Scientia Horticulturae 201 (2016) 190–198

Contents lists available at ScienceDirect

Scientia Horticulturae

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

Evaluation of the effects of saffron–cumin intercropping on growth, quality and land equivalent ratio under semi-arid conditions

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ARTICLE INFO

Article history:
Received 14 December 2015
Received in revised form 31 January 2016
Accepted 1 February 2016
Available online 11 February 2016

Keywords:
Crocin
High planting density
Picrocrocin
Replacement series
Safranal

ABSTRACT

Proper rows arrangement in an intercropping system is an important factor for reducing interference between plants and better absorption of environmental resources. Effects of saffron–cumin intercropping based on replacement series on growth, yield, quality and total land equivalent ratio (LER_T) was studied as two-year field experiment based on a randomized complete blocks design arranged in factorial with three replicates at Faculty of Agriculture, Ferdowsi University of Mashhad, Iran, during 2013–2014 and 2014–2015 growing seasons. Different planting densities of saffron (low, medium and high equal to 64, 128, 256 corms m^{-2}, respectively) and saffron–cumin intercropping (in proportion of 100–0, 75–25, 50–50, 25–75 and 0–100) were considered as the first and the second experimental factors, respectively. Based on the results, interaction between saffron planting density and saffron–cumin ratio was significant on flower number and dried stigma yield. However, crocin, picrocrocin and safranal were not affected by saffron planting density and intercropping ratios or their interaction. In each intercropping ratio, flower number and dried stigma yield increased with increasing saffron planting density. In the first and second year, reduction in cumin ratio in intercropping decreased cumin grain and essential oil yields. Nonetheless, saffron–cumin intercropping could partly compensate yield loss. For instance, in the second year, cumin yield in 50% saffron + 50% cumin treatment was found to be 23.33% less than cumin monoculture treatment. In both years of the experiment, the highest LER_T was observed in 50% saffron + 50% cumin treatment. Hence, this ratio along with high planting density of saffron (256 corms m^{-2}) is recommended for saffron and cumin intercropping.

1. Introduction

Saffron (*Crocus sativus* L.) is a perennial plant which grows in arid and semi-arid regions of the world such as Iran, Italy and Greece. In 2013, the area planted to saffron in Iran was 84,000 ha with average yield of 311 t, making Iran the largest saffron producer in the world (Agricultural Statistics, 2013). Saffron plays an important role in agricultural economy, especially in semi-arid regions, where precipitation is often trumped by evapotranspiration (Alizadeh et al., 2009; Moayedi Shahraki et al., 2010). Low water requirement and specific morphological characteristics such as narrow and thick leaves are the most important factors allowing the plant to grow in arid and semi-arid regions (Alizadeh et al., 2009; Kafi et al., 2002; Koocheki et al., 2014).

After flowering in November, daughter corms start to form. Later in March, when vegetative growth reached to its maximum, daughter corms' formation will be completed. In May, all above ground parts would dry and daughter corms remain dormant until October (Koocheki et al., 2014; Kumar et al., 2009). Hence saffron is known as a perennial crop in terms of agronomy but an annual plant in botany (Koocheki and Seyyedi, 2015).

In general, saffron vegetative growth and stigma yield are typically low in the first year. From the second year onwards, increase in saffron yield would be achieved which is highly due to increase in daughter corms number (Koocheki and Seyyedi, 2015; Koocheki et al., 2014). Consequently, reduced land use efficiency and increased nutrients loss occur during the first year which is substantially duo to low daughter corms density (Koocheki et al., 2014; Shabahang et al., 2013).

A higher planting density, which named “dense corm planting”, is required to compensate lower yield in the first year (Koocheki et al., 2011, 2012, 2014). However, under low and high planting densities, there is no vegetation in the saffron fields from May to November, so in addition to soil erosion, dormant corms can also be damaged due to high temperatures during summer seasons (Rezvani Moghaddam et al., 2013). Accordingly, strategies which

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http://dx.doi.org/10.1016/j.scienta.2016.02.005
0304-4238/

Table 1
The soil physic-chemical characteristics of the experimental site.

Soil analysis	2013–2014	2014–2015
Physical		
Clay (%)	42.5	44.2
Silt (%)	33.0	32.6
Sand (%)	24.5	23.2
Chemical		
OC (%)	0.61	0.57
Available N (mg kg^{-1})	10.8	9.32
Olsen-P (mg kg^{-1})	24.7	22.5
Available K (mg kg^{-1})	187	185
pH	8.17	8.08
EC (dS m^{-1})	0.92	0.89

Soil texture class (0–30 cm): clay (US system).

maintain vegetation on land during the first year would reduce water and nutrient loss, soil erosion and improve saffron yield in subsequent years.

