INNSPUB

Journal of Biodiversity and Environmental Sciences (JBES)
ISSN: 2220-6663 (Print) 2222-3045 (Online)
Vol. 9, No. 6, p. 64-68, 2016
http://www.innspub.net

RESEARCH PAPER | OPEN ACCESS

Effect of water deficit on field performance and essence yield of basil cultivars

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Article published on December 30, 2016

Key words: Basil, Chlorophyll content, Essence, Grain yield, Plant height

Abstract

Two experiments were conducted in 2014 and 2015 to evaluate the effect of different irrigation intervals on field performance and essence yield of *Ocimum basilicum* (sweet basil) and *Ocimum gratiss* imum (African basil) species. Three cultivars ofsweet basil (Mobarekeh from Iran, Siam Queen from thailand and Italian basil) and a cultivar of African basil (Cinnamon) were grown under normal irrigation and mild, moderate and severe water stress conditions. Plant height, leaves per plant, chlorophyll content, flowering branches and grain and essence yields of basil cultivars were determined in both years. The results showed significant differences among cultivars as well as irrigation treatments in all these traits. The cultivar × irrigation interaction was also significant for most of the traits, except chlorophyll content and flowering branches. The plant height, leaves per plant, flowering branches and grain yield of all basil cultivars considerably decreased under moderate and severe water stresses. However, chlorophyll content index increased with decreasing water supply, and essence yield of all cultivars was higher under mild and moderate water deficits, compared with normal irrigation. The Iranian cultivar Mobarekeh produced the greatest essence yield under different irrigation intervals, which is directly related with the highest grain yield of this cultivar in various watering conditions.

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Introduction

The genus *Ocimum* belonging to the plant family *Lamiaceae*, comprises 65 annual and perennial herbs and shrubs species native to the tropical and subtropical regions of Asia, Africa and South America (Darrah, 1988; Paton *et al*., 1999). Among the species of the genus *Ocimum basilicum* L. (basil) is the major essential oil crop around the world and cultured commercially in many countries. Basil is an annual plant with white-purple flowers, which is a widely grown aromatic crop cultivated either for the production of essential oil, or as vegetable (Ekren *et al*., 2012).

Basil essential oil has been utilized extensively in the food industry as a flavoring agent, and in perfumery and medical industries (Simon *et al*., 1999). In medical treatments, it has been utilized for headaches, coughs, worms, stomach-ache and kidney malfunctions (Simon *et al*., 1990). It possesses a range of biological activities such as insect repellent, nematocidal, antibacterial, antifungal agents and antioxidants activities (Simon *et al*., 1999; Juliani and Simon, 2002; Lee *et al*., 2005).

Water stress is one of the important environmental factors affecting crop growth and yield worldwide. Water deficit result in lowered water potential, reducing the water flow and cell turgor pressure needed to maintain plant structure and promote growth (Hopkins, 1995). Radusiene *et al*., (2011) reported that water deficit alters essential oil levels and constituency of aromatic plants.

Radacsi *et al.* (2011) found that different levels of soil water capacity (SWC 30, 50 and 70%) resulted in significant changes in physiological parameters of *Ocimum basilicum*. Severe water deficit increased malondialdehyde (MDA) content revealing an enhancement of oxidative stress and lipid peroxidation by 52 %, compared to the control plants. However, under a moderate water deficit, the plants exhibited a little decrease in RWC and water potential, as well as lower oxidative stress. According to Zamborine *et al.* (2005) a water supply of 140-480 mm year^{-1} positively influenced basil yield, but it had no effect on the essential oil content.

Since basil cultivars may respond differently to various levels of water stress, the objective of this research is to compare field performance and essence yield of basil cultivars from different countries under normal and limited irrigation conditions.

Material and methods

Location

Field experiments were conducted in 2014 and 2015 at a farm in Makoo, Iran. The soil of the experimental field was clay loam with a pH of 8.1, organic carbon 1%, available N 0.11 %, availaible P 12.21 ppm and exchangeable K 265 ppm.

Experimental design

Two species of basil including *Ocimum basilicum* (sweet basil) and *Ocimum gratis* imum (African basil) were used. Three cultivars ofsweet basil (Mobarekeh from Iran, Siam Queen from Thailand and Italian basil) and a cultivar of African basil (Cinnamon) were evaluated under four irrigation intervals (irrigation after 70, 100 and 130 and 160 mm evaporation from Class A evaporation pan). The experiments were laid out as split plot based on randomized complete block design with three replications. The irrigation treatments and cultivars were allocated to main and sub-plots, respectively. Each plot consisted of six rows with three m length, 25 cm row spacing and 10 cm of plant spacing in the row with a density of 40 plants per m^2.

Measurements

Plant height, leaves per plant, chlorophyll content index (CCI), flowering branches and grain yield for each plot were determined at reproductive stages. 10 plants from each plot were harvested at flowering stage. Each sample was separately dried in a room at about 25^{o}C and weighed. 20g from each sample was mixed with 300 ml of distilled water and the essential oil content was determined by hydro-distillation for 3 h, using a modified Clevenger apparatus. Then essential oil yield was calculated on the basis of plant biomass.

