Scientific Journal of Agricultural Sciences

Print (ISSN 2535-1796) / Online (ISSN 2535-180X)

Effect of Drought Stress on Growth and Productivity of Some *Mentha* Species

Mahmoud A-H. Mohmed[1*], Emain A. Mohamed[1], Wahed S. Botros[2], Ahmed A. Hassan[1]

[1]Hort. Dept., Fac. of Agric., Minia Univ.

[2] Medicinal and Aromatic Plant. Dep., Hort. Res. Inst., Agri. Res. Centre, Giza, Egypt

Citation: Mahmoud A-H. Mohmed, Emain A. Mohamed, Wahed S. Botros, Ahmad A. Hassan. (2023). Effect of Drought Stress on Growth and Productivity of Some Mentha Species. Scientific Journal of Agricultural Sciences, 5 (2): 43-51. 10.21608/sjas.2023.281749

Publisher :
Beni-Suef University, Faculty of Agriculture

Received: 15 / 5 / 2023
Accepted:12 / 6 / 2023

Corresponding author:
Mahmoud A-H. Mohmed

Email:
mmahmohamed@gmail.com

ABSTRACT

Three *Mentha* species were subjected to irrigation up to100, 66 and 33% of field capacity (FC). Plants were cut three times during the growing season. Plant fresh and dry weights, volatile oil percentage and yield were significantly varied among the three species and due to the reduction in FC. In the 1st cut, *M. piperita* L. plants had the highest fresh weights during both seasons, for example in the 1st one they had 18.07 and 19.08 g/plant, respectively when growing soil maintained at 100% FC. While the lowest plant fresh weights of that cut on both seasons were 5.41 and 6.50 g/plant, respectively were for *M. spicata*. By reducing FC from 100% to 33% in the 1st cut, plant dry weights of *M. spicata* L. were reduced by 48 and 34%, in the two seasons, respectively. Whereas the reduction was the lowest for *M. suaveolens* Ehrh. nevertheless, the lowest dry weights (0.73 g/plant) were for *M. piperita* grown at 33% FC. The volatile oil % was increased ($p \leq 0.5$) under 66% FC but it decreased under 33% FC compared with 100% FC treatment. Overall, in the 1st season the highest volatile oil percentage (0.90%) being for any of these species under 66% FC as well as M. *suaveolens* grown at 100%FC. Moderate drought stress using 66% FC could be recommended for *M. spicata* and *M. piperita* as no or slight reduction on VO yield was assessed. However, *M. suaveolens* is more sensitive for even mild stress (66%FC) and should be irrigated to maintain soil with full FC.

KEYWORDS: Mint, water stress, essential oils, field capacity

1. INTRODUCTION

Mentha plants are thought to have originated in the Mediterranean and Northern Africa. Based on their volatile oil (VO) content they had a high economic value and were universally used in cosmetics, confectionary, beverages, bakery, pharmaceuticals, and pesticides (Tucker and Naczi, 2006 and Shaikh et al., 2014). Moreover, secondary metabolites of mint plants have many physiological activities such as analgesic, anti-inflammatory, antioxidant, anti-microbial, and anti-carcinogenic (Rita and Animesh, 2011 and Shaikh et al., 2014). Edris et al. (2003) referred that the Egyptian flora contains many mint species included *M. spicata* L. however, *M. suaveolens* Ehrh is recently introduced to Egypt (Elansary and Ashmawy, 2013).

Any external factors that cause adverse effects on the plant growth and productivity can be defined as stress. One of the main stresses which affects plant growth, and its productivity, is water deficit (Jamil et al., 2011). Moreover, drought stress is severely affecting plant growth and productivity due to disturbing many physiological responses such as reducing water use efficiency, photosynthesis, and plant water relationship (Rao and Sandhya, 2019).

Volatile oil accumulation could be considered a defense mechanism to abiotic stress (Ghanbarzadeh et al., 2019) such as drought, one of the most vital physical elicitors. Yet drought stress could lead to a significant change on plant secondary metabolites (Vasconsuelo and Boland, 2007 and Thakur et al., 2019). Increasing VO under water deficit stress has been reported in many aromatic plants (Mohammadi et al., 2018 and Ghanbarzadeh et al., 2019).

