Industrial Crops and Products 54 (2014) 167–174

Contents lists available at ScienceDirect

Industrial Crops and Products

journal homepage: www.elsevier.com/locate/indcrop

Phenological, yield, essential oil yield and oil content of cumin accessions as affected by irrigation regimes

S. Alinian, J. Razmjoo*

Department of Agronomy and Plant Breeding, College of Agriculture, Isfahan University of Technology, Isfahan, Iran

A R T I C L E I N F O

Article history:
Received 3 October 2013
Received in revised form 14 January 2014
Accepted 19 January 2014
Available online 8 February 2014

Keywords:
Cumin
Deficit irrigation
Essential oil yield
Oil content
Yields

A B S T R A C T

Cumin (*Cuminum Cyminum* L.) is cultivated in arid and semi-arid regions where drought is a common problem, thus developing irrigation programs to minimize yield and quality reduction in this area is needed. Therefore, plant height, yield components (number of branches/plant, number of umbels/plant, number of umbellets/plant, seed numbers/umble and1000 seed weight), seed and essential oil yields, aerial parts essential oil content and seed oil content of four cumin accession were determined under 70, 150 and 200 mm irrigation regime based on evaporation of class A pan during 2011and 2012 in Isfahan, Iran. Seed and essential oil yields, number of irrigation per year and seed oil yield decreased, while annual water used and irrigation water use efficiency increased as drought level increased. Aerial essential oil content was not affected by severe but increased under moderate drought stresses. However, there was interaction between irrigation regime and accession and based on 40% or less reduction in seed yield, Isfahan and Khour could be cultivated under 70–200 mm, while Nishapur and Yazd could be planted under 70–150 mm irrigation regimes. Furthermore, based on 30% or less reduction in essential oil yield, Isfahan, Khour and Nishapur could be planted under 70–200 mm while Yazd could be planted under 70 mm irrigation regimes for essential oil yield production. Whereas, for both seed and essential oil yields production, Yazd under 70 mm, Isfahan under 150 and Khour under 200 mm irrigation regimes were the most productive accessions, thus recommended for cultivation under these conditions. The results suggested that cumin is a drought tolerant species, but its water requirement depends on genotypes and purpose of cultivation.

1. Introduction

Drought impairs plant growth and development and limits plant production more than any other environmental stress (Sionit et al., 1973). Soil or atmospheric drought is a serious agronomic problem in many parts of the world especially in arid and semi-arid areas (Flexas et al., 2004). Effects of drought on plants depend on drought severity and duration, the metabolic state of the plant, other environmental factors such as salt and heat stresses, plant species, plant developmental stage and even cultivars within a species (Ramachandra Reddy et al., 2004; Retondo and Westgate, 2009; Demirevska et al., 2009).

However, there are several evidences that water stress has several positive effects on the biosynthesis of secondary metabolites, solute accumulation and enzymes activities (Retondo and Westgate, 2009; Bettaieb et al., 2012). In addition, consumption of herbal medicines and use of natural antioxidants are continuously increasing in the world, thus increased in biosynthesis and accumulation of such metabolites could represent potential sources of herbal medicines and natural antioxidants for human health. Moreover, medicinal plants grown under arid and semi-arid conditions usually produce higher concentrations of natural products than the same plants, but cultivated in moderates climates due to soil or atmospheric drought and much higher light intensities (Shao et al., 2008).

One approach for adaptation to drought conditions would be switching to adapted plants which are not only considered as cash-crops for producers but also as alternative to current ordinary agronomic crops such as medicinal plants. Cumin (*Cuminum Cyminum* L.) is a small annual herbaceous industrial and medicinal plant growing to a height of about 25 cm. Its flowers are small, with white or pink color in compound umbel form (Bettaieb et al., 2011a). Seeds contain oil (approximately 10%), protein, cellulose, sugar, mineral elements and volatile oil (1–5%) (Li and Jiang, 2004). The essential oil ratio varies between 2.5% and 5% based on differing climate and soil conditions. Cuminaldehyde, cymene, and

Abbreviations: $IWUE_{sy}$, seed yield irrigation water use efficiency; $IWUE_{esy}$, essential oil yield irrigation water use efficiency.

