2015). Decreases in root fresh weight due to salt stress were also reported in different studies (Topçu et al., 2016; Yılmaz & Kısakürek, 2018; Castroluna *et al*., 2014). The decreases in root fresh weight of plants in S1 and S2 groups are presumed to be due to the osmotic stress of

salt stress in the rhizosphere, which decreases the amount of available water and slows down growth and development by causing physiological drought. Humic acid application increased the root fresh weight of plants in the S1 group exposed to salt stress. This increase after HA application is consistent with the results of studies on wheat (Osman *et al*., 2017) and cress (Masciandaro *et al*., 2002). Decreases in stem and leaf fresh weights of plants subjected to salt stress accord with the findings of Jaradat *et al*., (2004) in barley. HA, when applied in combination with 75 mM NaCl concentration, increased stem fresh weight compared to the group treated with 75 mM NaCl only. This result is supported by the results of studies conducted in maize (Eyheraguibel *et al*., 2008), Demre variety pepper (Çimrin *et al*., 2010) and quinoa (Rekaby *et al*., 2023). The results of Saidimoradi *et al*., (2019) on dry weight in the root of Paros and Kurdistan strawberry cultivars, Bat *et al*., (2020) on Echinacea stem, and Yıldıztekin *et al*., (2018) on pepper leaf support the changes in root, stem and leaf dry weights of plants exposed to 75 mM NaCl stress. Humic acid increased leaf area when applied to S1 and S2 groups compared to the groups treated with NaCl alone. These results are consistent with those of studies on *Urochondra setulosa* (Trin.) (C.E. Hubb.) (Bano *et al*., 2022), *Sorghum bicolor* (L.) (Moench) (Ali *et al*., 2022) and peas (Osman & Rady, 2012). It is thought that the decreases and regressions in growth parameters under salt stress are due to osmotic stress in the rhizosphere due to salt stress, which causes physiological drought by reducing the amount of available water.

The components of essential oils are derivatives of the 5-carbon (5C) isoprene (C5H8) structure. Monoterpenes (10C) and sesquiterpenes (15C), which are the main components, constitute more than 80% of vegetable essential oils. Monoterpenes account for 90% of bioactive essential oils. Some studies have shown that stress factors are highly effective on secondary metabolites in medicinal and aromatic plants. Baydar & Çoban (2017) reported that the amount of essential oil decreased significantly and the essential oil composition changed with increasing NaCl concentrations (100 and 150 mM). On the other hand, some studies with *Salvia officinalis* reported that moderate salinity stress increased essential oil biosynthesis, especially oxygenated monoterpene content (Hendawy & Khalid, 2005; Taarit *et al*., 2009; Aziz *et al*., 2013). Kulak *et al*., (2020) reported that different salt varieties and concentrations significantly changed the chemical composition of *Salvia officinalis* essential oil, resulting in new and different chemotypes. Askary *et al*., (2016) reported that essential oil content and menthol component decreased in *Mentha piperita* due to the increase in soil salinity, whereas mentofuron component increased. Baâtour *et al*., (2011) found that the sabinene component increased approximately 7.5-fold in the Tunisian variety of *Origanum majorana* L. (marjoram) exposed to 75 mM NaCl stress compared to the control group, while it decreased approximately 2.5-fold in the Canadian variety. Kahveci *et al*., (2021) reported elevated methyl eugenol content in basil (*Ocimum basilicum* L.) leaves on exposure to salt stress. Similar result was reported by Tarchoune *et al*., (2013) in basil (*Ocimum basilicum* L. var. Genovese) treated with 50 mM NaCl. For our study, there are studies consistent with the decrease in essential oil content and dramatic changes on some components in some groups depending on the severity of salt stress. The studies that contradict our results are mostly related to changes in essential oil composition. Although the common conclusion is that essential oil composition is affected by environmental factors, the direction of change of the components is highly dependent on the plant species, severity and duration of stress.

Table 4. Essential oil components of *Artemisia dracunculus* L. species according to experimental groups (%).

Order No.	Essential oil components (%)	C	S1	S2	S1+HA	S2+HA
1.	*(E)*-Methyl isoeugenol	1.0	1.3	1.5	3.0	0.6
2.	*(E)*-Sabinene hydrate	0.6	0.5	-	0.6	-
3.	(*E*)-β-Ocimene	0.8	-	-	-	-
4.	(*Z*)-Sabinene hydrate	0.6	0.5	-	0.5	-
5.	(*Z*)-β-Ocimene	1.2	0.7	-	0.6	-
6.	Bicyclogermacrene	-	0.5	0.5	0.5	0.6
7.	Elemicin	24.3	8.0	24.9	17.3	11.0
8.	Phytol	1.5	1.6	2.9	5.6	4.5
9.	Germacrene D	0.7	1.2	1.7	1.5	2.2
10.	Hexahydrofarnesyl acetone	-	-	1.0	0.5	1.1
11.	İsoelemicin	23.2	38.2	35.2	19.3	52.1
12.	Methyl eugenol	10.7	21.0	13.2	22.5	8.2
13.	Nerolidol	-	-	-	0.5	-
14.	Sabinene	18.7	12.0	2.0	7.1	1.9
15.	Citronellyl acetate	1.4	1.3	1.5	2.2	2.0
16.	Spathulenol	1.3	1.1	1.8	1.8	2.1
17.	α-Bisabolol	-	0.5	-	-	-
18.	α-Terpinene	0.5	-	-	-	-
19.	α-Terpinolene	0.5	-	-	-	-
20.	β-Caryophyllene+Terpinen-4-ol	1.7	1.5	1.2	2.3	-
21.	β-Myrcene	1.0	0.5	-	0.5	-
22.	γ-Terpinene	1.0	0.9	-	0.8	-
23.	Citronellol	-	0.5	0.8	0.7	0.9
24.	Terpinen-4-ol	-	-	-	-	0.7
	Total Identifiable	**90.7**	**91.8**	**88.2**	**87.8**	**87.9**

C = Control; S1 = 75 mM NaCl; S2 = 150 mM NaCl; S1 + HA = 75 mM NaCl + Humic acid; S2 + HA = 150 mM NaCl + Humic acid

Conclusion

In the present study, the roles of differing degrees of salt stress on *Artemisia dracunculus* L., seedlings and the growth parameters of seedlings irrigated with humic acid added at 10ml/l to these concentrations and the effects on the quantities and varieties of essential oils were determined.

Increased salinity in the soil was effective on *Artemisia dracunculus* L. (tarragon) seedlings moderately resistant to this stress factor, while the ameliorative effect of humic acid in salinized areas was limited in seedlings under increased salt stress. The gradual inhibitory effect of both salt concentrations on growth parameters was statistically significant in seedlings subjected to moderate salt stress. The positive effect of humic acid supplementation was especially noteworthy under moderate salt stress. Isoelemycin and methyl eugenol increased while sabinene decreased under salt stress, which draws attention to the importance of secondary metabolite production mechanisms under stress conditions. The fact that the utilisation of humic acid in salinized areas has determinative qualities on both growth and development and its positive effect on these oils is among the important issues to be emphasized and requires many studies with similar content to be carried out.

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