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Soil arthropod diversity, richness, and abundance in agroecological and conventional cotton production systems in Chaco, Argentina

Diversidad, riqueza y abundancia de artrópodos del suelo en sistemas de producción agroecológico y convencional de algodón en el Chaco, Argentina

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Abstract: In Argentina, agroecology has grown in last years as a scientific paradigm that seeks to design and evaluate agroecosystems considering sustainability, complexity, and uncertainty. Diversity is a key factor in the design and management of production systems and a necessary component for conservation biological control and the reduction of agrochemicals use. Cotton (*Gossypium hirsutum*) crop in northern Argentina is usually managed with high load of agrochemicals: agroecological production arises as an alternative. This study evaluated the diversity, richness, and abundance of soil arthropods using pitfall traps in two experimental cotton plots under conventional (CONV) and agroecological management (AE) in Chaco, Argentina. AE system presented higher diversity and richness of predators compared with CONV, even when natural preparations were used for pest control. The phytophagous arthropods showed higher diversity and richness in CONV, even when pyrethroid insecticides were applied for pest control and preventively. The abundance in AE was lower for predators and higher for phytophagous arthropods. Agroecological production of cotton can be a tool that favors conservative biological control and an alternative for areas where protecting the health of farmers and the ecosystem is a priority.

Keywords: Agroecosystems, conservative biological control, pesticides, polyculture, predators.

Resumen: En Argentina, la agroecología ha crecido en los últimos años como un paradigma científico que busca diseñar y evaluar agroecosistemas considerando la sustentabilidad, la complejidad y la incertidumbre. La diversidad es un factor clave en el diseño y manejo de los sistemas de producción y una componente necesaria para el control biológico de conservación y la reducción del uso de agroquímicos. El cultivo de algodón (*Gossypium hirsutum*) en el norte argentino suele manejarse con alta carga de agroquímicos: la producción agroecológica surge como una alternativa. Este estudio evaluó la diversidad, riqueza y abundancia de artrópodos del suelo mediante trampas de caída en dos parcelas experimentales de algodón bajo manejo convencional (CONV) y agroecológico (AE) en Chaco, Argentina. El sistema AE presentó mayor diversidad y riqueza de depredadores en comparación con el CONV, incluso cuando se utilizaron preparados naturales para el control de plagas. Los artrópodos fitófagos mostraron mayor diversidad y riqueza en CONV, aun cuando se aplicaron insecticidas piretroides para el control de plagas y de manera preventiva. La abundancia en AE fue menor para los depredadores y mayor para los artrópodos fitófagos. La producción agroecológica de algodón puede ser una herramienta que favorezca el control biológico de conservación y una alternativa para zonas donde proteger la salud de los agricultores y el ecosistema es una prioridad.

Palabras clave: Agroecosistemas, control biológico de conservación, depredadores, pesticidas, policultivo.

Introduction

Agroecology has gained strength in recent years in Argentina as a new scientific paradigm that seeks to design and evaluate agroecosystems from multidimensional thinking interrelating sustainability, complexity, and uncertainty against the predominant paradigm in agricultural sciences (Sarandón, 2019). Multiple experiences have shown the benefits of diversity as a critical component of integrated production systems (Altieri & Rosset, 2018). Industrialized agriculture is based on the simplification of systems, where permanent intervention through external inputs, mainly agrochemicals, is increasingly necessary, and where the fact that ecological principles are ignored or dismissed generates highly unstable systems.