Nowadays, the impact of water stress on different crops is the focus of many researches especially in arid and semiarid areas to improve their yield and production. Therefore, this study aimed to distinguish the effects of water stress on yield, VO content and yield of three species of *Mentha* one of them is recently introduced to Egypt.

2. MATERIALS AND METHODS

2.1.Plant material

A randomized complete block design experiment with two factors was carried out during 2020 and 2021 seasons at the Agricultural Experiments and Research Center, Minia University. Stem cuttings about 10-15 cm long of *M. spicata*, *M. piperita*, and *M. suaveolens* were collected from the Agricultural Experiments and Research Center, Minia University cultured on Feb. 15th using 10-cm in diameter plastic pots containing a mixture of sand and clay (1:3 v:v). The physical and chemical analysis (Table 1) of the used soil were determined according to Black et al. (1981). After one month, plantlets were transferred into a 30-cm in diameter plastic pot filled with 6 kg of the same soil mixture and left for two weeks before starting the drought stress treatments.

2.2.Drought stress treatment

Plants were irrigated every four days during the 1st month and every three days later to achieve 100, 66 and 33% of the field capacity (FC). Before irrigation, four pots were randomly selected, from each treatment, and weighed to calculate the required amount of water to maintain the soil at the required FC% as described by Mohamed (2000). The experiment included three replicates; each one contained 30 plants for each drought stress treatment. All experimental pots were irrigated to maintain full FC one time after each cut to sustain plant growth.

All plants were fertilized with 3 g/plant ammonium sulphate (20.6 % N), 2/pot of calcium superphosphate (15.5 % P_2O_5) and 1 g/plant potassium sulphate (48 % K_2O).

Table 1. Physical and chemical analysis of the used soil

Soil characters	Value	Soil characters		Value
Soil type	Clay loam	Avail. P (%)		5.00
Sand (%)	18	Exch. K(mg/100g)		4.70
Silt (%)	29	Exch.Ca (mg/100g)		3.1
Clay	53	Exch. Na (mg/100g).		1.74
(Org. Matt. (%)	2.00		Fe	8.39
CaCo3 (%)	3.60	DTPA	Cu	2.04
PH (1:2.5)	8.27	Ext.(ppm)	Zn	2.81
E.C (mmhos/cm)	1.23		Mn	8.19
Total N (%)	0.10			

Nitrogen fertilizer was divided into two doses; three weeks intervals, starting 3 weeks of transplanting. While all K fertilizer was added with the 1st batch of N fertilizer. Whereas, P was added during preparing soil to cultivate in both experimental seasons (Abdou and Mohamed, 2014).

2.3.Biomass and volatile oil yield

For each individual plant, the above-ground vegetative growth of 5 cm from the soil surface was harvested 3 times with 45 days intervals started on 15th May. For each cut the fresh herb for individual plants was weighted then air-dried to calculate the dry weights. The dry herb for the three cuts was mixed and crushed to estimate the VO%. The VO was extracted using hydro-distillation using clevenger apparatus for 2 hours using 20 g of material sample according to British Pharmacopoeia (1963). Then VO were dried over anhydrous sodium sulfate and their content was expressed in ml/g dry weight.

2.4.Statistical analysis

The obtained data were subjected to analysis of variance (ANOVA) and the difference among the means was compared according to Mead et al. (1993) using MSTAT program (version 4.0) edited in 1985 by the MSTAT development team, Michigan University and Agricultural University of Norway.

3. RESULTS AND DISCUSSION

3.1.Fresh weights

All mint fresh weights of the three cuts were varied among species ($p \leq 0.5$) and had been affected by FC at least during one investigated season (Table 2). Overall, plant fresh weights were severally reduced in the 3rd cut especially by reducing the FC to the lowest level. For all cuts, the highest plant fresh weights were for plants which irrigated to maintain 100% FC. Whereas the lowest values were for those grown in soil maintained at the lowest FC.

