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Intercropping sunflower and soybean in intensive farming systems: Evaluating yield advantage and effect on weed and insect assemblages

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ABSTRACT

Agricultural intensification has encouraged both landscape homogenization and biodiversity decline in agro-ecosystems. Intercropping may over yield sole crops and simultaneously enhance landscape heterogeneity and planned and associated biodiversity in agroecosystems. Thus, we assessed yield advantage in sunflower/soybean intercrops in the Southern Pampas (Argentina). We also expected weed and insect assemblages to differ between sole crops and intercrops and to be more diverse and productive in intercrops than in sole crops. Thus, we evaluated the effects of sunflower/soybean sole and intercrops on the composition, richness, and abundance of weed and insect assemblages. Sunflower/soybean sole crops and intercrops were sown in two experiments in the Southern Pampa during two consecutive years. Weeds and insects were surveyed and both crop yields and land equivalent ratio (LER) were calculated. Cover/abundance of weeds, abundance of insects and species frequency and richness of both taxa were also estimated. Weeds were classified according to life cycle (annual or perennial) and insects according to feeding habits (herbivores and non-herbivores). Yield advantage of intercropping was indicated by LER values higher than 1 in both experiments, indicating that intercrops were more productive than sole crops. Species compositions of weed and insect assemblages differed between sole crops and intercrops because some particular species characterized each cropping system. Total species number was higher in intercrops than in sole crops. However, mean richness and abundance per plot was similar among treatments for weeds and similar or lower in intercrops than in the rest of treatments for insects. Here, we show that intercropping warm-season crops constitute a feasible alternative to promote heterogeneity within-fields and therefore sustain biodiversity in conventional cropping systems in temperate regions, which have become highly simplified after agricultural intensification such as in the Southern Pampa.

1. Introduction

Agricultural intensification has considerably increased land productivity worldwide since the mid 20th century. Yield increase was mainly due to breeding few crops, often at the expense of reducing both crop type diversity and biodiversity [1,2]. Agricultural productivity was also increased by providing the resources that limit crop yield through irrigation and fertilization, and applying standardized chemical management strategies to protect crops from weeds, pests and diseases [3,4]. Spatial and temporal homogenization of agricultural landscapes may also reduce biodiversity [5]. Diversifying cropping systems by increasing the spatial and temporal heterogeneity of agricultural mosaics has been proposed as a feasible alternative to overcome the negative effects of modern agriculture [1,5–7]. Within fields, temporal heterogeneity can be achieved by growing several crops in sequences, while spatial heterogeneity can be enhanced by intercropping species differing in the patterns of resource use and their associated flora and fauna [1,4].

Intercropping is broadly defined as the agronomic practice in which two or more crops are grown simultaneously in the same area of land [8]. This farming system may be a practical application of ecological principles based on biodiversity, biotic interactions and other natural regulation mechanisms [9,10], allowing efficient

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weed and insect pest management with low reliance on off-farm inputs. In addition, intercropping may contribute not only to enhance planned biodiversity, which is associated with the crop types managed by the farmer in an agro-ecosystem, but also the associated biodiversity, which is the spontaneous biota occurring in agroecosystems [1,11].

Intercrops may suppress weed growth more effectively than sole crops mainly through competition [12]. Effective weed suppression and economic results can be similar to or higher than those of other pest management practices [13]. Although sometimes harder to manage, intercrops often produce higher and more stable yields than their sole crop components due to more efficient use of resources and reduced incidence of weeds, insect pests and diseases [8]. Successful inception of intercropping into conventional intensively managed cropping systems poses several challenges, not only regarding agronomic management, such as the choice of the optimum spatial arrangement, plant density, and sowing date of each crop in the mixture, but also for assessing the impact on the associated biodiversity. Agricultural research has an adequate tool-box of methods and models for technology development in conventional cropping systems. However, most information related to intercrops is based on low-input agriculture and there is little knowledge on managing intercrops in conventional farming systems [14].

In the Pampas of Argentina, crop diversity has notably decreased during the last decades due to agricultural intensification. Nowadays, croplands are mostly sown with transgenic soybean resistant to glyphosate by using no-tillage practices [15]. All these changes have promoted species diversity of weed and insect communities to decline over time and space [16–18]. Here, we present results of a study about how the diversification of homogeneous, intensively managed cropping systems through intercropping may increase land productivity. Using an experimental approach, we assessed the occurrence of yield advantage in sunflower/soybean intercrops in the Southern Pampas. We also evaluated the effects of sunflower and soybean sole and intercrops on the composition, richness and abundance of weed and insect assemblages. We expected weed and insect assemblages to differ between sole crops and intercrops, being more diverse in the latter.

