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Note

Impact of water stress and phosphorus fertilizer on fresh herb and essential oil content of dragonhead

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A b s t r a c t. A pot experiment was conducted with dragonhead (*Dracocephalum moldavica* L.) to evaluate the effects of phosphorus fertilizer rates and water stress levels on the fresh herb and essential oil content under the natural conditions of the greenhouse of the National Research Center, Dokki, Giza, Egypt. Herb fresh and essential oil yield of dragonhead were significantly lowered with the rise in water stress levels. Fresh herb and oil yields increased significantly with an increase in P application up to a higher dose. But, oil percentage increased with increase in moisture and P levels and increased significantly with the higher levels of irrigation and P in the two seasons. The maximum of herb fresh yield and essential oil content were obtained from plants irrigated with 80% available soil moisture (ASM) combined with P fertilizers 1.6 g pot $^{-1}$. The highest content of geranial (26.73%), geraniol (45.98%) and geranyl acetate (87.45%) resulted from the treatments at 40% ASM combined with 0.8 g pot $^{-1}$, 85% ASM alone and 60% ASM combined with 1.6 g pot $^{-1}$, respectively.

K e y w o r d s: dragonhead, water stress, phosphorus fertilizer, essential oil, fresh herb

INTRODUCTION

The *Lamiaceae* family (*Labiatae*) is one of the largest and most distinctive families of flowering plants, with about 220 genera and almost 4 000 species worldwide. This family has an almost cosmopolitan distribution. *Lamiaceae* are best known for the essential oils common to many members of the family. Many biologically active essential oils have been isolated from various members of this family. This family is one of the major sources of culinary, vegetable and medicinal plants all over the world (Naghibib *et al.,* 2005).

Dragonhead (*Dracocephalum moldavica* L.) is a genus of the family *Lamiaceae*. It is an annual herb, erect, bushy, branching plant, native to central Asia and is naturalized in eastern and central Europe. It is frequently consumed as a food additive and a herbal drug; it is used in stomach and liver disorders, headache and congestion. The extract of this herb have been used as an antitumer and an antioxidant and antimutagentic properties (Dasmalchi *et al*., 2007; Kakasy, 2006). Essential oils are plant secondary metabolites that are known for their fragrance and food flavour properties. They consist of a complex mixture of mono- and sesquiterpenes, phenyl propanoids and oxygenated compounds. Essential oils can be present in different plant organs and materials, and their storage is related to specialized secretory structure. The yield of essential oil from plant raw materials by distillation or pressing may on average vary from 0.1-1%, thus restricting the major essential oils production to the plant group of aromatic plants. Due to their function as signaling compounds between different types of organisms and diverse biological systems, their general antimicrobial and antioxidative effects and medicinal activity, essential oils offer a promising potential for future applications within the fields of agriculture, medicine, pharmaceutical industry and biotechnology. Changed consumer demands and raised interest in natural product compounds, especially, essential oils, have formed the basis for initiating the research study on dragonhead plant production to encourage its cultivation, processing, marketing and distribution as aromatic and medicinal plant.

Water deficit in plants may lead to physiological disorders, such as a reduction in photosynthesis and transpiration (Sarker *et al.,* 2005) and in the case of aromatic plants may cause significant changes in the yield and composition of essential oils, for example, water deficit decreased the oil yield of rosemary (*Rosmarinus officinalis* L.) (Singh and

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Ramesh, 2000) and anise (*Pimpinella anisum* L.) (Zehtab-Samasi *et al.,* 2001). By contrast, water stress caused a significant increased in oil yield of citronella grass (*Cymbopogen winterianus* Jowitt.) expressed on the basis of plant fresh mass (Fatima *et al.,* 2000) with the severity of the water stress response varying with cultivar and plant density and parsley (*Petroselinum crispum* L.) (Petropoulos *et al.,* 2008).

Phosphorus element is an essential nutrient for crop growth and high yield with good quality. In this respect El-Habbasha *et al.* (2005) reported that increasing phosphorus levels increased each of growth characters, oil percentage and oil yield on groundnut.

The aim of this study was to determine the effects of phosphorus fertilization on the content and chemical of dragonhead essential oil under water stress conditions.