In Argentina, the use of pesticides has increased by 900 % since 1996; 317 million kg of active ingredients were used in 2012. Cotton, *Gossypium hirsutum* L. (Malvaceae) crop is representative of northern Argentina and its conventional production system uses transgenic seeds and chemically synthesized pesticides. Under this system, 508,000 ha were planted during 2020/2021 of which 222,000 correspond to Chaco Province (Ministerio de Agricultura, Ganadería y Pesca de la Nación, 2021). Cotton agroecological production (AE) is an alternative to the predominant model and it is aimed at meeting a growing commercial demand for "clean" cotton. The AE approach incorporates species of nutritional value, edges as a refuge for beneficial insects, and native trees; it does not use synthetic pesticides, but rather homemade preparations and bio-inputs to control pests, seeking to encourage the presence of predators as a way of increasing functional diversity (Nicholls, 2010). Cotton systems that aim to increase biodiversity create the conditions for abundant populations of natural enemies as an effective approach to the biological control of pests and diseases (Chi et al., 2021).

The implementation of conservation biological control is based on the use of native natural enemies present in agroecosystems through maintaining its structural complexity (Lacava et al., 2020). Arthropods are sensitive to environmental changes, and due to their rapid response to changes mainly derived from human activities, small size, short life, and high reproductive rates, are used as indicators of biodiversity (Castiglioni et al., 2017). Within the native natural enemies, parasitoid and predatory arthropods are the most representative groups. Some studies have shown that for example, soil predators are a relevant group for biological control of several pests in crops (Beaumelle et al., 2021; Beretta et al., 2022; Pearsons & Tooker, 2017), however, some agricultural practices such as the application of pesticides might affect the ecosystem services provided by predators, as these groups are more susceptible against pesticides when compared to phytophagous insects (Heong & Schoenly, 1998).

The objective of this work was to evaluate agroecological (AE) and conventional (CONV) experimental cotton production plots on the diversity, richness, and abundance of predatory and phytophagous arthropods. The proposed hypothesis is that there would be less diversity and lower abundance of predators in CONV systems, while there could be an inverse trend concerning the phytophagous, that means, a more significant number of phytophagous in the CONV system which management tends to simplify the agroecosystem.

Materials and Methods

The evaluation was carried out in the Sáenz Peña Agricultural Experimental Station of INTA (National Institute of Agricultural Technology) (26°47′27″S, 60°26′29″W) in Chaco (Argentina) during April 2021. The study area has a subtropical climate with a marked dry period in autumn-winter; the average total annual rainfall is 979,7 mm; average temperature for the warmest month (January) is 28 °C -29 °C and for the coldest (June - July) is 12 °C -18 °C (Maciel & Goytía, 2022). The soils in the area are of loessic origin, mainly loamy to fine textured. Plots are located on *Udic Argiustol* soils with silty clay texture (Ledesma, 1996). Two experimental plots 225 m apart were evaluated under: a) agroecological management (AE), 0.42 ha with polycultures in 3 m strips interspersed with non-transgenic cotton variety (Guazuncho 3 INTA), squash, *Cucurbita* sp. (Cucurbitaceae), cassava, *Manihot esculenta* (Euphorbiaceae) and beans, *Phaseolus vulgaris* (Fabaceae), surrounded by edges of alfalfa, *Medicago sativa* (Fabaceae). During the cycle, the following was applied to control insects: diatomaceous earth, garlic slurry (25), ash-based insecticide and potassium and silicic soap (5 %), foliar biostimulant (2.5 %) and fertilizer (2 %); b) conventional management (CONV), in 0.48 ha, of transgenic cotton monoculture (Guazuncho 4 INTA BGRR) and with one application of glyphosate, five of bifenthrin insecticide (190 cc/ha) and one of hormonal defoliant thidiazuron 48 (120 to 200 gr/ha).

For the capture of insects, 35 pitfall (500 mL) were randomly placed in each system and filled which a 70 % alcohol solution where two to three drops of detergent were added, buried at 12 cm with an orientation from E to W, in a capture radius of 5 m (10 m between traps) during seven days. Ethanol was used since it allows DNA preservation and is efficient when capturing certain arthropod groups, being cheaper than other sampling methods (Szinwelski et al., 2012). Traps were checked weekly, and arthropods were removed and placed in ethanol (70 %) and processed at the Estación Experimental Agropecuaria (EEA) INTA Sáenz Peña (Chaco, Argentina) Cotton Area. All specimens are archived in the Agronomy and Natural Resources Area in EEA Sáenz Peña. Insect were determined by local specialists while spiders were identified following Grismado et al. (2014) identification key.