* Corresponding author. Tel.: +98 3113913455; fax: +98 3112254.
E-mail address: Krazmjoo@cc.iut.ac.ir (J. Razmjoo).

0926-6690/$ – see front matter © 2014 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.indcrop.2014.01.028

often terpenoids are the major constituents of the volatile oils of cumin (Bettaieb et al., 2011b). Seeds contain essential oils and phenolic compounds that are used for flavoring foods, treatment of toothache, diarrhea, epilepsy, dyspepsia and jaundice and natural antioxidant (Nostro et al., 2005; Bettaieb et al., 2012). Aerial parts of this plant contain carotenoids, flavonoids, phenolic compounds and anthocyanins, thus they could be used as natural antioxidants (Panico et al., 2005). This aromatic plant is adapted to dry conditions and planted either for production of essential oils or as a spice. Essential oils of cumin and other *Uumbelliferae* family help the plant to adapt to its environment and consequently produced higher quantities when plants meet extreme stress (Olle and Bender, 2010).

Another approach for adaptation to drought conditions would be using appropriate deficit irrigation. Several irrigation regimes have been used for cumin production.

Jangir and Singh (1996), Yava and Dahama (2003) and Ahmadian et al. (2011) recommended five, four and three irrigations per season for cumin production under different conditions, respectively. Rezaei Nejad (2011) compared no irrigation, one irrigation at sowing and two irrigations (sowing and seed formation) and showed that under two irrigations cumin produced higher seed and essential oil yields, but essential oil content decreased with increasing irrigation number. Motamedi-Mirhosseini et al. (2011) applied three and five irrigations and reported that yield and the most yield components of cumin accessions were reduced under three as compared with five irrigation regimes. The previous reports reviewed here showed that cumin were subject to some irrigation regimes at different growth stages or some supplemental irrigations. However, to allow for a more realistic response to drought, a sustained water stress is needed. Consequently, research is needed for appropriate irrigation management under deficit irrigation conditions in order to develop irrigation programs to minimize yield and essential oil yield reduction in arid and semi-arid regions. Though deficit irrigation was defined as providing less water to the plant at selected growth stages during the growing season (Behboudian and Mills, 1997). Our definition for deficit irrigation is providing less water than normally needed to the plant throughout of the plant life. In addition, it can be hypothesis that optimal biosynthesis of secondary metabolites would be obtained using drought tolerant species under water deficit situation. Therefore, the objectives of this study were to determine the most efficient use of water and the changes in the yield, yield components, seed essential oil, aerial parts essential oil and seed oil content and oil yield of four cumin accessions in dry area under three irrigation regimes.

2. Materials and methods

2.1. Experimental site

This experiment was conducted at the Research Station of the College of Agriculture, Isfahan University of Technology located in Lavark Najaf Abad, Isfahan, Iran at an altitude of 1630 m above sea level during 2010–2011 (Figs. 1 and 2) and 2011–2012 (Figs. 3 and 4) The soil was loamy clay (16% sand, 38% clay and 46% silt) with pH 7.5, containing 0.05% total nitrogen, 265 ppm available potassium, 17 ppm available phosphorus. The experimental design was a split-plot design with four replications and three irrigation regimes (70 mm, 150 mm and 200 mm evaporation based on Class A pan) were the main plots and four cumin accessions (Isfahan, Nishapur, Yazd and Khour) were the sub-plots. The 70, 150 and 200 mm irrigation regimes represented the non-stressed or control, moderate and severe drought stresses, respectively. Each plot consisted of six rows with 4 m length, 20 cm between rows and a distance of 5 cm between plants in the rows. Cumin seeds were obtained from

