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Changes in essential oil content of different organs of dill genotypes in response to water deficit

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ABSTRACT

A split plot experiment (based on RCB design) with four replications was conducted in 2014, to evaluate the effects of different irrigation treatments (I_1, I_2, I_3 and I_4: irrigation after 70, 100, 130 and 160 mm evaporation, respectively) on essential oil content of dill (*Anethum graveolens* L.) organs in two genotypes (Local and Mammoth). Irrigation treatments and genotypes were allocated to the main and sub-plots, respectively. Essential oil percentage of dill organs increased, but their essence yield decreased as water deficit severed. Mammoth had the highest essential oil percentage in all organs, but essential oil yield of vegetative organs and flowers of the local genotype was much more than that of mammoth genotype. However, the difference in essence yield of seeds between two genotypes was not significant. The highest essential oil percentage and yield under all irrigation intervals were obtained from seeds, followed by flowers and vegetative organs. It was concluded that seeds and flowers are the most beneficial organs of dill, regarding essential oil production, although dill is largely used as a vegetable.

INTRODUCTION

Medicinal and aromatic plants are very importance because of the increasing demand for their products. *Anethum graveolens* L. known as Dill, is an annual aromatic and medicinal plant belonging to the Apiaceae (Umbilliferae) family. Constituents of dill include essential oils, fatty oil, proteins, carbohydrates, fibre, ash and mineral elements such as calcium, potassium, magnesium, phosphorous, sodium, vitamin A and niacin (Kaur and Arora 2010). Dill is native to Mediterranean countries and south-eastern Europe, used primarily as a condiment. Dill seed and leaves are used as flavouring in sauces, vinegars, pastries, and soups. Dill has medicinal value as a diuretic, stimulant, and a carminative. The dill seeds have essential oil as an active substance, while carvone and limonene are the main constituents of essential oil (Bailer et al. 2001; Singh et al. 2005; Callan et al. 2007). Environmental factors such as water stress may influence essential oil content dill organs (Ghassemi-Golezani et al. 2008)

Water deficit is known as an important limiting factor for plant production in arid and semiarid regions (Rodriguez 2006). It is more important in regions which experience the problem due to climate change, but have not been paid attention (Chaves and Oliveira 2004), because the global environment change enhances water loss. Environmental stresses bring about a wide range of responses in plants from genetic changes to the changes in growth and yield (Reddy et al. 2004).

Among the different environmental constraints, drought is an important abiotic factor limiting plant productivity. Depending on the plant growth stages, drought stress influences morphology, anatomy, physiology and biochemistry of plants (Upadhyaya and Panda 2004). Since plant growth is the result of cell division and enlargement, water stress directly reduces growth by decreasing CO2 assimilation and cell division and elongation. There are a number of modifications in plant structures and processes as a consequence of drought stress including stomatal closure, osmotic adjustment,

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smaller cell volume, reduced leaf area, increased leaf thickness, hairy leaves, and increased root/shoot ratio, as well as several changes in enzyme and hormone syntheses and activity (Pugnaire et al. 1999). The adaptability and responses to water stress depend on duration and magnitude of stress and developmental stage of plant (Kramer 1983).

In medicinal plants, metabolite content is economically more important than the yield of the plant part containing the metabolite, as it determines the cost of its extraction (Jaleel et al. 2007). The biosynthesis of secondary metabolites in medicinal and aromatic plants is strongly influenced by environmental factors (Tabatabaie and Nazari 2007). Solinas and Deiana (1996) reported that secondary products of plants can be altered by environmental factors and water stress is a major factor affecting the synthesis of natural products. Most of the essential oil is produced in the seeds and flowers of dill, although leaves and stems also contain essential oil (Ghassemi-Golezani et al. 2008). Since water resources in north-west of Iran are limited at the later stages of dill growth and development, this research was carried out to investigate the effects of water stress on essential oil content of dill organs in two genotypes.

