Industrial Crops & Products 125 (2018) 622–629

Contents lists available at ScienceDirect

Industrial Crops & Products

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

# Crop productivity and chemical compositions of black cumin essential oil in sole crop and intercropped with soybean under contrasting fertilization

Maryam Rostaei[a], Sina Fallah[a,*], Zahra Lorigooini[b], Ali Abbasi Surki[a]

[a] Faculty of Agriculture, Shahrekord University, Shahrekord, Iran
[b] Medical Plants Research Center, Basic Health Sciences Institute, Shahrekord University of Medical Sciences, Shahrekord, Iran

ARTICLE INFO

*Keywords:*
Black cumin
Organic manure
Essential oil
P-cymene
Carvacrol

ABSTRACT

Intercropping systems and the application of organic manures play an important role in increasing of quantity and quality of plant products. In order to evaluate the quantity and quality of black cumin products under contrasting fertilization, a factorial experiment was conducted in a randomized complete block design with three replications in 2016. Soybean and black cumin seeds were sown in five planting patterns (sole black cumin, sole soybean and three intercropping ratios of soybean: black cumin (1:2): one row of soybean plus two rows of black cumin, soybean: black cumin (1:1): one row of soybean plus one row of black cumin and soybean: black cumin (2:1): two rows of soybean plus one row of black cumin. All these cropping systems were received organic manure and chemical fertilizer. The results indicated that the highest seed yield (on an average by 86 g $m^{-2}$) of black cumin was achieved in sole crop of black cumin treated with organic manure. The maximum seed yield of soybean (on an average by 247 g $m^{-2}$) and land equivalent ratio (1.06) was obtained in two rows of soybean + one row of black cumin under the application of chemical fertilizer. The p-cymene (20.51–62.77%), carvacrol (2.40–25.99%), longifolene (1.11–24.69%) and spathulenol (0.9–14.45%) were major chemical compositions of black cumin. The highest content of p-cymene and carvacrol of black cumin essential oil were recorded in one row of soybean + two rows of black cumin with the application of chemical fertilizer and one row of soybean + one row of black cumin under chemical fertilizer, respectively. The highest longifolene and spathulenol content was observed in one row of soybean + two rows of black cumin treated with organic manure. These major chemical compositions are useful for industrial use (food and pharmaceutical). Therefore, according to different subjects of applying in industries it could be suggested especial treatment with favorite major compounds.

## 1. Introduction

Intercropping system is considered as the simultaneous cultivation of two or more crops in the same field and is a more sustainable method for enhancing crop yields in comparison with sole cropping systems (Ehrmann and Ritz, 2014; Brooker et al., 2015). Complementarity in resource niches such as diff ;erent rooting depth, diff ;erential canopy architecture or diff ;erential resource use (as with nitrogen), are also other contributing factors to greater yield stability (Raseduzzaman and Jensen, 2017).

Previous studies have shown that legume plants are key species in increasing resource efficiency (Fallah et al., 2018). Adding legumes in intercropping systems is justified by their ability to fix atmospheric nitrogen (Duchene et al., 2017). Also, Intercropping system can provide many ecosystem services such as decreasing chemical inputs requirements for the purpose of control weeds (Letourneau et al., 2011; Iverson et al., 2014), insect pests (Liebman and Dyck, 1993) and plant diseases (Boudreau, 2013). One intercrop component may change the micro-climate for another component, which could be unfavorable for pest and disease attack, resulting in greater productivity and stability (Raseduzzaman and Jensen, 2017).