Statistical analysis

All the data were analyzed with SAS 9.20. After testing the assumptions of ANOVA, the combined analysis of variance was performed to determine significant effects of the factors and their interaction. Means were compared by Duncan multiple range test at $p \leq 0.05$, and the Fig.s were drawn by Excel software.

Result and discussion

The combined analysis of variance showed significant differences among irrigation intervals in all traits and among cultivars in most of traits (except CCI).

The interaction of irrigation × cultivar was also significant for plant height, leaves per plant, grain yield and essence yield per unit area. However, the effect of year on any of the traits was not significant and only year x cultivar interaction was significant for grain yield per unit area (Table 1).

Table 1. Combined analysis of variance for the studied traits in basil cultivars under different irrigation treatments.

S.O.V	df	MS					
		Plant height	Leaves per plant	Chlorophyll index	flowering branches	Grain yield	Essential oil yield
Year (Y)	1	1247.0	9460.5	35.7	75.8	46949.2	213.4
Rep (Y)	4	416.0**	1912.9**	7.2	12.4**	15623.4**	53.2**
Irrigation (I)	3	2334.7**	17226.9**	61.2**	366.0**	394404.8**	4255.2**
Y x I	3	13.2	22.3	0.6	0.4	960.6	11.1
Ea	12	22.9	91.5	6.7	0.3	579.8	12.0
Cultivar (C)	3	6183.6**	4276.5**	44.7-	136.2**	84233.7**	11917.0**
Y x C	3	12.2	104.8	0.8	0.2	1124.9**	16.3
C x I	9	63.1**	443.7**	12.8	4.3	3795.9**	270.1**
Y x I x C	9	5.2	19.3	1.0	0.3	129.1	5.1
Eb	48	8.1	107.3	12.0	2.5	231.2	13.5
CV%		3.9	3.8	19.8	10.1	2.1	5.28

Mobarakeh and Italian cultivars generally had the greatest plant height and leaves per plant, respectively. The plant height and leaves per plant of all cultivars considerably decreased under moderate and severe water stresses. The most reduction in plant height and leaves per plant due to water stress was recorded for Mobarakeh and Italian cultivars, respectively (Table 2).

Chlorophyll content index (CCI) increased, but flowering branches decreased with decreasing water availability (Fig. 1). CCI of Cinnamon and Thai cultivars was more than that of other two cultivars. In contrast Mobarakeh and Italian cultivars produced comparatively more flowering branches per plant (Fig. 2).

Table 2. Effect of irrigation treatments and basil cultivars interaction on the plant height, leaves per plant, grain and essence yields of *Ocimum* sp.

Cultivar	Irrigation treatments	Plant height (cm)	Leaves per plant	Grain yield (kg/ha)	Essence yield (kg/ha)
Cinnamon	I_1	68.5 *d*	290.7 *cd*	842.8 *e*	54.5 *h*
	I_2	67.5 *de*	285.0 *de*	784.0 *e*	54.5 *h*
	I_3	59.5 *f*	268.8 *fg*	624.0 *i*	59.7 *g*
	I_4	51.2 *h*	246.7 *ij*	502.0 *l*	35.8 *j*
Mobarakeh	I_1	104.5 *a*	282.0 *de*	938.5 *a*	109.6 *b*
	I_2	103.0 *a*	276.3 *ef*	866.3 *b*	116.2 *a*
	I_3	89.0 *b*	252.7 *hi*	737.7 *f*	105.7 *b*
	I_4	75.7 *c*	235.0 *jk*	628.2 *i*	70.5 *e*
Italian	I_1	89.7 *b*	311.7 *ab*	865.0 *b*	76.2 *d*
	I_2	86.5 *b*	323.0 *a*	803.0 *d*	77.5 *d*
	I_3	72.5 *c*	283.2 *de*	664.0 *h*	83.2 *c*
	I_4	66.2 *de*	256.5 *ghi*	599.2 *j*	48.2 *i*
Thai	I_1	64.0 *e*	300.0 *bc*	754.2 *f*	54.5 *h*
	I_2	64.5 *e*	304.7 *b*	717.3 *g*	58.4 *gh*
	I_3	54.8 *g*	262.7 *gh*	615.5 *ij*	65.0 *f*
	I_4	50.7 *h*	226.3 *k*	536.8 *k*	45.2 *i*

I_1, I_2, I_3, I_4: irrigation after 70, 100, 130 and 160 mm evaporation from class A pan. Different letters in each column indicate significant difference at $p \leq 0.05$.

Enhancing chlorophyll content index of basil cultivars under water stress may be related to the decrease in leaf area index (Dastborhan and Ghassemi-Golezani, 2015). Low leaf area enables leaves to intercept more sunlight for chlorophyll synthesis. An increase in leaf chlorophyll due to water deficit has also been observed in potato (Teixeira and Pereira 2007) and plantago (Rahimi *et al.* 2010).

