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Intercropping of fenugreek as living mulch at different densities for weed suppression in coriander

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ABSTRACT

Living mulch planted between rows might limit weed growth. The objective of this study was to determine the weed-suppressing effect of fenugreek intercropped with coriander, with the aim to select a suitable density of fenugreek for intercropping in coriander production. Five fenugreek densities and three weed control levels were evaluated in a factorial arrangement of treatments. Results indicated that increasing density of fenugreek living mulch suppressed weed growth and increased seed yield compared to weed infested conditions. Maximum weed biomass was recorded in sole coriander with no control (329 and 274 g m^{-2} in 2012 and 2013, respectively), while minimum weed biomass was recorded in plots which fenugreek intercropped at the density of 50 plants m^{-2} and one hand weeding was applied. Increasing fenugreek density decreased the LAI of coriander with similar gentle slopes for both years. The seed yields obtained from weed free, one hand weeding, and no control plots were 1618, 973, and 457 kg ha^{-1}, respectively. With increase in weed control level fenugreek density caused a decrease with greater impact on the coriander seed yield. Essential oil content from dried fruit ranged from 0.52 to 1.14% and 0.52 to 1.10% in 2012 and 2013, respectively. Our findings confirm that fenugreek can be used as living mulch in organic coriander production to reduce the biomass of weeds. However, the use of fenugreek did not provide reliable weed control throughout the season and so must be combined with additional weed management options to achieve acceptable control.

1. Introduction

Coriander (*Coriandrum sativum* L.) is a culinary and medicinal plant from the Umbelliferae family. This plant is of economic importance since it has been used as flavoring agent in food products, perfumes and cosmetics. As a medicinal plant coriander has been credited with a long list of medicinal uses (Emamghoreishi and Heidari-Hamedani, 2006). In Iran more than 3200 ha are under coriander with an average production of 2 t ha^{-1}. However, coriander is not a good competitive crop against weeds. Its early growth is slow and in typical planting pattern weeds cause significant decrease in coriander yields.

In modern agriculture, chemicals have become the most frequently used weed control strategy. However, environmental and economic costs, as well as increased weed resistance to herbicides have led to a desire for less herbicide use on farms (Yousefi and Rahimi, 2014). One environmentally sound way to decrease herbicide use is living mulch as a cultural weed control method. Such systems consist of a species pre-sown or intercropped with a main crop in order to serve as a soil cover, which contributes towards weed control. Living mulches have the potential to reduce soil erosion, increase soil organic matter and nitrogen, improve water filtration, lower weed pressure (Hartwig and Ammon, 2002), and reduce weed seed bank (Gibson et al., 2011). However, living mulches are hardly practiced to date in annual crops, mainly because of the risk of lower yields compared to traditional cropping systems (Hiltbrunner et al., 2007). This yield reduction is very likely caused by the competition for light, water and nutrients between the living mulch and main crop (Thorsted et al., 2006). Plant density has been shown to be a main factor which changes the outcome of competition in plant community (Yousefi et al., 2012). In some cases, increased plant density leads to quicker canopy closure, increased crop interference and greater weed suppression, resulting in increased yields (Kolb et al., 2012; Jamshidi et al., 2013). However, high density of living mulch plants can lead to increases in competition for resource between living mulch plants and main

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crop. Hence, determining optimal plant density (the density which led to high weed suppression and low competition to main crop) of living mulch crops is crucial for efficient intercropping.

One of the most promising vegetable species appeared to be appropriate for this purpose is fenugreek (*Trigonella foenum-graecum* L.), because of the low height (0.3–0.6 m), quickly seedlings emergence and excellent soil surface coverage at a short time after emergence. Additionally, fenugreek produces numerous secondary metabolites, and some of them show allelopathic activity. For instance, Omezzine et al. (2014) showed that the aqueous and organic extracts of fenugreek significantly delayed germination and seedling growth in lettuce (*Lactuca sativa*). Extracts from the shoots were most active and showed selective activity on several weeds (Haouala et al., 2008).

There is only limited information available on herbicide-free weed management practices that provide adequate weed suppression while maintaining acceptable yields. Despite reports on the effect of fenugreek as living mulch on weed suppression, to the best of our knowledge no study has investigated the fenugreek density effect to optimize living mulch efficiency. Therefore, the objective of this study was to determine the weed-suppressing effect of fenugreek intercropped with coriander, with the aim to select a suitable density of fenugreek for intercropping in coriander production.