Proper implementation of intercropping, especially in medicinal and aromatic plants, helps to cover soil and avoid loss of water and nutrients (Maffei and Mucciarelli, 2003; Rezvani Moghaddam et al., 2014; Singh et al., 2010; Weisany et al., 2016; Verma et al., 2013). Therefore, it seems that in saffron intercropping systems, green cover or companion crops' residues can effectively reduce the adverse effects of high temperatures on dormant daughter corms. In this regard, cumin (*Cuminum cyminum* L.) is an herbaceous and annual plant belonging to Apiaceae family (Bettaieb Rebey et al., 2012; Zhaveh et al., 2015) which is cultivated in arid and semi-arid regions of Iran as medicinal plant (Alinian and Razmjoo, 2014; Rahimi, 2013). About 26% of the total area under cultivation of medicinal plants in Iran is allocated to cumin cultivation (Koocheki et al., 2004).

Generally, saffron and cumin have similar ecologic characteristics. Cumin plants grow to 22–30 cm tall (Salehi Sardoei et al., 2014) and are drought-tolerant (Alinian and Razmjoo, 2014; Alinian et al., 2016) so can be intercropped with saffron. The cumin plants have relatively high branched stems and if they are cultivated at proper densities (about 150 plants per square meter) they can cover the entire soil surface (Mashayekhi Sardooyi et al., 2011; Rezvani Moghaddam et al., 2014).

Although there are some information about saffron and chamomile (*Matricaria chamomilla* L.) (Naderidarbaghshahi et al., 2013), saffron and black seed (*Nigella Sativa* L.) and saffron and ajwain (*Trachyspermum ammi* L.) (Koocheki et al., 2009) intercropping, there is very little information on saffron and cumin intercropping. On the other hand, efficiency of saffron and cumin intercropping might be affected by saffron planting density. Therefore the current study was aimed to evaluate the effects of saffron and cumin intercropping based on replacement series on growth, yield and qualitative traits as well as land equivalent ratio of both crops.

2. Material and methods

2.1. Site description

The study was conducted in 2013–2014 and 2014–2015 growing seasons (June–May), at the experimental station, Faculty of Agriculture, Ferdowsi University of Mashhad, Iran (latitude: 36°15′ N; longitude: 59°28′ E; elevation: 985 m altitude). Some local meteorological data for the two growing seasons are presented in Fig. 1. The soil physic-chemical characteristics of the experimental site are given in Table 1.

2.2. Experimental design and field management

A randomized complete block design arranged in factorial with 15 treatments and three replicates was used. Different planting densities of saffron (low, medium and high equal to 64, 128, 256 corms m^{-2}, respectively) and saffron–cumin intercropping based on replacement series (in proportion of 100–0, 75–25, 50–50, 25–75 and 0–100) were considered as the first and the second experimental factors, respectively (Table 2 and Fig. 2A,B).

The experimental field was prepared according to the local practice for saffron and cumin production and then plots were established. Each plot was 6 m^2 (2 m long and 3 m width) and 0.5 m apart. Between blocks, 1.5 m alley was kept to eliminate all influence of treatments.

Saffron mother corms were planted using basin method on 20th of June 2013. 180 kg ha^{-1} N from urea was applied as top dress at six times (24th of October 2013, 18th of February 2014, 5th of April 2014, 16th of October 2014, 18th of February 2015, and 7th of April 2015). Due to soil chemical properties of experimental site, there was no need to use phosphorus and potassium fertilizers.

Cumin seeds were sown in both growing seasons on 16th of February 2014 and 2015. Seedlings were thinned at four-true leaf stage based on proportion of saffron–cumin intercrops (Table 2). The first irrigation was done after seed sowing (which was coincident with the fourth irrigation in saffron). Irrigation schemes of saffron and cumin are given in Table 3. Weed management was carried out by hand-removal over growing seasons. No herbicides or pesticides were used throughout the growing seasons.

2.3. Sampling and measurements

2.3.1. Saffron

In the first year of the experiment, flowers were manually picked up daily from the first to 20th of November 2013. In the second year, picking began on 19th of October and finished on 19th of November 2014. In both years, flower number and dried stigma yield were recorded. Stigmas were dried in an oven at 30°C for 24 h to a constant weight before weighing (Gresta et al., 2009).

Crocin, picrocrocin and safranal were determined based on ISO 3632 trade standard (ISO/TS 3632, 2003), using UV–vis spectrometric method. Crocin, picrocrocin and safranal are expressed as direct reading of the absorbance of 1% aqueous solution of dried saffron at 440, 257 and 330 nm, respectively (Lage and Cantrell, 2009).

2.3.2. Cumin

At maturity stage (21st of May 2014 and 2015), eight plants from each plot were chosen randomly and plant height, umbel number in plant and 1000 seed weight were recorded. In addition, final grain, biological and essential oil yields were measured. Essential oil content was determined using the Clevenger apparatus. Briefly, grounded seeds (50 g) were mixed into 500 mL distilled water and run for 4 h. The essential oil content was reported as relative percentage (Jalali-Heravi et al., 2007). After determination of grain yield, plant residue (Table 4) was left on experimental plots.

2.3.3. Land equivalent ratio

For the saffron–cumin intercrops, partial and total land equivalent ratio (LER) were calculated according to the following equations (Rao and Willey, 1980):

$$LER_S = \frac{Y_{SI}}{Y_{SS}} \quad (1)$$

$$LER_C = \frac{Y_{CI}}{Y_{CS}} \quad (2)$$

$$LER_T = LER_S + LER_C \quad (3)$$