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Determining water requirements of biblical hyssop using an ET-based drip irrigation system

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ABSTRACT

Biblical Hyssop (*Marjorana syriaca*) is a perennial herb having high commercial and medicinal uses, with little known about its water and nitrogen requirements. The aim of this research was to investigate the effect of different irrigation regimes and nitrogen doses on the morphometric characteristics (shoot height and weight), crop yield, and water productivity of *Marjorana syriaca*. Growth parameters and soil water use of the crop were monitored in a randomized split-plot two-year (2014–2015) field experiment under four irrigation regimes (60%, 80%, 100%, and 120% of crop evapotranspiration – ET) and four nitrogen treatments (0, 75, 150, and 225 kg ha^{-1}) using an automated ET- based drip irrigation system in a semi-arid climate. The results showed that *Marjorana syriaca* adapted best to the higher irrigation regimes, with fresh weight and dry leaf weight higher by 185% and 165% respectively than the lowest irrigation treatment. Although applying medium doses of nitrogen improved yield at higher irrigation regimes, it did not affect the harvest index or crop water productivity. Dry matter fraction (ratio of dry to fresh aboveground biomass) and to a higher extent crop water productivity (ratio of marketable dry yield to unit of water used) significantly decreased when irrigation was doubled. Biblical hyssop can be grown and perform best when irrigated with 100% fraction of evapotranspiration at full stage and when supplied with 150 kg N ha^{-1} yr^{-1}.In case of water shortage, managed deficit irrigation at 60% ET increased water productivity, sustained yield, and saved water.

1. Introduction

In arid and semi-arid environments, irrigation remains a necessity for profitable agricultural production (Kijne et al., 2003). Yet over-irrigation can decrease crop economic productivity and pose a stress on land, water and energy resources (Debaeke and Aboudrare, 2004; Jaafar, 2014; Jaafar and Ahmad, 2015). Precision irrigation has a high potential for green water savings in agriculture. In precision irrigation, economic returns per unit of water applied are improved through applied irrigation water according to real-time measurements of ET and/or soil water status monitoring/status monitoring (Levidow et al., 2014).

Crops have different yield responses to irrigation, and this has been (and will continue) to be studied thoroughly for many crops under different conditions, given the advances in irrigation techniques and management (Ali et al., 2007; Dogan et al., 2013; Ghamarnia et al., 2014; Klocke et al., 2011; Atallah et al., 2011). *Marjorana syriaca*, also known as Lebanese Oregano or Syrian Marjoram, is a native-to-Orient aromatic perennial herb of the Lamiaceae family (Kintzios, 2003). It is a shrub-like herb that grows in the wild in the Mediterranean region, being pervasive on the coast and on the west side of Mount Lebanon. It produces for about 5 years. *Marjorana syriaca* is considered as one of the most important essential oils – producing crop, mainly the of carvacrol type (Alma et al., 2003). Essential oils of Oregano are known for their antimicrobial, antioxidant (Martucci et al., 2015), antiseptic (Oka et al., 2000), nematicidal (Daouk et al., 1995), anti-fungal (Hossain et al., 2016; Tunc et al., 2000) and even anti-cancer-cell proliferation properties (Marrelli et al., 2015). *M. syriaca* is an important food constituent as it is well known for its use in salads as fresh produce, as a spice and herbal tea, and in pastries as ground dried leaves (usually mixed with sesame, sumac, and olive oil) (Tepe et al., 2005). It is well used as a spice in many Mediterranean as well as Mexican cuisines. When dried, mixed with dried sumac, salt, roasted sesame seeds and olive oil, it forms a major constituent of the "Manakeesh", a popular Levantine food breakfast (Riolo, 2007). Commercial planting can be promising as it could satisfy the market demand and improve the natural occurrence of the plant (Atallah et al., 2011).

Response of other oregano species (*Origanum vulgare*, *Origanum majorana*) to water and nitrogen applications has been

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documented, more so in pot experiments than in the field. Murillo-Amador et al. (2015) studied response of *Origanum vulgare* L. to organic fertilizers, and Karamanos and Sotiropoulou (2013) studied response of *Origanum vulgare* ssp. *hirtum* to nitrogen applications. Said-Al Ahl et al. (2009) studied the effect of water stress on *Origanum vulgare* L. by irrigating at three different soil moisture levels in pots. Azizi et al. (2009) tested response of *Origanum vulgare* L. planted in pots to different soil moisture regimes and nitrogen applications. Oregano species have been found to exhibit high physiologic variability (Ietswaart and Ietswaart, 1980). To the best of the authors' knowledge, scientific literature on water and nitrogen requirements of *M. syriaca* is sparse. Atallah et al. (2011) studied growth response of *M. syriaca* to different irrigation timings (once every week, 2 weeks and 3 weeks) with fixed water amounts. Omer Elsayed (1999) studied effect of nitrogen fertilization on pot-grown Egyptian oregano (*M. syriaca* L. var. *aegyptiacum*) under sandy soils. Kiyyam et al. (2007) studied the effect of nitrogen and plant density on herbal yield of *M. syriaca*.