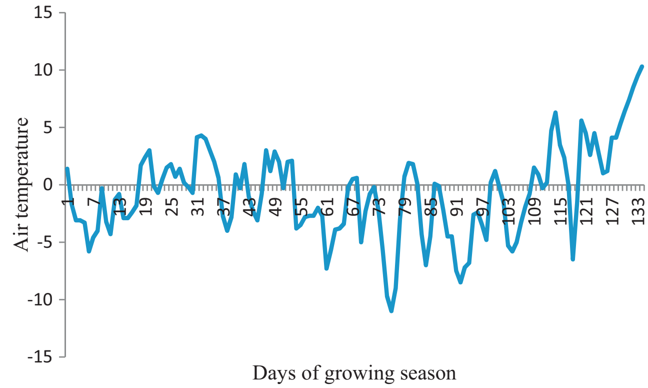

Fig. 1. Daily values of air temperature (°C) precipitation (mm) of years 2010 to 2011.

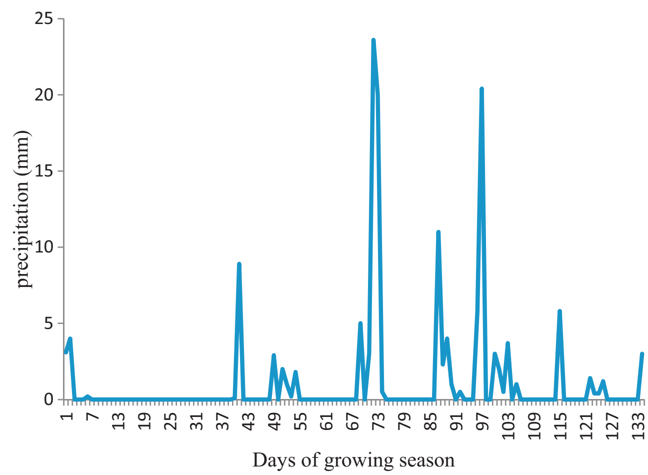

Fig. 2. Daily values of precipitation (mm) of years 2010 to 2011.

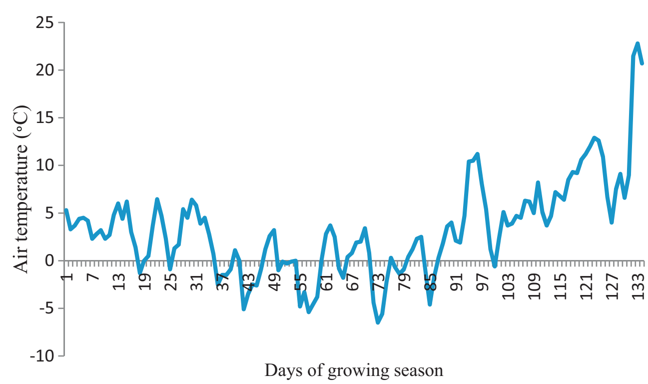

Fig. 3. Daily values of air temperature (°C) of years 2011 to 2012.

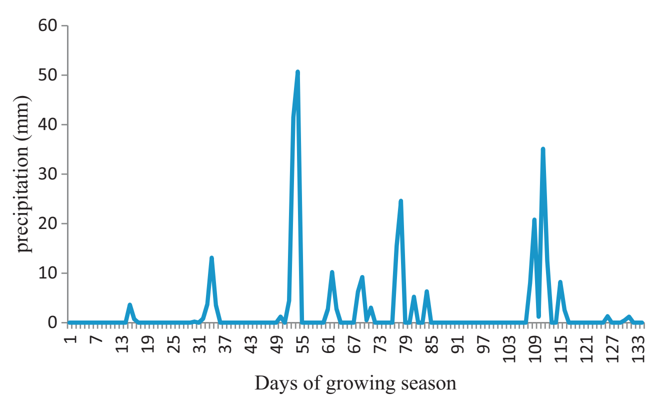

Fig. 4. Daily values of precipitation (mm) of years 2011 to 2012.