Table 2. Effect of field capacity on plant fresh weights (g/plant) for three cuts of different mint species

Field capacity % (B)	*Mentha* species* (A)			Mean (B)	*Mentha* species (A)			Mean (B)
	M. spic.	***M. pip.***	***M. suav.***		***M. spic.***	***M. pipe.***	***M. suav.***	
	1st season (2020)				**2nd season (2021)**			
				1st cut (g)				
100	15.39	18.07	15.71	16.39	16.48	19.08	16.65	17.40
66	12.06	14.42	12.47	12.98	14.87	15.36	13.43	14.55
33	5.41	7.56	8.04	7.00	6.50	8.55	9.01	8.02
Mean(A)	10.95	13.35	12.07		12.62	14.33	13.03	
LSD 5%	A: 0.57 B: 0.57 AB:0.99				A: 1.08 B: 1.08 B: 1.86			
				2nd cut (g)				
100	15.30	17.97	15.19	16.15	16.38	19.05	16.30	17.24
66	11.98	14.39	12.52	12.96	13.00	15.45	13.62	14.02
33	5.28	7.50	7.98	6.92	6.31	8.54	9.09	7.98
Mean(A)	10.85	13.29	11.90		11.90	14.35	13.00	
LSD 5%	A: 0.54 B: 0.54 AB: 0.93				A: 0.54 B: 0.54 B: 0.94			
				3rd cut (g)				
100	10.43	15.17	14.61	13.40	11.48	16.17	15.68	14.44
66	7.50	13.19	10.28	10.32	8.55	14.31	11.39	11.42
33	4.49	7.07	4.96	5.51	5.60	8.20	5.96	6.59
Mean(A)	7.47	11.81	9.95		8.54	12.89	11.01	
LSD 5%	A: 0.58 B: 0.58 AB: 1.01				A: 0.45 B: 0.45 AB: 0.79			

* *M. spic.: M. spicata, M. pip.: M. piperita, M. suav.: M. suaveolens*

On the other hand, the interaction between species and drought stress was significant for all cuts in both seasons. Generally, *M. piperita* growing on soil maintained at 100% of FC had the highest fresh weights for the 1st cut on both seasons (18.07 and 19.08 g/plant, respectively). While the lowest plant fresh weights of that cut on both seasons (5.41 and 6.50 g/plant, respectively) were for *M. spicata*. Related results were estimated on the 2nd season with a slight increase in all cases.

3.2.Plant dry weights

Mint plant dry weights were significantly varied among species at the three cuts except for the 1st one in the 1st season, however, drought stress had significant effects on dry weights of all cuts (Table 3). Moreover, the interaction between *Mentha* species and FC% was significant in both seasons. In the 1st season, reducing the FC from 100% to 33% caused a reduction of the 1st cut plant dry weights of *M. spicata* from 1.82 g/plant to 0.93 g/plant and from 2.16 to 0.95 g/plant in the two seasons, respectively. However, the reduction of *M. piperita* dry weights was more pronounced (from 1.82 and 2.16 g/plant to 0.73 and 1.1 g/plant in the two seasons, respectively). In this context, the lowest reduction was for *M. suaveolens*. Overall, the lowest plant dry weight (0.73 g/plant) was for *M. piperita* which grown under 33% FC in the 1st season however the highest plant dry weights (1.66 to 1.89 g/plant) being under 100% FC with no significant difference among the investigated species. The same trend was obtained in both seasons (Table 3).

Table 3. Effect of field capacity on plant dry weights (g/plant) for three cuts of different mint species