The captured arthropods were identified at the level of genus and morphospecies. The diversity and richness of predatory and phytophagous arthropods in AE and CONV were analyzed employing the effective number of species, considering the reduced number of specimens collected, using the values corresponding to richness (q0) and Shannon diversity (q1). The analyses were applied to both predators and pests present in both systems. Diversity data was analyzed using the package iNEXT (Chao et al., 2014). The differences between systems diversity measurements were evaluated by evaluating the overlap of the confidence intervals at 95 % between the curves made, following the methodology of Chao et al. (2014), this approach standardizes the samples using as a reference sample size and completeness and compares diversities based on rarefaction/extrapolation sampling curves.

The total abundance of arthropods was compared using a generalized linear model with a negative binomial distribution, considering the behavior of the data. The model included abundance as a response variable, while arthropod order and management were used as explanatory variables. Similarly, the abundance of the different orders present in both treatments were compared. Analysis was performed using R v 4.0 (R Core Team, 2023).

Results

In total of both systems, 1180 specimens were captured. In AE, 592 specimens: 40 spiders, 372 Coleoptera, 161 Orthoptera and 19 Hemiptera; whereas in CONV 588 specimens in total: 24 spiders, 521 Coleoptera, 41 Orthoptera and 2 Hemiptera were captured.

Diversity and richness: In the case of predators, a higher richness was found in the AE system (21 species, sampling coverage:0.97), when compared with the CONV (14 species, sampling coverage:0.98). The same tend was observed when evaluating diversity (Figures 1 A and B), being the differences in the case of both evaluated parameters were statistically significant, since there was no overlap in the confidence intervals. In the case of phytophagous, the observed values for richness were similar (14 species in AE system, sampling coverage 0.98; 12 species in CONV system, sampling coverage 0.94), given the overlap of confidence intervals observed. Phytophagous diversity was higher in CONV system when compared to AE system.

Abundance: In the case of predators, we found a significant interaction between the predator order and the treatment (GLMnb: $X^2 = 6.04$, df = 1, $p < 0.01$). Overall, a higher abundance of Coleoptera was observed in both systems, with opposite trends in spiders, which showed a slightly higher numbers in AE systems. Hemipterans were excluded from the analysis since they were found only in AE system with two individuals.

In the case of phytophagous insects, we found a higher abundance arthropods in AE system when compared to CONV system (GLMnb: $X^2 = 6.50$, df = 1, p = 0.01). When comparing the different orders, orthopterans were significantly higher than the other groups (GLMnb: $X^2 = 12.19$, df = 2, $p < 0.01$). Although we did not find a significant interaction between the order and the treatment groups (GLMnb: $X^2 = 1.27$, df = 2, p = 0.52), orthopterans in the AE system were more abundant, followed by the CONV system (Fig. 2 B).

When discriminating the abundance of predators at family level between insects and spiders, we found that carabids and spiders were the most representative groups of predators in both evaluated systems. The different families of predators are shown in Figure 3.

Discussion

Our results show different trends in the two evaluated groups. For example, in the case of predators the richness and diversity measurements, were higher in AE system when compared to CONV management, while in the case of phytophagous arthropods, richness was similar between the two systems, while the diversity was higher in the CONV system. In the case of predators, these are a common group in cotton, as there have been reported more than 500 to 600 species within 45 families of predatory arthropods in cotton crops around the world (Altieri et al., 2005; Luo et al., 2014). The higher diversity of predatory species is an indicator of efficiency within the agroecosystem since a more significant number of species of natural enemies can maintain the level of harmful insects below the thresholds of damage (Snyder, 2019). In addition, increases in crop diversity results in a more