2. Materials and methods

2.1. Study site and field experiments

Two field experiments including sole crops and intercrop of sunflower and soybean were carried out in consecutive years in the Southern Pampa, Argentina (37°20' S, 59°08' W, 188 m.a.s.l.). Experiments were set in different fields each year using the regular cropping management used by the farmers in the region. Soil was clay-loam (Typic Argiudol, USDA Soil Taxonomy) with a deep top layer (> 1.5m) rich in organic matter (c. 5%). Average annual rainfall is 940 mm with a spring-summer bias (*i.e.* 64% of rainfall in October - March). However, rainfall was 988 mm and 678 mm in the first and second experimental years, respectively.

The two experiments, henceforth referred to as Exp. 1 and Exp. 2, were set by using a completely randomized design with two and three replicates, respectively. Treatments in both experiments were the sole crops and intercrops of sunflower and soybean. Two cultivars of each crop were sown in each experiment (Table 1). Soybean cultivars were genetically modified to resist glyphosate. Thus, eight treatments were included in the experiments, being two sole crops of each soybean and sunflower and four intercrops (2 soybean cultivars x 2 sunflower hybrids). Each treatment was assigned to plots 5 m wide by 45 m long in both experiments [19]. Sole crops and intercrops were sown on the same date in each experiment (Table 1). Crops were sown with a no-tillage drilling machine in rows 0.52 m apart. Target densities in sole crops were 7.4 for sunflower and 38.5 plants m^{-2} for soybean. To sow intercrops, a sunflower row was replaced by two soybean rows (Fig. 1). The number of plants in the row was similar to that of sole crops. Sunflower rows in intercrops were sown 1.04 m apart, whereas the two soybean rows were sown 0.52 m apart from each other in the sunflower inter row and 0.26 m away from the adjacent sunflower row (Fig. 1). Sunflower sole crops and intercrops were sown on the usual optimum sowing dates, whereas in intercrops soybean was sown a month later than the usual optimum date for sole crops in the region, for agronomic and eco-physiological reasons. Late sowing of soybean contributes to mimic farmers' management and to decrease the overlapping between the critical periods for seed setting of both crop species in the intercrop [20]. Plots were fertilized at sowing of sunflower with 60 kg ha^{-1} of triple super phosphate (46% P_2O_5).

Crop management in both experiments was similar to that used by farmers (for details see Table 1).

Table 1
Crop management experiments sown with sole- and intercrops of sunflower and soybean.

	Experiment 1	Experiment 2
Sunflower		
Fertilization	Triple superphosphate (46% P2O5): 60 kg ha^{-1} at sowing.	
Hybrids	MG 60 (Dow AgroSciences, Argentina)	
	N 6860 (Nidera Semillas, Argentina)	Paraiso 68 (Nidera Semillas, Argentina)
Sowing date	29 Oct 2007	30 Oct 2008
Herbicides		
Pre-sowing	Glyphosate: 1.44 kg a.i. ha-1 2,4-D: 800 g a.i. ha-1	
Pre-emergent	Acetochlor: 670 g a.i. ha-1	
Post-emergent	imazethapyr (52.5%) + imazapyr (17.5%): 143 g a.i. ha-1	
After crop maturity	Glyphosate: 2 kg a.i. ha-1 (only in intercrops)	
Insecticides		
4 weeks after sowing	Cypermethrin: 112 g a.i. ha-1 imidacloprid: 0.019 kg a.i. ha-1 during	
Flowering	Cypermethrin: 112 g a.i. ha-1 chlorpyrifos: 0.49 kg a.i. ha-1	
Soybean		
Fertilization	Triple superphosphate (46% P2O5): 60 kg ha^{-1} at sowing.	
Cultivars (GM)	N 5009 RG (Nidera Semillas, Argentina)	
	SPS 4500 RG (Semillera SPS, Argentina)	N 4613 RG (Nidera Semillas, Argentina)
Sowing date	12 December 2007	5 December 2008
Herbicides		
Pre-sowing	Glyphosate: 2 kg a.i. ha^{-1}	
Post-emergent	Glyphosate: 2 kg a.i. ha-1 (4 weeks after crop emergence)	
Insecticides		
4 weeks after sowing	Cypermethrin: 112 g a.i. ha^{-1}	

2.2. Measurements

Grain yield of sunflower and soybean in sole crops and intercrop was measured at crop maturity. Sunflower was harvested on April 1st and soybean on May 27th at commercial maturity by using an experimental plot combine harvester. Grain yield of both crop types was calculated at 12% moisture content and expressed in kg ha^{-1}.

Weeds and insects were surveyed at sunflower full flowering in both experiments (Exp. 1: 14 January 2008, Exp. 2: 22 January 2009) considering that: (1) most weed species of both spring-summer and autumn-winter growing cycles were present, (2) herbicides and insecticides had already been applied affecting weeds