Field capacity % (B)	*Mentha* species* (A)			Mean (B)	*Mentha* species (A)			Mean (B)
	M. spic.	*M. pip.*	*M. suav.*		*M. spic.*	*M. pipe.*	*M. suav.*	
	1st season (2020)				2nd season (2021)			
1st cut (g)								
100	1.82	1.82	1.59	1.74	2.16	2.16	1.91	2.08
66	1.34	1.27	1.28	1.30	2.05	1.99	1.66	1.90
33	0.93	0.73	0.80	0.82	0.95	1.11	1.11	1.06
Mean	1.36	1.27	1.22		1.72	1.75	1.56	
LSD 5%	A: NS B: 0.06 AB: 0.10				A: 0.07 B: 0.07 AB: 0.12			
2nd cut (g)								
100	1.82	1.89	1.66	1.79	2.91	2.91	2.64	2.82
66	1.37	1.30	1.27	1.31	2.47	2.41	2.36	2.41
33	0.94	1.03	1.02	0.76	1.05	1.22	1.15	0.88
Mean	1.27	1.34	1.25		2.04	2.09	1.98	
LSD 5%	A: 0.15 B: 0.15 AB: 0.26				A: 0.14 B: 0.13 AB: 0.95			
3rd cut (g)								
100	2.17	2.16	1.91	2.08	2.32	2.67	2.37	2.45
66	2.06	1.99	1.66	1.90	1.67	2.49	2.15	2.10
33	1.10	1.12	1.21	1.18	0.94	1.66	1.57	1.39
Mean	1.71	1.86	1.59		1.64	2.27	2.03	
LSD 5%	A: 0.04 B: 0.04 AB: 0.06				A: 0.04 B: 0.04 AB: 0.06			

* *M. spic.: M. spicata, M. pip.: M. piperita, M. suav.: M. suaveolens*

In the 3rd cut, the reduction in plant dry weights of *M. spicata*, *M. piperita* and *M. suaveolens* by reducing FC to 66% was 24.7, 31.2 and 23.5%, respectively, as compared with these grown under 100% FC in the 1st season. However, reducing FC to 33% caused sever reduction in plant dry weights (48.4, 45.5, and 38.6%) for these three species, respectively. Unlike the 1st and the 3rd cut data, it showed no significant difference among the three species on their 2nd cut dry weights under the same level of FC. The same trend was recorded in the 3rd cut (Table 3).

The assessed variation among the investigated *Mentha* species on fresh and dry weights were similar to data reported by Soltanbeigi et al. (2021). Under the same experiment conditions Anwer et al. (2018) assessed variations among *M. spicata*, *M. piperita*, *M. suveolens* as well as some *M. spicata* ecotypes and concluded that *M. spicata* yielded ($p \leq 0.5$) had the highest biomass. Çalıskan and ¨Ozgüven (2017), Santos et al. (2012) and Özgüven and Kirici (1999) had similar conclusion on different mint species.

The assessed negative impact in harvestable material due to drought stress had also been described in different *Mentha* species. Bayram (2022), Zade et al. (2019), Elansary et al. (2019) Figueroa-Pérez et al. (2014) and Shormin et al. (2009) estimated significant reductions on biomass of different *Mentha* species under different irrigation regimes which caused drought stress. These studies suggested that the reduction in biomass could be due to vegetative growth, leaf number and plant height, that decreased under water stress. The drops in transpiration and photosynthetic rates, and the stomatal conductance, are common physiological signs of drought stress. These physiological parameters are indicators of water shortage and could associate with morphological biometric (Lu¨ttschwager et al. 2015 and Correˆa de Souza et al. 2013). The significant interaction between *Mentha* species and FC% on harvestable herbs could be related to the genetic differences which exist among these genotypes. Plant biomass is affected by many ecological factors (Piccaglia et al., 1993) and the genetic nature of the plant (Tugay et al., 2000). Also, the plant genetic constitute adjusts its response to the environmental conditions by the alteration the cellular, biochemical, and physiological actions. All these principles mediate the photosynthesis capacity, and assimilates partitioning to the sinks therefore, stimulus the biomass characteristics and productivity. The gross photosynthesis rate could be directly reflected in dry biomass.