MATERIALS AND METHODS

The pot experimental study was carried out under the natural conditions of the greenhouse of the National Research Center, Dokki, Giza, Egypt, during the two successive seasons of 2005/2006 and 2006/2007. The soil texture was sandy loam (44.5% sand, 28.8% silt, and 26.7% clay), organic matter content – 0.85%, pH – 8.25, EC – 0.87 mmohs cm^{-1}, total nitrogen – 0.11%, available phosphorus – 2.33 mg 100 g^{-1}, potassium – 19.03 mg 100 g^{-1}. The field capacity (FC) and wilting point (WP) were determined according to the pressure membrane methods. The field capacity, permanent wilting point, available soil moisture (ASM) and bulk density (BD), as means over the two seasons were 34.5, 16.0, 18.5% and 1.36 g cm^{-3}, respectively.

Seeds of dragonhead were introduced from Conservator El-Jerdins Botanious D-Nancy in France. The seeds were sown in the 15th November in the two seasons into pots of (30 cm dia, 40 cm depth) filled with 8 kg of air dried soil. The soil related to the Typic Torrifluvents (USDA, 1996). Three levels of phosphorus fertilizer (0, 0.8, and 1.6 g pot $^{-1}$, as super phosphate, 15.5% P_2O_5) was applied at once before sowing, and after two months, water stress treatments (80 (I-80), 60 (I-60) and 40% (I-40) ASM) were equal to 30.8, 27.1, and 22.6% soil moisture. Pots were weighted daily and when soil moisture percentage reached the aforementioned points, pots were irrigated to reach field capacity (34.5% soil moisture). The differences between the needed soil moisture for the previous treatments and field capacity were calculated and added to the pots in the different treatments. The amounts of the irrigation water during the growing seasons were summed together to estimate plant water requirements for the different treatments. The meteorological data at Giza, Egypt during the two growing seasons are shown in (Table 1). The experimental layout was factorial experiment in complete randomized design (CRD) with three replications. Each replicate contained seven pots, while the pot contained three plants. Plant fresh mass (g plant $^{-1}$) of each replicate was determined at the flowering stage after six months from planting. Essential oil determination was carried out at the flowering stage after six months from planting. Essential oil percentage of the fresh herb was determined according to the method described in the British Pharmacopoeia (2002) by using Clevenger apparatus and expressed as (ml 100 g^{-1} fresh herb), while essential oil yield per plant was expressed as ml plant $^{-1}$. GC/MS analysis of essential oil was performed separately with a Hewlett Packard model 5890. Gas chromatograph equipped with 5 series Mass selective detector 9144 (HP). The column used was SE-54 (30 m x 0.25 mm i.d.). The oven temperature was maintained at 60°C 2 min^{-1}, after injection, and then programmed at 5°C min^{-1}, to 270°C. The injector temperature was 270°C and MS condition was kept at 280°C and compounds were identified by matching of their mass spectra with those recorded in the MS library and further confirmed by comparison of the mass spectra with those of reference compounds or with published data. Except for the constituents of the

T a b l e 1. Meteorological data at Giza (CLAC, Egypt) during the two growing seasons

Months	2005/2006					2006/2007				
	T(°C)		Rs	RH	ETp	T(°C)		Rs	RH	ETp
	Max.	Min.	(MJ m^{-2} d^{-1})	(%)	(mm d^{-1})	Max.	Min.	(MJ m^{-2} d^{-1})	(%)	(mm d^{-1})
November	23.4	10.5	18.6	51.9	2.9	25.2	14.9	17.8	56.9	3.4
December	19.9	7.3	17.5	54.1	2.0	20.3	10.7	17.7	59.3	2.4
January	20.8	7.5	16.0	54.8	1.9	17.9	8.2	15.9	65.1	2.1
February	22.7	9.9	17.0	52.4	2.4	19.7	10.8	16.4	59.2	2.4
March	24.6	10.5	19.2	50.4	3.1	22.8	12.0	18.1	54.1	3.4
April	27.4	15.6	23.0	48.5	4.6	26.4	14.5	19.4	53.7	5.1
May	31.0	16.9	24.7	48.3	6.8	32.0	19.0	21.1	49.2	6.9

Monthly average: T – temperature, Rs – solar radiation, RH – relative humidity, ETp – potential evapotranspiration.

