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Research paper

Floral visitor assemblages related to coriander genotypes and sowing dates: Relationship with volatile signals

Adriana E. Lenardis[a,*], Alejandra Gil[a], Juan Pablo Torretta[b], Diego Ganly[a], Juan Pablo Bouilly[a], Elba B. de la Fuente[a]

[a] *Universidad de Buenos Aires, Facultad de Agronomía, Departamento de Producción Vegetal, Cátedra de Cultivos Industriales, Av. San Martín 4453 (C1417DSE), Ciudad de Buenos Aires, Argentina*

[b] *Universidad de Buenos Aires, Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET), Facultad de Agronomía, Departamento de Recursos Naturales y Ambiente, Cátedra de Botánica General, Av. San Martín 4453 (C1417DSE), Ciudad de Buenos Aires, Argentina*

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ABSTRACT

Intraspecific diversity of crops producing volatile organic compounds could harbor different assemblages of flower visiting insects, improving agricultural landscape heterogeneity and thus, natural regulation of crop pests. In this context, the objectives of this work were i) to evaluate the composition, abundance and richness of floral visitor assemblages in different coriander crop genotypes and sowing dates and ii) to determine the relationship between insect assemblages and volatile signals emitted by the different coriander genotypes. Two field experiments (Exp. 1 and 2) were conducted in a completely randomized design with four replications, at the Faculty of Agronomy in the University of Buenos Aires, Argentina. Exp. 1 included early and late sowing dates while Exp. 2 included only late sowing date. Treatments were three coriander genotypes from different origins: Leisure 2008 (L) a variety from USA, GSN 2008 (G) a variety from France and a population from Argentina (A). At full flowering, floral visitor insects were sampled using an entomological net. The sampling units were the corianderś umbels contained in squares of 40 × 40 cm. Two squares were randomly placed in each plot and several samplings were made in each of them, along 10 min-periods. Floral visiting insects were classified into pollinator, predator, parasite, herbivore and decomposer functional groups according to their habits and food preferences. Composition and abundance of floral visitor assemblages differed among genotypes, mainly for the early sowing date. Differences could be attributed to the intraspecific variability of volatile signals to which some insects were sensitive. Although richness was similar among assemblages related to each genotype, different species composition suggests that the combination of different coriander genotypes in cropping systems could enhance insect species diversity of the agricultural system and natural pest regulation.

1. Introduction

Plants emit a great variety of volatile signals that can actively participate in plant growth and protection against biotic and abiotic stresses (Pichersky and Lewinsohn, 2011). The use of plants to provide signals for enhancing natural enemy activity in agroecosystems is an interesting practice, but candidate crops species and varieties are not always screened for their attractiveness to insects in the system being studied. Signals related to VOCs concentration and composition can vary within and among crop species (Gil et al., 2000; Bálint et al., 2016) and environments (de la Fuente et al., 2003; Loreto et al., 2014), thus generating different volatile signals that could harbor different insect communities. Up to date, only few studies reported the influence of crop intraspecific variation of volatile emissions on insect attraction, and they were mainly focused on honeybees (Klatt et al., 2013). However, there is growing evidence indicating that intraspecific differences can be important to explain the trophic structure and functioning (Johnson and Agrawal, 2005; Crutsinger et al., 2006; Barbour et al., 2015). For arthropod herbivores in particular, there is strong support demonstrating that genetic variation in host plants is a key factor shaping their diversity and composition but, in many cases, the mechanism determining such variation remains poorly explored (Barbour et al., 2015). For example, a significant effect of genetic variation of *Tanacetum vulgare* on arthropod abundances (Bálint et al., 2016) and of *Solidago altissima* on floral visitor richness and abundance was detected (Genung et al., 2010; Burkle et al., 2013).

Coriander plants emit signals from vegetative and reproductive structures. Floral volatiles serve as attractants, especially for pollinators

* Corresponding author.
E-mail address: lenardis@agro.uba.ar (A.E. Lenardis).

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and casual visitors, whereas volatiles emitted from vegetative parts, appear to protect plants by deterring herbivores or by attracting natural enemies (Potter and Fagerson, 1990; Lenardis et al., 2007; Bendifallah et al., 2013). Many of these compounds, mainly terpenes, accumulated in coriander tissues and emitted to the environment may have ecological impact (Harborne, 1997) as chemical signals attracting beneficial insects or repelling herbivores, therefore, protecting the crop (Lenardis et al., 2007). Volatile signals may change among coriander genotypes and crop environments (Diederichsen, 2017; de la Fuente et al., 2003). The production of VOCs is strongly regulated by genetics, making VOC emissions site-specific (Olle and Bender, 2010), species-specific (Splivallo et al., 2012) and/or even genotype-specific, as observed in apple accessions and tomato varieties (Farneti et al., 2012; Farneti et al., 2014). For instance, variations in the sowing dates of the crop change the climatic and weather conditions, affecting crop growth, development and terpens synthesis, and thus possibly, also the volatile cues emitted by the crop (Olle and Bender, 2010).