MATERIALS AND METHODS

This experiment was conducted in 2014 at the Research Farm of the Faculty of Agriculture, University of Tabriz, Tabriz, Iran (Latitude 38° 05´N, Longitude 46° 17´E, Altitude 1360 m above sea level) to evaluate the effects of different irrigation treatments on essential oil content of dill organs. The climate is characterized by mean annual precipitation of 245.75 mm per year and mean annual temperature of 10°C. The experiment was arranged as split plot experiment (using RCB design) with four replications with irrigation treatments (I_1, I_2,I_3 and I_4: irrigation after 70, 100, 130 and 160 mm evaporation from class A pan, respectively) in main plots and dill genotypes (Native of Tabriz and Long island mammoth) in sub-plots.

Each plot consisted of 8 rows with 3 m length and 25 cm apart. Seeds were treated with Benomyl at a rate of 2 g/kg and were sown by hand on 30 April, 2014, in 1/5 cm depth of a sandy loam soil. All plots were irrigated immediately after sowing. After seedling establishment, irrigations were carried out according to the treatments. Weeds were controlled by hand during crop growth and development as required.

At flowering stage, vegetative organs (leaves and stems) and flowers and at maturity, seeds were harvested from middle part of each plot. Each sample was dried in a room at about 20-25ºC for seven days and separately weighed. A sample of 15 g from each organ was mixed with 250 ml distilled water and then it was subjected to hydro-distillation for 3 hours, using a Clevenger-type in 250 ºC (Darzi et al. 2012). Analyses of variance of the data were carried out by MSTAT-C software and means of each trait were compared by Duncan test at $p \leq 0.05$.

RESULTS AND DISCUSSION

The results of analyses of variance showed that the irrigation treatments had significant ($P \leq 0.01$) effects on essential oil percentage and yield of dill organs. Essential oil percentage and yield of vegetative organs and flowers were significantly ($P \leq 0.01$) affected by genotype. Genotype had also significant ($P \leq 0.01$) effect on essential oil percentage of seeds, but not on their essential oil yield ($P > 0.05$).

Essential oil percentage of dill organs significantly increased, but their essence yield per unit area decreased as a result of water stress, although there was no significant difference in essential oil yield of seeds under well watering (I_1) and mild water deficit (I_2). Mammoth genotype had the highest essential oil percentage, but the lowest essential oil yield in all organs. However, the difference in essential oil yield of seeds between local and mammoth genotypes was not statistically significant (Table 1).

Ghassemi-Golezani et al. (2008) also reported that the essential oil percentage of dill significantly improved, when plants were subjected to water stress during reproductive stages. This may be attributed to the function of secondary metabolites as self-defence components against stress conditions. In other words, the stress conditions accelerate the biosynthesis of essential oils (Ezz et al. 2009). Drought stress increases the essential oil percentage of medicinal and aromatic plants, in order to prevent oxidization within the plant cells (Aliabadi et al. 2009).

Reduction in essential oil yield of dill organs under water stress (Table 1) directly related with the reduction of individual organ yield under stressful condition (Ghassemi-Golezani et al. 2008, 2011). Essential oil percentages of palmarosa (*Cymbopogon martinii*) and citronella java (*Cymbopogon winteranus*) leaves were also increased, but essential oil yields were decreased due to water stress (Fatima et al. 2006). Rahmani et al. (2008) showed that the highest oil percentage of calendula (*Calendula arvensis*) was achieved under drought stress, but the highest oil yield was obtained under none-stress condition. The reduction in essential oil yield is due to disturbance

Table 1- Means of the essential oil percentage and yield of dill organs for different irrigation treatments and genotypes

Treatments	Essential oil percentage (%)			Essential oil yield (g/m^2)		
	leaves and stem	flower	seed	leaves and stem	flower	seed
Irrigations						
I_1	0.084 d	0.881 d	1.284 d	2.374 a	3.189 a	3.58 a
I_2	0.126 c	1.272 c	1.697 c	1.925 b	2.658 b	2.94 ab
I_3	0.166 b	1.646 b	2.132 b	1.556 c	2.165 c	2.39 b
I_4	0.216 a	2.042 a	2.678 a	1.273 d	1.731 d	2.24 b
Genotypes						
Local	0.136 b	1.373 b	1.896 b	1.877 a	2.521 a	2.99 a
Mammoth	0.160 a	1.548 a	2.178 a	1.687 b	2.351 b	2.95 a