T a b l e 2. Effect of irrigation levels, phosphorus rates and their interactions on herb fresh yield, essential oil and oil yield of dragonhead plants in two seasons

Parameters	Fresh mass (g $plant^{-1}$)		Essential oil (%) x 10^{-2}		Oil yield ($plant^{-1}$) x 10^{3}	
	2005/2006	2006/2007	2005/2006	2006/2007	2005/2006	2006/2007
I-40	28.13c ± 3.301	27.99c ± 3.497	5.12b ± 0.652	5.22b ± 0.712	14.53c ± 3.178	14.80c ± 3.600
I-60	32.19b ± 2.966	31.78b ± 3.075	6.13a ± 0.312	6.22a ± 0.363	19.77b ± 2.355	19.85b ± 2.967
I-80	36.32a ± 4.165	36.85a ± 4.497	6.21a ± 0.710	6.28a ± 0.870	22.76a ± 4.956	23.38a ± 5.707
LSD	0.629	0.756	0.329	0.316	0.906	1.225
P0	28.10c ± 3.303	27.72c ± 3.460	5.48b ± 0.735	5.44b ± 0.768	15.53c ± 3.401	15.28c ± 3.666
P1	32.63b ± 3.415	32.96b ± 3.655	5.57b ± 0.60	5.61b ± 0.486	18.26b ± 3.284	18.55b ± 2.990
P2	35.91a ± 4.184	35.94a ± 4.693	6.42a ± 0.581	6.67a ± 0.612	23.26a ± 4.728	24.20a ± 5.283
LSD	0.629	0.756	0.329	0.316	0.906	1.225
I-40xP0	23.98f ± 0.881	23.50f ± 0.625	4.67c ± 0.577	4.50e ± 0.500	11.17f ± 1.244	10.58g ± 1.254
I-40xP1	29.22e ± 0.901	29.30e ± 0.693	4.83c ± 0.289	5.17d ± 0.289	14.11e ± 0.546	15.13f ± 0.729
I-40xP2	31.19d ± 0.529	31.17d ± 0.289	5.87b ± 0.116	6.00c ± 0.000	18.29cd ± 0.354	18.70de ± 0.173
I-60xP0	29.03e ± 0.834	28.27e ± 0.305	6.00b ± 0.400	6.00c ± 0.000	17.40d ± 0.842	16.96ef ± 0.183
I-60xP1	31.81d ± 0.684	32.07d ± 0.737	6.10b ± 0.173	6.00c ± 0.000	19.40c ± 0.416	19.24cd ± 0.442
I-60xP2	35.73c ± 0.191	35.00c ± 1.732	6.30b ± 0.361	6.67b ± 0.289	22.51b ± 1.199	23.35b ± 1.876
I-80xP0	31.28d ± 0.453	31.38d ± 0.318	5.77b ± 0.379	5.83c ± 0.289	18.03cd ± 0.956	18.31de ± 1.010
I-80xP1	36.85b ± 0.441	37.50b ± 0.458	5.77b ± 0.252	5.67cd ± 0.577	21.26b ± 1.178	21.27bc ± 2.398
I-80xP2	40.81a ± 0.405	41.67a ± 0.577	7.10a ± 0.173	7.33a ± 0.289	28.98a ± 0.964	30.55a ± 1.064
LSD	1.089	1.309	0.569	0.548	1.568	2.123

Means with different letters within each column are significant at 0.05 level and means in the same column with the same letters are not significant. P – phosporus fertilizer, P0 – control, P1– 0.8 g P pot^{-1}, P2 – 1.6 g N pot^{-1}. I – irrigation of: 40, 60, 80% ASM, respectively.

essential oil, the data in this study were analyzed with the analysis of variance (ANOVA) using MSTATC program. When significant differences ($P<0.05$) were detected, the least significant difference (LSD) test was used to separate the mean values.

RESULTS AND DISCUSSION

Under water stress, increase in moisture significantly enhanced the fresh herb yield (Table 2). Oil percentage increased with increase in moisture and phosphorus levels and increased significantly with the higher levels of irrigation and P in the two seasons. Fresh herb and oil yields increased significantly with increasing levels of irrigation from 40 to 80% ASM. The irrigation applied at 80 and 60% increased fresh herb yield by 22.55 and 12.62, 24.05 and 11.93% in the first and second seasons, respectively over that at 40% ASM, while, the corresponding increase in oil yield was only to the extent of 36.16 and 26.51, 36.7 and 25.5% in the first and second seasons respectively over that at 40% ASM. It was found that increasing levels of water stress reduce growth and yield due to reduction in photosynthesis and plant biomass. Under increasing water-stress levels photosynthesis was limited by low CO_2 availability due to reduced stomatal and mesophyll conductance. Drought stress is associated with stomatal closure and thereby with decreased CO_2 fixation. The decrease in oil yield with an increase in moisture stress on fresh herb yield. These results are in close agreement with those of (Dunford and Vazques, 2005; El-Naggar *et al.,* 2004; Khalid, 2006; Leithy *et al.,* 2006; Misra and Strivastava, 2000; Moeini Alishah *et al.*, 2006; Singh and Ramesh, 2000; Zehtab-Samasi *et al.,* 2001).