The objective of this research was to assess, over a period of two years, the effect of four reference evapotranspiration (ET) – based irrigation regimes and four nitrogen applications on the above-ground fresh and dry biomass, dry leaf yield, dry matter fraction, harvest index, and water productivity of *M. syriaca*) in semi-arid open field conditions. The research contributes to the understanding of the water and nutrient needs for this medicinal and edible herb with high commercial potential. The research quantifies the currently unknown yield response of the selected crop to water and nitrogen application by relating yield to irrigation as a fixed percentage of evapotranspiration.

2. Materials and methods

2.1. Site description

The research experiment was carried out at the American University of Beirut's Agricultural Research and Education Centre (AREC) located in the centre of the Beqaa Valley of Lebanon (995 m ASL) during years 2014 and 2015. Mean annual rainfall for 58 years of record at AREC is 521 mm, with a coefficient of variation of 0.31 and no observable trend. The climate is classified as semi-arid, with an average annual grass reference evapotranspiration of 1.5 m, 70% of which occurs between April and September. Monthly weather data for the two years of the experiment are shown in Fig. 1. The soil of the experimental plot was shallow gravelly clay (Calcaric Cambisols) having a pH of 7.89, an electrical conductivity of 0.4 dS m^{-1}, $CaCO_3$ of 32.5% and an organic matter content of 2.48%. The volumetric water content at −33 kPa was measured at 42%, and that at −500 kPa was 32.7% (using a pressure plate extractor). The important available plant nutrients (mg kg^{-1} of soil) in the *Ap* horizon (0–15 cm) at the time of planting were: N, 12; P, 20; and K, 530.

2.2. Treatments and experimental design

The field was planted on May 29, 2014, with two – month old *M. syriaca* plants. The seeds of the plants were earlier sown in a peat moss-based medium in germination trays. Approximately one centimeter of shoot tips from each plant was removed at planting to enhance multiple shoot formation. The experiment consisted of four equal-interval irrigation treatments based on percentages of grass-reference Hargreaves ET (Hargreaves and Samani, 1985), multiplied by the crop coefficients (Kc) for mint (60% ETc, 80% ETc, 100% ETc and 120% ETc). Kc curve of mint (Allen et al., 1998) was chosen because it is a perennial crop belonging to the same (Lamiaceae) family. Four nitrogen treatments were applied (0, 75, 150 and 225 kg N ha^{-1}). The control treatment is the 100% ETc, zero nitrogen application. Hargreaves ET was chosen because the controller used for the irrigation treatments calculates ET based on: (1) temperature data sent from a wireless mini weather station (Model SLW5, Weathermatic™, Garland, Texas, USA); and, (2) user-specified latitude for extra-terrestrial solar radiation calculations. Treatments were arranged in a randomized split-plot design that was replicated four times. The irrigation treatments were randomized at the whole plot level (hard to change), and the nitrogen treatment were randomized within the whole plots at the subplot level (easy to change).

The experimental design and the irrigation system layout are shown in Fig. 2. Each whole plot had three lines of the crop spaced 0.4 m apart, with 1.2 m between the whole plots (a total of 16 whole plots). Each subplot consisted of 4 plants per line spaced 0.4 m apart, with a total of 12 plants per subplot, yielding a density of 6.25 plants m^{-2}. Subplots were levelled and slightly diked so as to prevent runoff. The irrigation variable was achieved by applying a percentage of ETc during each irrigation event rather than decreasing the irrigation frequency across treatments, which was not feasible using the automated system that calculates the timing based on the set percentages. A zero-irrigation treatment was not sought as the crop will not survive rain-fed ecosystems in the

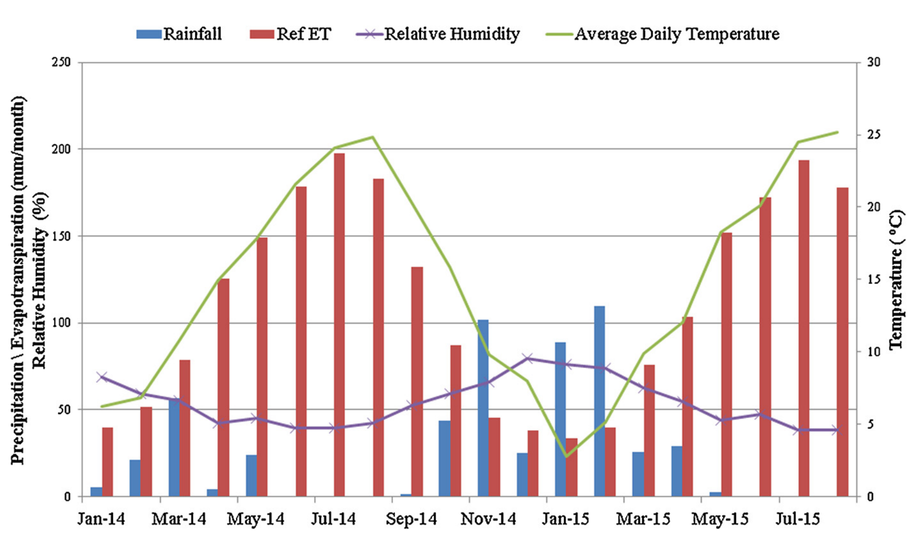

Fig. 1. Weather and reference evapotranspiration data for the period of the experiment.