Previous studies have mainly focused on intercropping of legume with non-legume (Lithourgidis et al., 2011; Dabbagh Mohammadi Nassab et al., 2011; Franco et al., 2015). At present, intercropping of legume with medicinal plants is increasing. Intercropping of legume with medicinal plants, improve the quality and quantity of essential oil in medicinal and aromatic plants (Fallah et al., 2018; Amani Machiani et al., 2018a). Soybean is known to be a leguminous crop and an important source of food in many countries (Cabrera et al., 2015). Nitrogen fixation in soybean plant is the result of symbiosis between

* Corresponding author at: Faculty of Agriculture, Shahrekord University, P.O. Box 115, Shahrekord, Iran.
*E-mail address:* fallah-s@sku.ac.ir (S. Fallah).

https://doi.org/10.1016/j.indcrop.2018.09.044
Received 14 July 2018; Received in revised form 18 September 2018; Accepted 21 September 2018

soybean roots and bacterium *Bradyrhizobium japonicum* (Fan et al., 2017). The amount of nitrogen fixation by soybean plant is estimated to be 65-115 kg $ha^{-1}$ during the growing season (Amani Machiani et al., 2018a).

One of the most important medicinal plants is black cumin (*Nigella sativa* L.). This plant is an annual plant belonging to the family Ranunculaceae, which is cultivated in the countries around Mediterranean Sea (Gharibzahedi et al., 2010).

The components of the essential oil are used in industry. P-cymene is commonly used in pastries and to flavor beverages (Sintim et al., 2015). Carvacrol has been shown to exhibit anti-mutagenic, anti-inflammatory, anti-microbial, anti-platelet, anti-oxidant, analgesic, anti-angiogenic, anti-parasitic, anti-elastase, insecticidal and cell-protective characteristics (Sokmen et al., 2004; Can Baser, 2008). Spathulenol is used as a base material in various fields such as medicines, foods, detergents, toothpaste and cosmetics (Ziaei et al., 2011; Paksoy et al., 2016). Longifolene is used in perfumery industry due to its woody odor (Tyagi et al., 2009).

Although chemical fertilizers are widely applied to increase crop yield, but their long-term application enhances soil pH, reduces beneficial soil microflora, pollutes water bodies and imbalances soil ecological system (Ahmadian et al., 2011; Bistgani et al., 2018). Consequently, in recent years, demand for organic products has increased due to health and sustainable environment consideration (Sangkumchaliang and Huang, 2012) particularly for medicinal products. On the other hand, a trend of medicinal plants cultivation with the application of organic manures is increasing at a rapid pace (Bajeli et al., 2016). Organic manure contains essential nutrients for crop growth. It improves chemical and physical properties of the soil and enhances organic matter, cation exchange and water holding capacity and ultimately the yield (Schlegel et al., 2015a,b; Pandey et al., 2016). Also it can effect on chemical compositions and the quality of medicinal plants (Fallah et al., 2018).

Previous studies have exposed that the application of organic manure has enhanced the quantity and quality of plant products. Abou El-Magd et al., (2008) reported the addition of organic manure enhanced the seed yield of fennel. Fallah et al. (2018) found that the application of broiler litter increases aerial yield, essential oil yield of dragonhead. Bajeli et al. (2016) reported that the use of organic manures (poultry manure, farmyard manure and vermicopmost) enhances aerial yield, oil yield and menthol content of the mint. Pandey et al. (2016) illustrated that the farmyard manure and poultry manure enhances methyl chavicol content of basil.

In the present study, the specific objectives were (a) to study the effects of chemical fertilizer and organic manure on black cumin yield in sole crop and intercrop, (b) to compare the essential oil production and chemical composition in black cumin plants cultivated under contrasting fertilization and (c) to assess the advantage of black cumin/ soybean intercropping over sole cropping through the use of land equivalent ratio (LER).

## 2. Materials and methods

### 2.1. Experimental set up

Field experiment was carried out in 2016 growing season at research farm of Shahrekord University (50° 49´E, 32° 21´N; 2050 m above sea level). The experiment was carried out with a factorial arrangement based on randomized complete block design with three replications. Soybean and black cumin seeds were sown in five planting patterns (sole crop soybean (D), sole crop black cumin (S) and three intercropping ratios of soybean: black cumin (1:2): one row of soybean + two rows of black cumin, soybean: black cumin (1:1): one row of soybean + one row of black cumin and soybean: black cumin (2:1): two rows of soybeans + one row of black cumin)). All these treatments were applied with organic manure and chemical fertilizer.