Fresh herb and oil yields increased significantly with an increase in P application up to a dose of 1.6 g pot $^{-1}$. Higher yields of dragonhead plant with increased P application have been reported in soils of low P content. Application of P fertilizer at 1.6 g pot $^{-1}$ and 0.8 g pot $^{-1}$ increased fresh herb yield by 22.03 and 14.19; 22.88 and 15.90% in the first and second seasons respectively over that of no fertilizer, while the corresponding increase in oil yield was only to the extent of 33.24 and 14.96, 36.86 and 17.63% in the first and second seasons respectively over that of no fertilizer. Improved phosphorus nutrition appears to stimulate processes which reduce plant water stress. Physiological studies under well watered conditions showed suboptimal phosphorus levels reduce root hydrautic conductivity causing low plant water potential and stomatal conductance. Furthermore, phosphorus fertilized plants had lower stomatal conductance and net photosynthesis rate (Dosskey *et al.,* 1993). Particularly, with application phosphorus fertilizer was revealed to make an effect positive to increasing doses on essential oil content and yield on cumin plant (Tuncturk and Tuncturk, 2006).

There was a significant difference in most of interaction treatments between irrigation and P levels. Increases in both of moisture and P levels enhanced the fresh herb yield, essential oil percentage and oil yield. The irrigation applied at 80% ASM, combined with P fertilizer at 1.6 g pot $^{-1}$ gave the best results of fresh herb yield, essential oil percentage and oil yield in the two seasons.

The content of geranial, geraniol and geranyl acetate of the essential oil was affected by soil moisture and p levels (Table 3). Increase of moisture from 40 to 80% ASM, increased geranial content, in contrast geraniol content decrease with increase of moisture levels, while irrigation applied at 60% ASM gave the highest content of geranyl acetate followed by 40% ASM, then 80% ASM gave the lowest content. As compared soil moisture with P levels, the content of geranial, geraniol and geranyl acetate were more affected by soil moisture than P levels. Increases of P levels from 0 to 1.6 g pot $^{-1}$ differ of the contents of geranial, geraniol and geranyl acetate. P fertilizer at 0.8, 0 and 1.6 g pot $^{-1}$ gave the highest mean values. The highest content of geranial (26.73%), geraniol (45.98%) and geranyl acetate (87.45%) resulted from the treatments at 40% field capacity combined with 0.8 g pot $^{-1}$, 80% ASM alone and 60% ASM

T a b l e 3. Effect of irrigation levels and /or phosphorus rates on geranial, geraniol and geranyl acetate of *Draccoceplalum moldavica* L. plants in 2006/2007

Treatments		Components (%)		
		Geranial	Geraniol	Geranyl acetate
Irrigation	40xP0	20.77	2.12	70.89
	40xP1	26.73	5.37	64.81
	40xP2	21.01	2.38	73.32
	60xP0	0.49	8.76	80.76
	60xP1	6.79	10.13	70.59
	60xP2	0.44	4.16	87.45
	80xP0	0.56	45.98	45.18
	80xP1	0.41	34.57	60.32
	80xP2	0.35	44.27	49.63
Mean	I-40	22.87	3.29	69.67
	I-60	2.57	7.68	79.60
	I-80	0.44	41.61	51.71
	P0	7.27	18.95	65.61
	P1	11.31	16.69	65.24
	P2	7.26	16.93	70.13

Exlanations as in Table 2.

combined with 1.6 g pot $^{-1}$, respectively. Baher *et al.* (2002) the main constituents such as carvacrol increased while γ-terpinene concentration decreased under water stress conditions of *Satureja hortensis*. Also, Khalid (2006) found that increasing levels of water stress reduce eugenol and methylchavicol while, farnesene and 1,8-cineol were increased in basil herb.

CONCLUSIONS

1. Phosphorus fertilizer was optimum for plant production and quality, resulting in higher herb fresh, essential oil yields and its quality under well-watered conditions at 80% ASM, also under moderate-watered conditions at 60% ASM and under water deficit conditions at 40% ASM.

2. The optimum irrigation levels for the highest yields of fresh herb and essential oil was 80 % available soil moisture.

3. Increasing irrigation levels affected the geranial, geraniol and geranyl acetate contents of dragonhead plant.

4. Increase of moisture from 40 to 80% available soil moisture increased geranial content, in contrast geraniol content decrease with increase of moisture levels, while irrigation applied at 60% available soil moisture gave the highest content of geranyl acetate followed by 40% available soil moisture, then 80 % available soil moisture gave the lowest content.

