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Arthropod communities related to different mixtures of oil (*Glycine max* L. Merr.) and essential oil (*Artemisia annua* L.) crops

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ABSTRACT

Plants can host many herbivores and their natural enemies during their growth cycles. For this reason, changes in the relative abundance of crop and weed plants in a monocropping system as well as different crop plants in an intercropping system may produce great bottom up impacts in the specific and functional structure of spontaneous communities of arthropods. The hypothesis of this study was that the combination of two contrasting species, soybean (*Glycine max*, Fabaceae, N_2 fixing plant) and annual wormwood (*Artemisia annua*, Asteraceae, VOCs plant), would be related to different spontaneous communities of arthropods depending on the proportion of each species, and this would favor crop biodiversity without compromising crop production. The objectives of the study were: (a) to analyze the differences of spontaneous communities of arthropods related to different soybean (S)–annual wormwood (W) mixtures, using standard crop management for S production in Argentina, (b) to determine S and W total biomass and W essential oil content and yield and, (c) to analyze the relationship between arthropod communities and crop productivity. Factorial field experiments with 3 replications were done during 2006 and 2007. S density was kept constant (40 plants m^{-2}) and different W densities (plants m^{-2}) were added. Treatments were pure S, S + 2W, S + 4W, S + 8W and pure W (8 plants m^{-2}). Arthropods were sampled at soybean full flowering and were classified in functional groups as herbivores and non-herbivores. S and W total and relative biomass and W essential oil content and yield from leaves and inflorescences were estimated in reproductive stage. Arthropod morphospecies abundance and richness were determined for each treatment. Data were analyzed using uni (ANOVA) and multivariate (CCA) techniques. Arthropods belonging to 7 orders presented a total richness of 48 morphospecies in 2006 and 36 in 2007, while total abundance was 379 in 2006 and 318 in 2007. The proportion of non-herbivores was higher than the proportion of herbivores. Different arthropod communities were observed according to each treatment. No differences were found among treatments in S + W and S total biomass production, while W total biomass and essential oil yield were both different among treatments. Relative biomass production of S and W was the main explanatory variable related to the contrast of arthropod communities between pure annual wormwood (W) and the rest of the treatments. Annual wormwood could be used as an accompanying essential oil crop or left as a weed in the densities tested in this work, favoring biodiversity and, eventually, pest management without compromising soybean crop yield.

1. Introduction

Plants can host many herbivores and natural enemies of herbivores during their growth cycles. For this reason, changes in the relative abundance of different plant components may produce great bottom up impacts in the spontaneous communities of arthropods (Marshall et al., 2003). Said components are crop and weed plants in a monocropping system or different crop plants in an intercropping system. As primary producers, crop and weed plants directly serve as food for herbivores and, in turn, herbivores can serve as a food source for beneficial arthropods. Weeds can also serve as alternative hosts for crop pests when the crop is absent or its phenological stage is unsuitable for the pest. Many beneficial arthropods also feed directly on plant material, such as nectar or pollen, at some stage during their life cycle. Such plant feeding, at adult or immature stages, is often required for optimum performance of the beneficial arthropods (Norris and Kogan, 2005) in addition to the herbivore prey.

Interactions between arthropods and plants are mediated by physical (color, shape, and texture) and chemical (odor and taste) characteristics of the plants (Gershenzon, 1984; Coleman, 1986; Rausher, 1992; Dicke, 1999; di Giulio et al., 2001; Norris and Kogan,

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2005). Plant traits such as leaf nitrogen and water content, toughness, thickness, color, internal and volatile organic compounds (VOCs), are known to be important determinants of arthropod behavior (Coleman, 1986; Gershenzon, 1984; Howe and Westley, 1988; Pastor et al., 1997; Tomassini Barbarossa et al., 2007) and thus, of community structure (Lenardis et al., 2007). For instance, VOCs often serve as attractants or repellents for feeding and oviposition (Städler, 1986; Bernays and Graham, 1988; Unsicker et al., 2009). Stimulus showed dose-dependent opposite effects, attraction or repellency, on odor-induced insect behavior depending on signal concentrations (Dethier and Yost, 1952, cited by Tomassini Barbarossa et al., 2007). VOCs dose is related to the genotype and the environment (Gershenzon, 1984).

VOCs emitted by crops can mix with those emitted by other species that share the habitat, for example weeds or accompanying crops (Harborne, 1987; Städler, 1992; Bernays and Chapman, 1994). Many arthropods may be very sensitive to the relative species composition in the mixture (Khan et al., 2008). The role of different weeds-crop or intercrop mixtures on spontaneous communities of arthropods may be explained considering that weeds or accompanying crops represent a diluting factor in the concentration of the predominant crop plant. The introduction of an element of biodiversity expands the spectrum of natural enemies available to colonize the crop stand depending on the availability of prey or hosts (Root, 1973). If the weed or accompanying crop is chemically or taxonomically related to the main crop, the associated fauna may be a threat to the crop. Otherwise, the herbivores may be irrelevant for the crop, unless they are a polyphagous species. The arthropod fauna on unrelated weeds or accompanying crops may harbor prey for natural enemies that are important for the crop. However, the importance assigned to plant mixtures to develop IPM and as sources of diversity should be weighed in relation to competition (i.e. crop yield loss) and their role in hosting beneficial arthropods as well as crop pests (Norris and Kogan, 2005).