In the agricultural landscape design the inclusion of different coriander genotypes in monocrops or intercrops, could favor functional and species diversity of homogeneous and impoverished agroecosystems such as the Argentinean Pampas. In this region, the lack of rotations and the few crop species included, affected the ecosystem services like natural pest control and pollination (Aizen et al., 2009). Intra and interspecific diversity, intended to attract natural enemies of crop pests and pollinators (Patt et al., 1997), could have enormous potential to improve crop pest management and reduce dependence on pesticides (Hassanali et al., 2008). Genotype mixtures could be an excellent practice for exploring not only stability (Tilman et al., 2001) but also synergies between genotypes (Schöb et al., 2015) and more complex plant–plant interactions (Brooker et al., 2016).

In this context, the hypothesis of this work was that structure and richness of floral visitor assemblages will be related to volatile signals emitted by the crop depending on genotypes and sowing dates. Thus, the objectives of this work were i) to evaluate the composition, abundance and richness of floral visitor assemblages in different coriander crop genotypes and sowing dates and ii) to determine the relationship between insect assemblages and volatile signals emitted by the different coriander genotypes.

2. Materials and methods

2.1. Study site and field experiments

During two consecutive years, field experiments were conducted at the Faculty of Agronomy in the University of Buenos Aires, Argentina (34°35 S, 58°25 W) on a silty clay loam soil classified as Vertic Argiudoll according to the USDA taxonomy (1999). The experiments involved three treatments arranged in a completely randomized design (DCA) with four replications. Treatments were three coriander genotypes from different origin: Leisure 2008 (L), a variety from USA, GSN 2008 (G), a variety from France and a population from Argentina (A). Twelve plots of 12 m^2 were sown on June 4th (early sowing date) and on August 4th (late sowing date) in the first year (Exp. 1), whereas twelve plots of 8 m^2 were sown on August 21st (late sowing date) in the second year (Exp. 2). The soil was ploughed and refined to produce a smooth seed bed. The sowing was made very carefully in order to achieve a uniform coriander seed germination and seedling emergence. Coriander seeds (with over 98% germination) at a rate of 150–200 plants m^{-2} were placed along the rows, covered with soil, lightly compacted and irrigated (Gil et al., 1999). The total crop cycle and sowing-flowering phase durations (days) were different among genotypes and sowing date (for details see supplementary data).

Spontaneous weeds were manually removed throughout the crop cycle. During the experiments, plots were irrigated to supplement natural rainfall with the objective of maintaining the soil near field capacity.

2.2. Measurements

When coriander was at full flowering (from October 15th to November 15th), floral visitor insects were sampled using an entomological net, then killed in situ and preserved to be later identified (Torretta and Poggio, 2013). The sampling units were the coriander's umbels contained in squares of 40 × 40 cm. Two squares were randomly placed in each plot and several samplings were made in each one, along 10 min-periods. The samplings were carried out under similar climatic conditions (sunny and without wind), between 12:00 and 13:00 h in all the experiments.

Floral visitors were taxonomically determined at species level, when possible, or at morphospecies level. The analysis at morphospecies level allows studying insect assemblages since the differences between the number of morphospecies and taxonomic species are, in many cases, very small (Derraik et al., 2002). Floral visiting insects were classified into pollinator, predator, parasite, herbivore and decomposer functional groups according to their habits and food preferences at both immature and adult stages. The main ecological role was assigned based on the information available in the literature (Colomo de Correa and Roig-Alsina, 2009; Gramajo and Mulieri, 2011). Insect samples are available in the entomological collection in the Faculty of Agronomy, University of Buenos Aires.

The structure of assemblages was analyzed in terms of abundance and richness of floral visitor insects. Floral visitor abundance was the total number of individuals per species or morphospecies captured per plot, and richness was the total number of species or morphospecies captured per plot (Magurran, 1988).

Coriander volatile emissions were evaluated using artificial "nose" technology (Szpeiner et al., 2009). An electronic nose consists of an array of non-specific gas sensors which generates an aromatic pattern of each plot based on the signal received by the nose sensors. Sensors are able to recognize simple and complex odors as a whole blend but not as isolated chemical compounds. Three samples were taken in each plot (at the bottom, the middle and the top of coriander's canopy) to characterize the blend of chemical signals from each genotype. In order to relate insect assemblages and signals, both samplings were made at the same phenological state on all sowing dates.

2.3. Statistical analysis

The abundance of insects from each genotype and sowing date was classified using a cluster analyses PCORD 5 (McCune and Grace, 2002), to quantify the degree of similarities among treatments. Classification provides useful summary of large data matrices. A Sorensen coefficient version modified by Bray and Curtis (Magurran, 1988) was used as distance measure. Farthest neighbor (complete linkage) was used as similarity measure (Van Torengen, 1987). Results from the classification were presented in tables for each sowing date, where insect groups are shown in rows and insect assemblages related to genotypes are shown in columns.

Abundance and richness of pollinators, natural enemies (predators and parasitoids) and total insects visiting different genotypes on different sowing dates were analyzed with, using Infostat 2016 (Di Rienzo et al., 2016). Abundance was transformed from discrete to continue variable using square root transformations. Means were compared by Tukey's significant difference test at the 0.05 probability level. Both homogeneity of variance and normal distribution have been tested.

The hypothesis stating differences between species compositions of floral visitor assemblages in different genotypes was tested by using the Multi-Response Permutation Procedure (MRPP) (Mielke, 1984). In this analysis, data about presence-absence of morphospecies were considered and genotypes as categorical variables were used (Johnson and Agrawal, 2005).

The relationship between abundance of floral visitors on coriander genotypes and chemical signals was analyzed with principal component