Different letters in each column indicate significant difference at $P \leq 0.05$.
I_1, I_2, I_3, I_4: Irrigation after 70, 100, 130 and 160 mm evaporation, respectively.

in photosynthesis and carbohydrate production and suppression of the plant growth under stress condition (Flexas and Medrano 2002).

Essential oil percentage of all organs in Mammoth was higher than that of local genotype, but essential oil yield of vegetative organs and flowers of the local genotype was much more than that of mammoth genotype, with no significant difference in essential oil yield of seeds between two genotypes (Table 1). This indicates that individual organ mass of local genotype was higher than that of mammoth genotype. Secondary metabolites in the medicinal and aromatic plants are strongly influenced by genotypes and environmental conditions (Yazdani et al. 2002). Ozturk (2004), Safikhani (2007) and Farahani (2009) believed that depending upon the plant species and genotype, drought stress can increase, decrease or have no effect on the levels of metabolites.

Essential oil percentage linearly increased in dill organs with increasing irrigation intervals. The rate of essence enhancement in leaves and stems was low, but in flowers and grains it was high, as indicated by the slope of the regression lines. Seeds had the highest essence percentage under all irrigation treatments, followed by flowers and vegetative organs (Figure 1a). In contrast, essential oil yield of dill organs linearly and almost with similar trend decreased as water deficit increased. The highest essential oil yield under all irrigation intervals was also recorded for seeds and then for flowers and vegetative organs, respectively. Very low essence percentage of vegetative organs of dill to some extent was compensated by their high mass and essence yield per unit area (Figure 1b). Seeds and flowers of dill also produced more essential oil in comparison with leaves under drought (Ghassemi-Golezani et al. 2008) and salinity (Ghassemi-Golezani et al. 2011) stresses.

CONCLUSION

Essential oil percentage of dill organs linearly increased, but their essence yield decreased with decreasing water availability. The highest essential oil percentage and yield under all irrigation treatments were obtained from seeds, followed by flowers and vegetative organs. Essential oil yield of vegetative organs and flowers of the local genotype was much more than that of mammoth genotype, with no significant difference in essence yield of seeds. Therefore, seeds and flowers of dill were the

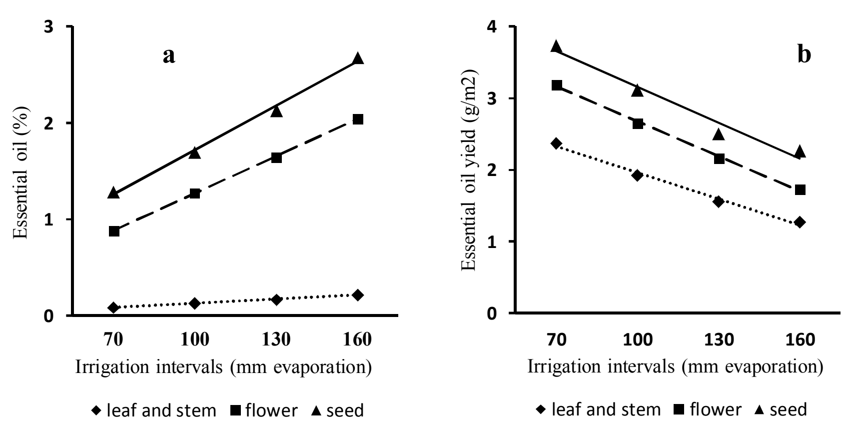

Figure 1. Changes in essential oil percentage (a) and yield (b) of dill organs at different irrigation intervals

most beneficial organs for essential oil production, and local genotype was generally superior in this regard.

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