REFERENCES

Baher Z.F., Mirza M., Ghorbanil M., and Rezaii M.Z., 2002. The influence of water stress on plant height, herbal and essential oil yield and composition in *Satureja hortensis* L. Flav. Fragr. J., 17, 275-277.

British Pharmacopoeia Commission, **2002.** A Dictionary of Drug Names for Regulatory Use in the UK. The Stationary Office Press, London, UK.

Dasmalchi K., Damien H.J., Laakso I., and Hihunen R., 2007. Chemical composition and antioxidative activity of moldavian balm (*Dracocephalum moldavica* L.) extracts. LWT Food Sci. Technol., 40, 239-248.

Dosskey M.G., Boersma L., and Linderman R.G., 1993. Effect of phosphorus fertilization on water stress in Douglas fir seedlings during soil drying. Plant and Soil, 150, 33-39.

Dunford N.T. and Vazques R.S., 2005. Effect of water stress on plant growth and thymol and carvacrol concentrations in Mexican oregano grown under controlled conditions. J. Appl. Hort., 7, 1, 20-22.

El-Habbasha S.F., Kandil A.A., Abu-Hagaza N.S., El-Haleem A.K.A., Khalafallah M.A., and Behairy T.G., 2005. Effect of phosphorus levels and some biofertilizers on dry matter, yield and yield attributes of groundnut. Bull. Fac. Agric., Cairo Univ., 56, 237-252.

El-Naggar A.A.M., El-Naggar H., and El-Fawakhry F.M., 2004. Physiological studies on growth and flowering of *Cyprus papyrus* L. Alex. J. Agric. Res., 49(3), 93-105.

Fatima S.F., Farooqi A.H.A., and Srikant S., 2000. Effect of drought stress and plant density on growth and essential oil metabolism in citronella java (*Cymbopogen winterianus* Jowitt). J. Med. Arom. Plant Sci., 22, 563-567.

Kakasy A.Z., 2006. New phytochemical data on *Dracocephalum* Species. Ph.D. Thesis, Pharmacognosy Dept., Semmelweiss Univ., Budapest, Hungary.

Khalid Kh.A., 2006. Influence of water stress on growth, essential oil, and chemical composition of herbs (*Ocimum* sp.). Int. Agrophysics, 20, 289-296.

Leithy S., El-Meseiry T.A., and Abdallah E.F., 2006. Effect of biofertilizer, cell stabilizer and irrigation regime on rosemary herbage oil yield and quality. J. Appl. Sci. Res., 2, 10, 773-779.

Misra A. and Strivastava N.K., 2000. Influence of water stress on Japanese mint. J. Herb Spices Med. Plants, 7(1), 51-58.

Moeini Alishah H., Heidari R., Hassani A., and Asadi Dizaji A., 2006. Effect of water stress on some morphological and biochemical characteristics of purple basil (*Ocimum basilicum*), J. Biol. Sci., 6(4), 763-767.

Naghibib F., Mosaddegh M., Motamed S.M., and Ghorbani A., 2005. *Labiatae* family in folk medicine in Iran: from ethnobotany to pharmacology. Iranian J. Pharm. Res., 2, 63-79.

Petropoulos S.A., Daferera D., Polissiou M.G., and Passam H.C., 2008. The effect of water deficit stress on the growth, yield and composition of essential oil of parsley. Sci. Hort., 115(4), 393-397.

Sarker B.C., Hara M., and Uemura M., 2005. Proline synthesis, physiological responses and biomass, yield of eggplants during and after repetitive soil moisture stress. Sci. Hort., 103, 387-402.

Singh M. and Ramesh S., 2000. Effect of irrigation and nitrogen on herbage, oil yield and water-use efficiency in rosemary grown under semi- arid tropical conditions. J. Med. Aromatic Plant Sci., 22, 659-662.

Tuncturk R. and Tuncturk M., 2006. Effects of different phosphorus levels on the yield and quality components of cumin (*Cuminum cyminum* L.). Res. J. Agric. Biol. Sci., 2(6), 336-340.

USDA, Soil Survey Staff, **1996.** Keys to Soil Taxonomy. NRCS Press, Washington, DC, USA.

Zehtab-Salmasi S., Javanshir A., Omidbaigi R., Aly-Ari H. and Ghassemi-Golezani K., 2001. Effects of water supply and sowing date on performance and essential oil production of anise (*Pimpinella anisum* L.). Acta Agron. Hung., 49(1), 75-81.