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Assessment of the attack of *Hyadaphis foeniculi* (Passerini) (Hemiptera: Aphididae) on biomass, seed and oil in fennel intercropped with cotton with colored fibers

Francisco de Sousa Ramalho[a,*], José Bruno Malaquias[a], Bárbara Davis dos Santos Brito[a], Francisco Sales Fernandes[a], José Cola Zanuncio[b]

[a] *Unidade de Controle Biológico, Embrapa Algodão, Av. Osvaldo Cruz, 1143, Campina Grande, PB CEP 58428-095, Brazil*
[b] *Universidade Federal de Viçosa—UFV, Viçosa, MG, Brazil*

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ABSTRACT

The fennel aphids, *Hyadaphis foeniculi* (Passerini) (Hemiptera: Aphididae) attack umbels and may thus, cause to failure of fruit setting and also attack during the phase of seed development. Our research investigated the severity of biomass, seed and essential oil damages related to infestation by the fennel aphid, *H. foeniculi* in fennel (*Foeniculum vulgare* Miller) plots and plots of fennel intercropped with cotton with colored fibers. A randomized complete block design was used with four treatments: (1) two rows of fennel: three rows of cotton (2F: 3C) (non-treated plot), (2) two rows of fennel: three rows of cotton (2F: 3C) (treated plot), (3) fennel (F) (non-treated plot), and (4) fennel (F) (treated-plot), with four replications. The average of the weight of fennel seeds from umbels in the green stage in treated plots (0.19 mg) was higher (21%) than in the non-treated plots (0.15 mg). There was no significant difference in the essential oil extracted from biomass between two cropping systems for both treated and non-treated plots. However, the amount of essential oil extracted from fennel biomass in treated plots was higher in fennel plots than in fennel in non-treated plots. The average of the essential oil of 1000 fennel seeds from fennel–cotton intercropping system (0.17 ml) was higher (18%) than in the fennel cropping system (0.14 mg). The aphid attack reduced 29% of fennel seed weight. On the other hand, the average amount of essential oil extracted of the non-attacked seeds was two folds higher than of the attacked seeds. Therefore, our results showed that the effects of *H. foeniculi* on these yield components were smaller in the plots with fennel–cotton intercropping than in fennel plots. We suggest that seed composition responses to *H. foeniculi* injury should be an important consideration when conducting research to develop IPM systems for this fennel pest.

1. Introduction

Fennel (*Foeniculum vulgare* Miller) occurs naturally in the North America (Ramalho et al., 2012). It is spreaded in Mediterranean region and Central Europe (Aprotosoaie et al., 2010; He and Huang, 2011) and it is widely cultivated throughout the temperate and tropical regions of the world for its aromatic fruits, widely applied in medicinal preparations (He and Huang, 2011).

It was introduced into Brazil by the first settlers and rapidly spread through the states of Bahia, Sergipe, Paraíba, and Pernambuco (Ferreira and Sousa-Silva, 2004). The fennel has a guaranteed market in northeastern Brazil and is important for family farming in the region (Ramalho et al., 2012).

Fennel is known by the use of its fruits and its essential oil in the manufacture of perfumes, toothpaste, soaps and herbal medicine (Madueno Box, 1973; Silva Júnior, 1997). Herbal drugs and essential oil of fennel have antispasmodic, diuretic, anti-inflammatory, analgesic and antioxidant effects (Parejo et al., 2002; Choi and Hwang, 2004). According to Singh et al. (1988), it has fungicidal activity. The Brazilian cosmetic industry uses fennel oil in many ways (soothing, cleansing, and toning effects on the skin and hairs) (Ramalho et al., 2012).

Factors that impair fennel production and seed quality in Brazil include insect pests, especially the aphid, *Hyadaphis foeniculi* (Passerini) (Hemiptera: Aphididae). *H. foeniculi* is a cosmopolitan

* Corresponding author at: Embrapa Algodão, CNPA, UCB, Osvaldo Cruz, 1143-Centenário, Campina Grande, PB CEP 58428-095, Brazil. Fax: +55 83 3182 4367.
E-mail address: ramalhohvv@globo.com (F. de Sousa Ramalho).

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species and a vector for at least 12 types of virus, including mosaic potyvirus, yellow luteovirus and carlavirus (Ferreira and Sousa-Silva, 2004). Since it continually sucks sap, it causes flowers and fruits to wilt and dry up (Ramalho et al., 2012). It also produces a secretion known as "honeydew" which is favorable to the development of the fungus *Capnodium* spp., leading to the formation of sooty mold (Lazzari and Lazzarotto, 2005) which prevents the plant from transpiring and reduces the photosynthetic area, weakening the plant (Leite et al., 2006). In the state of Paraíba, Brazil, *H. foeniculi* usually reproduces during hot periods, forming colonies inside flowers (Ramalho et al., 2012).

In northeastern Brazil, fennel is intercropped with colored-fiber cotton (*Gossypium hirsutum* Linnaeus) (Malaquias et al., 2010; Fernandes et al., 2013; Ramalho et al., 2012). Natural colored cotton is ecologically friendly, as it reduces the dyeing stage in industrial production in which frequently and perhaps incorrectly used chemicals, can be damaging to human health (Horstmann, 1995). Development of cotton with colored fibers intercropping with fennel is an alternative for recuperating agribusiness in cotton cultivation in northeast Brazil. Intercropping fennel with colored-fiber cotton has contributed to a 80% drop in the damage caused by *H. foeniculi* to the fennel crop (Ramalho et al., 2012).