Although habitat richness provides organisms that can take advantage of this habitat (Benton et al., 2003), the general trend of agricultural intensification has been the simplification and specialization of the agro ecosystem including very low richness of species (few weeded crops), genes (few cultivars) and management (few active ingredients or tillage systems) (Vandermeer et al., 1998). Moreover, high input of fertilizers and chemical pesticides has led to losses in the arthropod populations (Ewald and Aebischer, 1999; Biaggini et al., 2007), directly through toxicity and indirectly through both food availability and habitat quality (Kromp, 1999; Holland and Luff, 2000). The Pampean agroecosystem is not an exception to this trend since transgenic soybean [*Glycine max* (L.) Merr.], resistant to glyphosate and permanent no-tillage, is the main land use in Argentina (Pengue, 2005; Cerdeira and Duke, 2006). In addition to the effect of agroecosystem simplification, fields growing with herbicide resistant soybean could have fewer arthropods (Buckelew et al., 2000), probably due to the reduction of weed population and not through the direct effect of herbicide or transgenic varieties on arthropods (Marshall et al., 2003; Norris and Kogan, 2005).

Annual wormwood (*Artemisia annua* L.) is a component of the weed community in the Rolling Pampa Argentina (de la Fuente et al., 2006) that could interfere with soybean crop by competition for resources and by the release of VOCs affecting crop growth (Duke et al., 1987; Weston, 1996; Weston and Duke, 2003). However, annual wormwood is also an essential oil crop of economic value (Bagchi et al., 2003; Fulzele et al., 1995) that could be introduced as a planned component of the agroecosystem.

It is expected that the combination of two contrasting species (i.e. soybean, Fabaceae, N_2 fixing plant and annual wormwood, Asteraceae, VOCs plant) will lead to greater overall biological productivity than each species grown separately because the mixture can use resources more effectively than separate monocultures (Willey, 1979; Willey et al., 1986). In many instances, the increased resource use is not a necessary condition for intercrop advantage over separate monocultures (Vandermeer, 1989; Keating and Carberry, 1993; Ong and Black, 1994). Facilitation is frequently involved, such as when one crop attracts natural enemies to the system and thus facilitates the escape of the second crop from some fraction of pest attack (Vandermeer, 1984, 1989).

Within this context, the hypothesis of this study was that the combination of two contrasting species, soybean and annual wormwood, would be related to different spontaneous communities of arthropods depending on the proportion of each species and this would favor crop biodiversity without compromising crop production. Therefore, the objectives of the study were (a) to analyze differences in spontaneous communities of arthropods related to different soybean–annual wormwood mixtures using standard crop management for soybean production in Argentina, (b) to determine soybean and annual wormwood total and relative biomass and annual wormwood essential oil content and yield and, (c) to analyze the relationship between arthropod communities and crop productivity.

2. Materials and methods

2.1. Field experiment

Two factorial field experiments were carried out in the Faculty of Agronomy, University of Buenos Aires (34°35′5″ lat. S, 58°29′ long. W), during 2006 and 2007. Treatments were arranged in a completely randomized block design in 2006 and in a completely randomized design in 2007 with three replications. In both years a soybean cultivar of maturity group IV (DM 4800) inoculated with *Bradyrhizobium japonicum* (10^9 colony forming units/g inoculant) was sown in plots 8 m long and 2 m wide with 0.35 m inter-row spacing on 10 January. In order to synchronize soybean and annual wormwood growth, annual wormwood was sown previously and then transplanted into the inter-row, 10 days after soybean sowing.

According to an additive model, soybean density in each plot was kept constant (40 plants m^{-2}) and different densities of annual wormwood plants were added. Thus, different treatments were pure soybean (S) and annual wormwood (W) (8 plants m^{-2}), and different mixtures of soybean (40 plants m^{-2}) and 2 (2W), 4 (4W) and 8 (8W) annual wormwood plants m^{-2}.

During the experiment, spontaneous weeds were removed manually. The crop was irrigated when needed to avoid water stress. Herbivorous arthropods were chemically controlled only during vegetative stage of soybean (V2; Fehr and Caviness, 1977) with the equivalent of 100 cm^3 ai ha^{-1} of cypermethrin and 0.8 l ha^{-1} of chlorpyrifos.

2.2. Arthropod sampling and determination

In both years, arthropods were sampled when soybean was at full flowering (R2; Fehr and Caviness, 1977). This time interval was chosen based on three criteria: (1) spring–summer communities were present, (2) chemical control had already been applied, and (3) crops had achieved maximum ground cover. Arthropod sampling was done using a sweep net (Tonkyn, 1980). Fixed net sizes (30 cm diameter) and sweeping patterns were used (two net sweepings in each plot) in the central zone of each plot, avoiding margins. In both years, the sampling was carried out under similar climatic conditions (sunny and without wind), at the same time of day, between 10.00 AM and 15.00 PM (h) each day.

Arthropod determination was performed at order, family and morphospecies level in all cases, and order and morphospecies