3.3.Volatile oil percentage and yield/plant

Volatile oil percentage and yield were varied ($P \leq 0.5$) among *Mentha* species in both seasons. The highest and lowest VO % in the 1st season were for *M. piperita* and *M. spicata*. (0.80 and 0.74%, respectively). Drought stress significantly affected the VO % nevertheless, it was increased ($p \leq 0.5$) under the moderate stress but it was more sensitive for sever stress (33% FC) which significantly decreased to 0.74 and 0.71 % in both seasons, respectively. Overall, under 66% FC all mint species had higher VO% than those irrigated with 100%FC. Furthermore, there was a significant interaction between mint species and applied FC% overall, in the 1st season the highest VO% (0.90%) being for any of these species under 66% FC as well as *M. suaveolens* growing under 100% FC. However, in the 2nd season *M. piperita* grown in soil with 66% FC had significantly the highest percentage (0.94%).

In fact, results showed significant effect of mint species as well as FC% on VO yield in both seasons, moreover, there was a significant interaction between the two factors in both seasons. In all cases reducing FC to 33% significantly reduced VO yield compared with 66 or 100% FC in both seasons. However, under 66% FC *M. spicata* in both seasons and *M. piperiat* in the 2nd one had higher VO yield than these grown under 100% FC. But VO yield of *M. suaveolens* was more sensitive to drought in both seasons ($p \leq 0.5$). Overall, in the 2nd season *M. piperita* grown in soil with 66% FC, as well as *M. suaveolens* which grown in soil with 100% FC had the highest VO yield (0.062 ml/plant) However, in the 1st season these species had the highest VO yield once they grow in soil with 100% FC with no significant difference between them (Table 4).

This achieved effects of drought on VO% and yield agree with earlier results in different *Mentha* species (Elansary et al., 2019 and Araghi et al., 2019). Water stress reduced the photosynthesis and activity of primary metabolites. However, the activation of VO as a secondary metabolite pathway is a known

Table 4. Effect of field capacity on volatile oil percentage and yield of different mint species

Field capacity % (B)	*Mentha* species* (A)			Mean (B)	*Mentha* species (A)			Mean (B)
	M. spic.	*M. pip.*	*M. suav.*		*M. spic.*	*M. pipe.*	*M. suav.*	
	1st season (2020)				2nd season (2021)			
Volatile oil%								
100	0.71	0.80	0.90	0.80	0.74	0.80	0.91	0.81
66	0.90	0.90	0.90	0.90	0.81	0.94	0.91	0.81
33	0.60	0.71	0.51	0.74	0.64	0.70	0.80	0.71
Mean	0.74	0.80	0.77		0.73	0.88	0.87	
LSD 5%	A: 0.03 B: 0.03 AB: 0.05				A: 0.03 B: 0.03 AB: 0.05			
Volatile yield (ml/plant)								
100	0.040	0.046	0.045	0.044	0.045	0.059	0.062	0.055
66	0.042	0.043	0.038	0.040	0.050	0.062	0.055	0.056
33	0.014	0.019	0.014	0.016	0.017	0.026	0.029	0.024
Mean	0.032	0.036	0.032		0.037	0.049	0.049	
LSD 5%	A: 0.003 B: 0.003 AB: 0.005				A: 0.003 B: 0.003 AB: 0.005			

* *M. spic.: M. spicata, M. pip.: M. piperita, M. suav.: M. suaveolens*

phenomenon under mild water stress. Moreover, our study showed significant variations on VO % and yield among the different species due to water stress. However, these results are in contrary to studies of Ekren et al. (2012) in basil.

Kleinwächter et al. (2015) reported that water stress reduced primary metabolites, yet the plant activated the biosynthesis pathways of VO as a one of secondary metabolite to challenge the stress, so far, the VO yield increased. However, the study added that the response is varied among the different genotypes. A recent study showed an increase in VO under mild drought stress (66% FC) similarly, Okwany et al. (2012) referred that moderate deficit irrigation of *M. spicata* may be profitable as the VO was maintained. However, water deficits over 40% of full required water are not suggested. Elevated temperature and mild drought stress can increase the biosynthesis of VO in the most plant species (Figueiredo et al., 2008 and Llusia et al., 2006).