2. Materials and methods

2.1. Field experiments

Two field experiments were conducted at the Research Farm of the University of Zanjan, Zanjan, Iran, in 2012 and 2013. This region is characterized by a semi-arid cool climate, with an annual mean temperature of 11 °C and mean precipitation of 293 mm for the past 30 years. Mean monthly temperature and rainfall data during the growing season, recorded near the experimental area, are given in Table 1. The soil type was a sandy loam, with a pH of 8.1 and 8.18, and soil organic matter of 1.1% and 1.3% in 2012 and 2013, respectively. The soil was ploughed using a mouldboard plough (20–25 cm) that was followed by two disks to prepare the seedbed. As the crops were grown under organic conditions, only animal manure (20 t ha^{-1}) was added prior to plowing, and then thoroughly incorporated in the soil.

Coriander (cv. Esfahan) and fenugreek (cv. Ardakani) were sown at a row spacing of 0.25 m on 10 May 2012 and 4 May 2013. The plots consisted of ten 5-m-long rows. Furrow (in 2012) and drip (in 2013) irrigation were used on all plots. Irrigation was carried out weekly until physiological maturity of the coriander. Weeds were manually removed in weed-free plots throughout the season; no chemicals (herbicide and pesticide) were applied to the plots in both seasons.

Table 1
Average monthly air temperatures (°C) and rainfall (mm) during the coriander growing season in 2012 and 2013.

Month	Temperature (°C)						Rainfall (mm)	
	Mean		Maximum		Minimum			
	2012	2013	2012	2013	2012	2013	2012	2013
May	14.7	12.7	22.3	19.8	7.2	5.7	55.0	11.6
June	18.9	19.0	26.7	27.6	11.1	10.3	17.7	3.0
July	22.0	22.3	30.2	31.6	13.7	13.1	33.4	0.0
August	24.3	23.2	32.8	31.8	15.8	14.7	5.4	2.0
September	21.2	21.5	29.1	31.0	13.4	11.9	6.0	3.0
October	15.7	14.0	24.4	22.6	6.9	5.3	5.7	0.4
November	9.8	7.8	15.6	13.0	4.0	2.5	58.2	24.6

2.2. Experimental treatments

The study was arranged as factorial experiment based on randomized complete block design with three replications. Factors were five fenugreek densities (0, 10, 20, 30, 40 and 50 plants m^{-2}), which were intercropped with coriander in three levels of weed infestations (un-weeded control, weed free control, and one hand-weeding at 35 days after crop emergence). Fenugreek and coriander were over seeded to ensure uniform crop establishment, and were then thinned to the desired densities at 3–4 leaf stage. The density of 50 plants m^{-2} for coriander was established.

2.3. Plant sampling

For assessing the effect of the treatments on coriander leaf area (LA), destructive sampling was carried at flowering in both years. All coriander plants from a 50-cm length of the two middle rows of each plot were harvested by cutting at the soil surface. The areas of green leaves were measured using a Delta-T leaf area meter (Delta-T Devices, Cambridge, England). Leaf area index (LAI) of coriander was calculated by the following equations:

$$\mathrm{LAI} = \mathrm{LA}/\mathrm{GA} \quad (1)$$

where LA is leaf area (cm^2) of sampled area and GA is sampled area (cm^2).

At coriander maturity weeds were cut at ground level from a 1 m × 1 m area in each plot. Weeds were counted and dried at 75 °C for 72 h for biomass determination. For assessing the effect of the treatments on coriander yield, crops growing along a 2-m length of the centre two rows in each plot were hand clipped at maturity (on 8 September 2012 and 23 August 2013) and dried to a constant weight at 70 °C for 48 h.

2.4. Isolation of essential oil

Fruits were dried in oven at 40 °C until constant mass and crushed by grinder for isolation of essential oil. Crushed fruits were subjected to hydrodistillation in Clevenger-type apparatus. 40 g crushed fruit were watered with 400 ml distilled water (1:10). Distillation lasted for approximately 3 h at boiling point. The obtained oil was separated from water and dried over anhydrous sodium sulfate.

2.5. Statistical analysis

Data were tested for normality of distribution (Shapiro–Wilk test) and homogeneity of variance by SigmaPlot (11.0). For the weed density data, square root transformation was made before analysis; preliminary ANOVA was used using PROC GLM in SAS Software (Version 9.1, SAS Institute Inc., Cary, NC) to find out treatment effects and their interactions. Linear regression was used using SigmaPlot for describing the changes in measured indices against increasing density of fenugreek. To compare the treatment effects including experiment year, the estimated parameters were compared using t-test (with SAS) and the value of standard error of parameters.

3. Results

3.1. Weed species composition

The common weeds found during the experiments were prostrated pigweed (*Amaranthus blitoides* S. Wats.), redroot pigweed (*Amaranthus retroflexus* L.), Italian bugloss (*Anchusa italica* Retz).