The climate of the region is classified by a temperate and cold climate with warm and dry summer, with average annual precipitation of 316 mm and an average monthly temperature of 12.12 °C. For soil analysis, soil samples were randomly collected from a depth of 0–30 cm at ten points using a soil auger. All soil samples were air-dried in the laboratory for 4 days and then crushed and sieved through a 2 mm sieve. The physical and chemical properties of the soil and the broiler litter were analyzed. The research farm soil is Entisol. The others properties of soil are as follows: pH: 8.09, electrical conductivity (EC): 0.587 (dS $m^{-1}$), total nitrogen: 0.59 (g $kg^{-1}$), available phosphorus: 0.021 (g $kg^{-1}$), available potassium: 0.313 (g $kg^{-1}$). The characteristics of broiler litter are as follows: pH: 7.56, electrical conductivity (EC): 5.57 (dS $m^{-1}$), total nitrogen: 19.1 (g $kg^{-1}$), total phosphorus: 6.9 (g $kg^{-1}$), total potassium: 12.9 (g $kg^{-1}$).

In this experiment, the sources of chemical nitrogen and phosphorus were urea (46% N) and triple superphosphate (44% $P_2O_5$), respectively. Chemical fertilizers (152 kg $ha^{-1}$ of urea and 141 kg $ha^{-1}$ of triple superphosphate) and organic manure (7.4 Mg $ha^{-1}$) were added before sowing. The black cumin and soybean seeds were obtained from Pakan Bazr Company, Isfahan, Iran, and Lorestan Agriculture and Natural Resource Research Center, respectively. Soybean seeds were inoculated with commercial rhizobia and sown 15 min after inoculation on 23th May 2016 simultaneously with black cumin. The soybean and black cumin were sown at 30 and 80 seeds $m^{-2}$ in both the sole and intercropped plots, respectively. The sole and intercropped soybean and black cumin were sown in the same rows spacing. The size of each plot was 2 × 5 m and consisted of 12 rows. The distance between rows spacing was 0.5 m. The crops were cultivated according to organic agriculture practices with no use of herbicide or pesticide applications. Weeds were controlled by hand weeding during the growing season.

### 2.2. Determination of soybean and black cumin seed yield

The black cumin and soybean were harvested at maturity stage (133 and 126 days after sowing), respectively. The plants were cut at ground level from each plot with manual shears. For yield determination of the soybean and black cumin, samples were transferred to the laboratory and kept at 70 °C to dry in an oven for 2 days. After drying, the seed yield was measured in g $m^{-2}$.

### 2.3. Nitrogen and phosphorus concentration

The nitrogen content of the black cumin and soybean seeds was determined using the KJeldahl method. The phosphorus content was determined spectrophotometerically with a Pharmacia LKB Novaspec-II spectrophotometer.

### 2.4. Isolation of essential oil

The seeds of the black cumin were harvested at the maturity stage (133 days after sowing), shade-dried and powderded. The amount of essential oil of black cumin seeds was determined through water and steam distillation and by means of Kaiser-Long Apparatus. The samples of essential oils were dehydrated over anhydrous sodium sulphate and stored at 4 °C until gas chromatography-mass spectrometry (GC–MS). The essential oil yield was calculated using the following equation (Bistgani et al., 2018):

Essential oil yield (g $m^{-2}$): (Black cumin seed yield g $m^{-2}$ × essential oil content g kg)/1000

### 2.5. Gas chromatography

Gas chromatography (GC) was carried out using a Thermoquest-Finnigan device equipped with FID detector and DB-5 capillary column (30 m × 0.25 mm i.d., film thickness 0.25 μm). The oven temperature was programmed as follows: The oven temperature was initiated at