As a conclusion investigated *Mentha* species limited their growth and development specially under severe drought stress conditions as an adaptive mechanism for water stress. Moreover, VO as secondary products has a capacity to scavenge reactive oxygen species was increased but the reduction in the biomass must be considered in this respect. However, a significant variation on biomass, as well as VO% and yield, were observed among investigated species. Moderate drought stress 66% FC could be recommended for *M. spicata* and *M. piperita* no or slight reduction on VO yield was assessed. However, *M. suaveolens* was more sensitive for even mild stress (66% FC) and should irrigated to maintain soil with full FC.

4. REFERENCES

Abdou M and Mohamed MAH (2014). Effect of plant compost, salicylic and ascorbic acids on *Mentha piperita* L. plants. Biological Agriculture & Horticulture, 30:131-143,

Anwer GM, Mohamed MA-H, Ragab R and Youssif A (2018). Essential oils and molecular diversity analyses in some *Mentha* species and Egyptian ecotypes. Minia J. of Agric. Res. & Develop., 38: *187*-202.

Araghi MA, Nemati SH and Shoor M (2019). Influence of water stress on agro-morphological traits and essential oil content among Iranian genotypes of *Mentha longifolia*. Proc. Natl. Acad. Sci., India, Sect. B Biol. Sci., 89: 1219–1230.

Bayram SE (2022). Effects of prolonged water stress on biomass yield and nutrient uptake by aerial parts of mint (*Mentha* × *piperita*

L.). Notulae Botanicae Horti Agrobotanici Cluj-Napoca, 50: 12894-12894.

Black CA, Evans DD, Ensminger LE, White GL and Clark FE (1981). Methods of Soil Analysis. Part 2, Agron. Inc. Madison. Wisc., USA. Pp. 1-100**.**

British Pharmacopoeia (1963). Determination of volatile oil drugs. The Pharmaceutical Press, London, UK. pp. 1210.

Çalıskan T and ¨Ozgüven M (2017). The ontogenetic variability and molecular characterisation of *Mentha arvensis* (L.) var. piperascens Holmes. In, Proceedings of the Second International Mediterranean Science and Engineering Congress. Adana, Turkey, pp. 2224–2232.

Correˆa de Souza T, Magalha˜es PC, Mauro de Castro E, Pereira deAlbuquerque PE and Marabesi MA (2013). The influence of ABA on water relation, photosynthesis parameters, and chlorophyll fluorescence under drought conditions in two maize hybrids with contrasting drought resistance. Acta Physiol Planta, 35: 515–527.

Edris AE, Shalaby AS, Fadel HM, Abdel-Wahab MA (2003). Evaluation of a chemotype of spearmint (*Mentha spicata* L.) grown in Siwa Oasis, Egypt. Eur. Food Res. and Technol., 218: 74-78.

Ekren S, Sönmez Ç, Özçakal E, Kurttas YSK, Bayram E and Gürgülü H (2012). The effect of different irrigation water levels on yield and quality characteristics of purple basil (*Oiumum basilicum* L.). Agric. Water Manag., 109: 55–161.

Elansary HO and Ashmawy NA (2013). Essential oils of mint between benefits and hazards. J. of Essential Oil-Bearing Plants, 16, 429–438.

Elansary O, Mahmoud H, Elansary DO and Mattar MA (2019). Effects of water stress and modern biostimulants on growth and quality characteristics of mint. Agron., 10: 6

Figueiredo, AC, Barroso, JG, Pedro LG and Scheffer JJC (2008). Factors affecting secondary metabolite production in plants, volatile components and essential oils. Flavor Fragr. J., 23: 213–226.

Figueroa-Pérez MG, Rocha-Guzmán NE, Pérez-Ramírez IF, Mercado-Silva E and Reynoso-Camacho R (2014). Metabolite profile, antioxidant capacity, and inhibition of digestive enzymes in infusions of peppermint (*Mentha piperita*) grown under drought stress. J. Agric. Food Chem. 62: 12027–12033.

Ghanbarzadeh Z, Mohsenzadeh S, Rowshan V and Moradshahi A (2019). Evaluation of the growth, essential oil composition and antioxidant activity of *Dracocephalum moldavica* under water deficit stress and symbiosis with *Claroideoglomus etunicatum* and *Micrococcus yunnanensis*. Scientia Hort. 256: 10862.