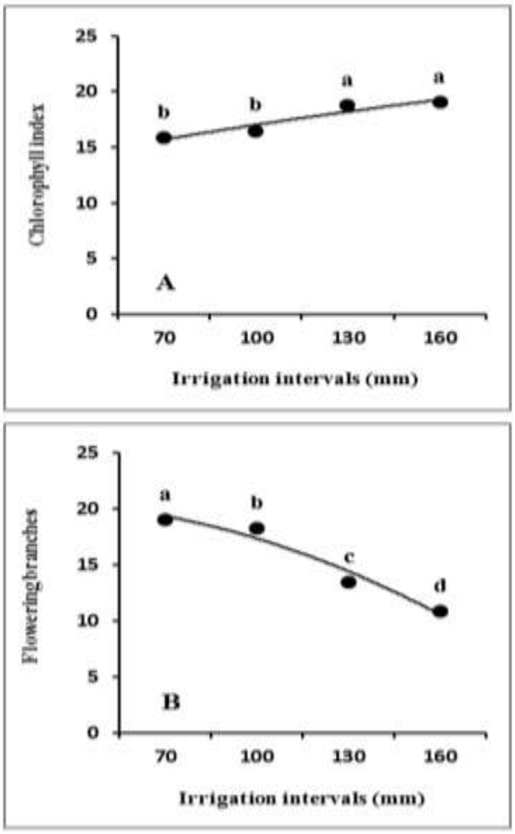
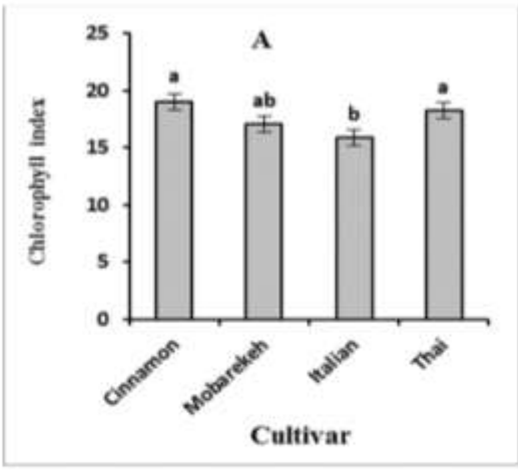


Fig. 1. Changes in mean chlorophyll index (A) and flowering branches (B) of basil at different irrigation intervals.



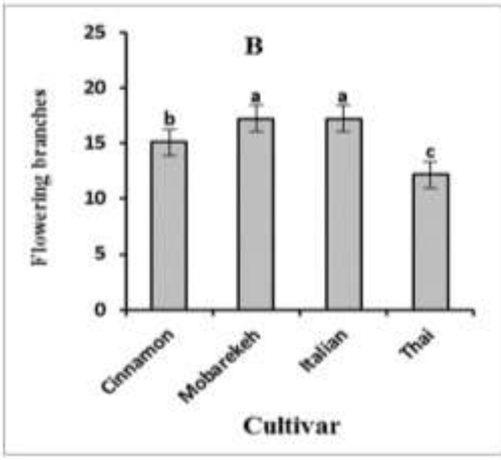


Fig. 2. Means of chlorophyll index (A) and flowering branches (B) for different basil cultivars.

Maximum grain yield of all basil cultivars was obtained under normal irrigation, which was decreased with increasing water limitation. The greatest grain yield per unit area under all irrigation intervals was recorded for Mobarakeh cultivar. This superiority was reduced with diminishing water supply (Table 2). The highest grain yield of Mobarakeh could be the result of producing more flowering branches per plant (Fig. 2).

Essence yield significantly increased when basil cultivars exposed to mild and moderate water deficits, compared with normal irrigation. However, it was decreased under severe water stress, because of a large reduction in grain yield per unit area. Essence yield of Mobarakeh was considerably higher than that of other cultivars under all irrigation treatments, which also directly related with the highest grain yield of this cultivar at different watering conditions (Table 2).

Radacsi *et al.* (2010) also reported that the essential oil content per plant dry mass of basil increased slightly as a consequence of drought stress. Ade-Ademilua *et al.* (2013) found that water stress boosted essential oil content of African basil under shade, but reduced that under full sunlight. Ghassemi-Golezani *et al.* (2016) obtained the highest essential oil yield per unit area of dill genotypes under mild and moderate water deficits, as a result of less reduction in grains per plant, grain weight and yield and also greater essence percentage in comparison with well watering.

Similarly, the results of our research clearly indicated that mild and moderate water stresses could significantly enhance essence yield of basil cultivars, due to increment of essence content of grains under these conditions (Table 2).

Conclusion

Decreasing water availability led to significant reduction in plant height, leaves per plant, flowering branches and grain yield of all basil cultivars. However, essence yield of all cultivars improved under mild and moderate water limitations. The Mobarekeh cultivar produced the highest essence yield under different irrigation intervals, followed by Italian cultivar. The superiority of these cultivars in essence yield directly related with their greater grain yield per unit area at different watering conditions.

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