Hyadaphis foeniculi is considered a major insect pest on fennel (Ramalho et al., 2012), mainly attacking flowers, fruits and leaves. By continually sucking the sap, it causes these organs to wilt and dry up, impairing the fennel seed (Ferreira and Sousa-Silva, 2004). On the other hand, essential oils are concentrated in the biomasses and mainly in fruits and provide the unique aroma and taste. The quality of the oil essence of the fennel has great importance and it depends on the stage of maturity of fennel fruits, as well as, insect attack (Maranca, 1985).

We know that fennel aphids reduce the fennel seed yield by 80% in the sole fennel plots compared with 30% for all intercropping systems (Ramalho et al., 2012). However, there is no information on the effect of *H. foeniculi* on the biomass yield, seed weight and oil content of fennel from fennel crop and fennel intercropped with cotton with colored fibers. For this reason, field experiments were carried out in 2009 and 2010 seasons to determine whether fennel aphids cause significant reduction in biomass yield, seed weight and essential oil content of fennel from fennel crop and fennel intercropped with cotton with colored fibers. We have hypothesized that (1) the fennel seeds attacked by *H. foeniculi* are less heavy than the non-attacked seeds; (2) the aphids *H. foeniculi* reduce the amount of essential oil in the fennel seeds; (3) the aphids *H. foeniculi* do not reduce the amount of essential oil in the fennel biomass. Such difference changes depend on the crop systems.

2. Material and methods

2.1. Research location and cotton and fennel cultivars

The study was carried out during 2009 and 2010 seasons at an experimental farm located in the countries of Montadas and Lagoa Seca Paraiba, Brazil, a rural wetland microregion at an elevation of 634 m, S 7°10′5″ W 35°51′13″. A fennel (*F. vulgare*) cultivar (Montadas) and a naturally colored cotton (*G. hirsutum*) cultivar (BRS Safira) were planted under dry land conditions. Field plots were planted between the first and second week of May in 2009 and in the second week of May in 2010. Weed control was done by hoeing.

2.2. Bioassays and experimental design used

A randomized complete block design was used with four treatments: (1) two rows of fennel: three rows of cotton (2F: 3C) (non-treated plot), (2) two rows of fennel: three rows of cotton (2F: 3C) (treated plot), (3) fennel (F) (non-treated plot), and (4) fennel (F) (treated-plot) (Fig. 1), with four replications. The area of each experimental unit was 462 m^2.

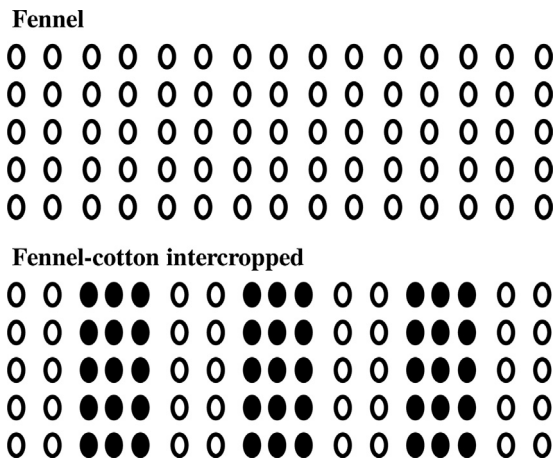

Fig. 1. Layout of experimental units in the fennel–cotton intercropping system (2F: 3C) and fennel (F). Fennel plant (open circles) and cotton plant (closed circles).

The treated plots were sprayed with thiamethoxam insecticide at the rate of 120 g a.i/ha at 1-week intervals beginning with the emergence of the cotton plants to keep the plants aphid-free, i.e. full protection. The spray was made with a hand-operated knapsack sprayer with 200-l water per hectare. The non-treated plots were not sprayed with any insecticide to allow for natural aphid infestation, along with their predators and parasitoids.

The experimental units of the fennel–cotton intercropping system consisted of rows of naturally colored cotton (BRS Safira) between rows of fennel (Montadas cultivar) with a row of 21 m (Fig. 1). Fennel rows were spaced 1.5 m apart, and there was 0.50 m between fennel plants in a row (Fig. 1). In the intercropped plots, cotton rows were spaced 1 m apart, whereas the spacing between the cotton and fennel rows was 1.50 m (Fig. 1).

2.3. Biomass and seed yield and oil content

Samples of biomass and seeds of fennel plants were collected in the plots with 100 (from umbels in green stage) and 150 day-old (from umbels in dry stage). The biomass yield (shoot system plus umbels in green stage) was taken from 10 plants by randomly selecting five plants in each of the second and penultimate rows of all the plots at the umbels green stage. However, at seed ripening (dry umbels) stage only seeds were collected. The extraction of essential oils from fennel biomasses and seeds was achieved by steam-distillation (Bowles, 2003). The biomasses and seeds were distilled for four hours. The oil was stored in a dark glass bottle.

2.4. Data analysis and statistics

The biomass and seed yield and also the oil content from seeds and biomasses were tested for normality (Kolmogorov D normality test) and homogeneity of variance (Bartlett's test). The mean of biomass weight, seed weight, oil content of biomass and seed development were subjected to three-way analysis of variance (ANOVA) [year, crop system, and aphid control (treated and non-treated plots)], using PROC GLM of SAS (SAS Institute, 2006) and the averages were compared using the *F* test or Student–Newman–Keuls test ($P = 0.05$).