Jamil A, Riaz S, Ashraf M and Foolad MR (2011). Gene expression profiling of plants under salt stress. Crit. Rev. Plant Sci. 30: 435-458.

Kleinwächter M, Paulsen J, Bloem E, Schnug E and Selmar D (2015). Moderate drought and signal transducer induced biosynthesis of relevant secondary metabolites in thyme (*Thymus vulgaris*), greater celandine (*Chelidonium majus*) and parsley (*Petroselinum crispum*). Ind. Crops and Prod., 64: 158-166.

Llusià J, Peñuelas J, Alessio GA and Estiarte M (2006). Seasonal contrasting changes of foliar concentrations of terpenes and other volatile organic compound in four dominant species of a Mediterranean shrubland submitted to a field experimental drought and warming. Physiologia Plantarum. 127: 632-649.

Lu¨ttschwager D, Ewald D and Alı´a LA (2015). Consequences of moderate drought stress on the net photosynthesis, water-use efficiency and biomass production of three poplar clones. Acta Physiol Planta. 38:1-6.

Mead R, Currow RN And Harted AM (1993). Statistical methods in agricultural and experimented biology 2nd Ed. Chapman and Hall, London, UK. pp 472.

Mohamed MAH, Harris PJC and Henderson J (2000). *In vitro* selection and characterisation of a drought tolerant clone of *Tagetes minuta*. Plant Sci. 159: 213–222.

Mohammadi H, Ghorbanpour M and Brestic M (2018). Exogenous putrescine changes redox regulations and essential oil constituents in field-grown *Thymus vulgaris* L. under well-watered and drought stress conditions. Ind. Crops Prod. 122: 119-132.

Okwany RO, Peters TR and Ringer KL (2012). Impact of sustained deficit irrigation on spearmint (*Mentha spicata* L.) biomass production, oil yield, and oil quality. Irrig. Sci. 30: 213–219.

Ozgüven M and Kırıcı S (1999). Research on yield, essential oil, contents and components of mint (*Mentha*) species in different ecologies. Turk. J. Agric. For. 23: 465–472

Piccaglia R, Dellacecca V, Marotti M and Giovanelli E (1993). Agronomic factors affecting the yields and the essential oil composition of peppermint (*Mentha ×piperita* L.). Acta Hortic. 344: 29–40.

Rao S and Sandhya H (2019). *In vitro* Selection and Genetic Engineering for Abiotic Stress Tolerant Plants and Underlying Mechanisms. In: Ramakrishna A. and Gill SS. (Eds). Metabolic Adaptations in Plants During Abiotic Stress. CRC Press Taylor & Francis Group., Pp, 283-290.

Rita P and Animesh DK (2011). An update overview on peppermint (*Mentha × piperita* L.). Int. J. Pharm. Pharm. Sci. 8: 1-10.

Santos VMCS, Pinto MAS, Bizzo HR and Deschamps C (2012). Seasonal variation of vegetative growth, essential oil yield and composition of menthol mint genotypes at southern Brazil. Biosci. J. 28: 790–798.

Shaikh S, Yaacob HB and Rahim ZHA (2014). Prospective role in treatment of major illnesses and potential benefits as a safe insecticide and natural food preservative of mint (*Mentha* spp.): a review. Asian J. Biomed. Pharm. Sci. 4: 1-12.

Shormin T, Khan MAH and Alamgir M (2009). Response of different levels of nitrogen fertilizer and water stress on the growth and yield of Japanese mint (*Mentha arvensis* L.). Bangladesh J. Sci. Ind. Res. 44: 137–145.

Soltanbeigi A, Özgüven M, Hassanpouraghdam MB (2021). Planting-date and cutting-time affect the growth and essential oil composition of *Mentha × piperita* and *Mentha arvensis*. Ind. Crops and Prod. 170: 113790.

Thakur E, Bhattacharya S, Khosla PK and Puri S (2019). Improving production of plant secondary metabolites through biotic and abiotic elicitation. J. of App. Res. on Med. and Aroma. Plants. 12:1-12.

Tucker AO and Naczi RFC (2006). Mentha: An overview of its classification and relationships. In Lawrence B.M. (Ed.) Mint. The genus Mentha. Medical and Aromatic Plants – Industrial Profiles Boca Raton, London, New York: CRC Press, Taylor and Francis Group. Pp 3-35.

Tugay ME, Kaya N, Yilmaz G, Telci I and Donmez E (2000). Botanic and technological characteristics of some aromatic plants commonly in Tokat and its surroundings. The Scientific and Technological Research Council of Turkey (TÜB˙ITAK). Agri. and Forestry Res. Group, Final Report (TOGTAG-1690).

Vasconsuelo A and Boland R (2007). Molecular aspects of the early stages of elicitation of secondary metabolites in plants. Plant Sci. 172: 861-875.

Zade NSE, Sadeghi A, Moradi P (2019). Streptomyces strains alleviate water stress and increase peppermint (*Mentha piperita*) yield and essential oils. Plant Soil. 434: 441–452.

الملخص العربي

تأثير إجهاد الجفاف على نمو وإنتاجية بعض أنواع النعناع

محمود عبد الحكيم محمود[1]، ايمان عدلى محمد [1]، وحيد سعد بطرس[2] و احمد على حسن[1]

[1]قسم البساتين، كلية الزراعة، جامعة المنيا.

[2]قسم النباتات الطبية والعطرية، معهد بحوث البساتين، مركز البحوث الزراعية، الجيزة، القاهرة

تم رى ثلاثة أنواع من النعناع هى النعناع البلدى والفلفلي والتفاحى لمستويات ١٠٠ ، ٦٦ و ٣٣٪ من السعة الحقلية. تم حش النباتات ثلاث مرات خلال موسم النمو. بشكل عام ، تباينت أوزان النباتات الطازجة والجافة ونسبة الزيت الطيار والمحصول بشكل كبير بين الأنواع الثلاثة بسبب الانخفاض في السعة الحقلية. في أول حشة سجلت نباتات النعناع الفلفى أعلى أوزان طازجة في كلا الموسمين، على سبيل المثال في الموسم الأول سجلت ١٨,٠٧ و ١٩,٠٨ جم/نبات على التوالي عند الزراعة فى تربة تحتوى على ١٠٠% من السعة الحقلية. بينما سجلت أقل أوزان نباتية فى هذه الحشة في الموسمين ٥,٤١ و ٦,٥٠ جم / نبات على التوالي لنبات النعناع التفاحى . من خلال تقليل السعة الحقلية من ١٠٠٪ إلى ٣٣٪ ، انخفض الوزن الجاف للنبات فى الحشة الأولى لنباتات النعناع البلدى بنسبة ٤٨ و ٣٤٪ في الموسمين، على التوالي. بينما كان الانخفاض هو الأقل بالنسبة للنعناع التفاحى، ومع ذلك فإن أدنى أوزان جافة (٠,٧٣ جم / نبات) كانت لنباتات النعناع الفلفلى المزروعة فى تربة تحتوى على ثلث السعة الحقلية. سجلت زيادة معنوية فى نسبة الزيت المتطاير تحت ٦٦٪ من السعة الحقلية. لكنه انخفض تحت ثلث السعة الحقلية مقارنة مع احتواء التربة على تمام السعة الحقلية. وبشكل عام ، في الموسم الأول كانت أعلى نسبة زيت طيار (٠,٩٠٪) لأي من هذه الأنواع نامية فى تربة ذات محتوى ٦٦% من السعة الحقلية أو نباتات النعناع التفاحى النامية فى تربة بها ١٠٠% من السعة الحقلية. وبشكل عام ، يمكن التوصية بإجهاد الجفاف المعتدل بنسبة ٦٦ ٪ من السعة الحقلية حيث سجل انخفاض طفيف فى إنتاج الزيت الطيار لنباتات النعناع البلدى والفلفلى . لكن كانت نباتات النعناع التفاحى أكثر حساسية للإجهاد الخفيف عند ٦٦% من السعة الحقلية لذا يفضل ريها حتى الوصول إلى تمام السعة الحقلية.