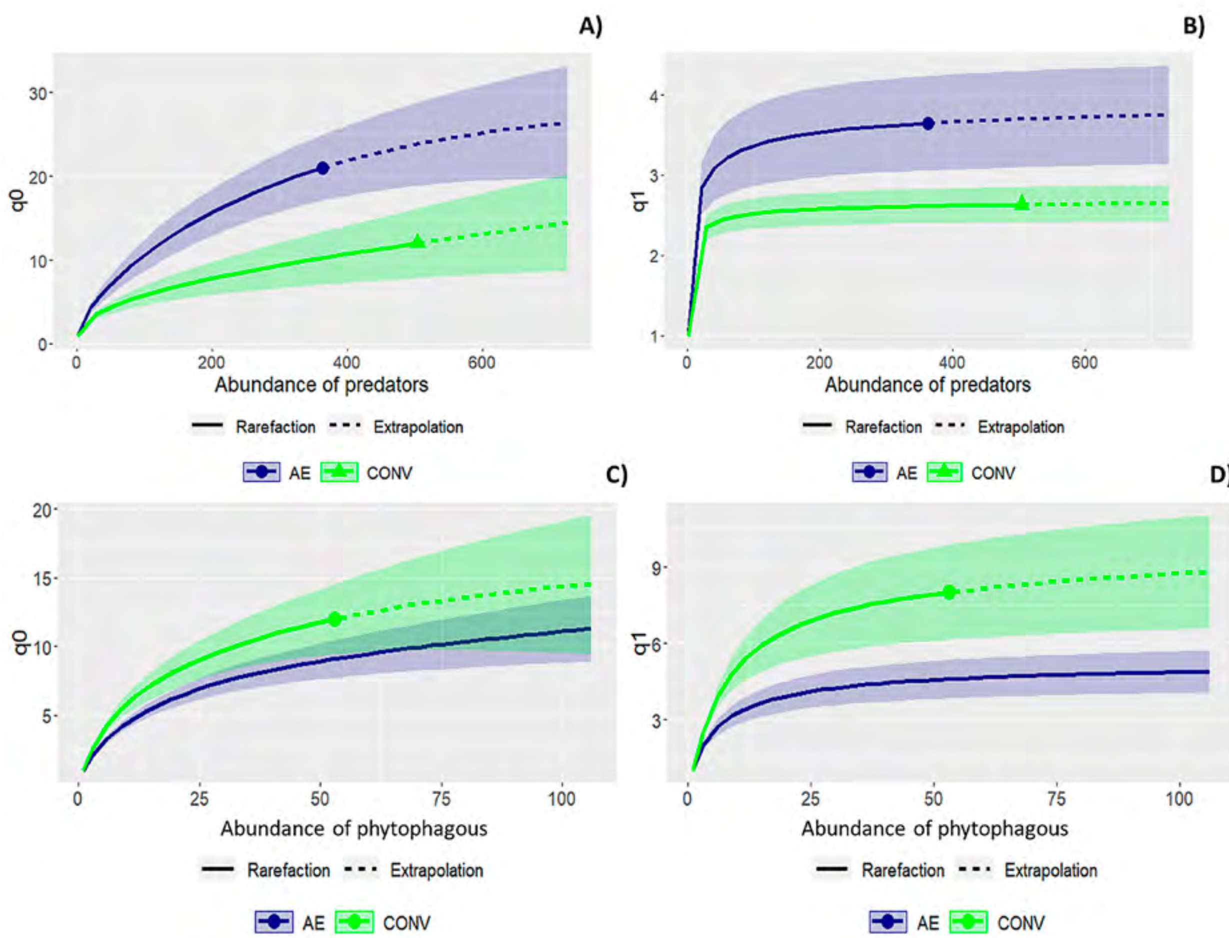

Figure 1. A) Analysis of richness (q0) and B) diversity (q1) of predators; and C) richness (q0) and D) diversity (q1) of phytophagous arthropods in cotton crops with agroecological (AE) and conventional management (CONV).

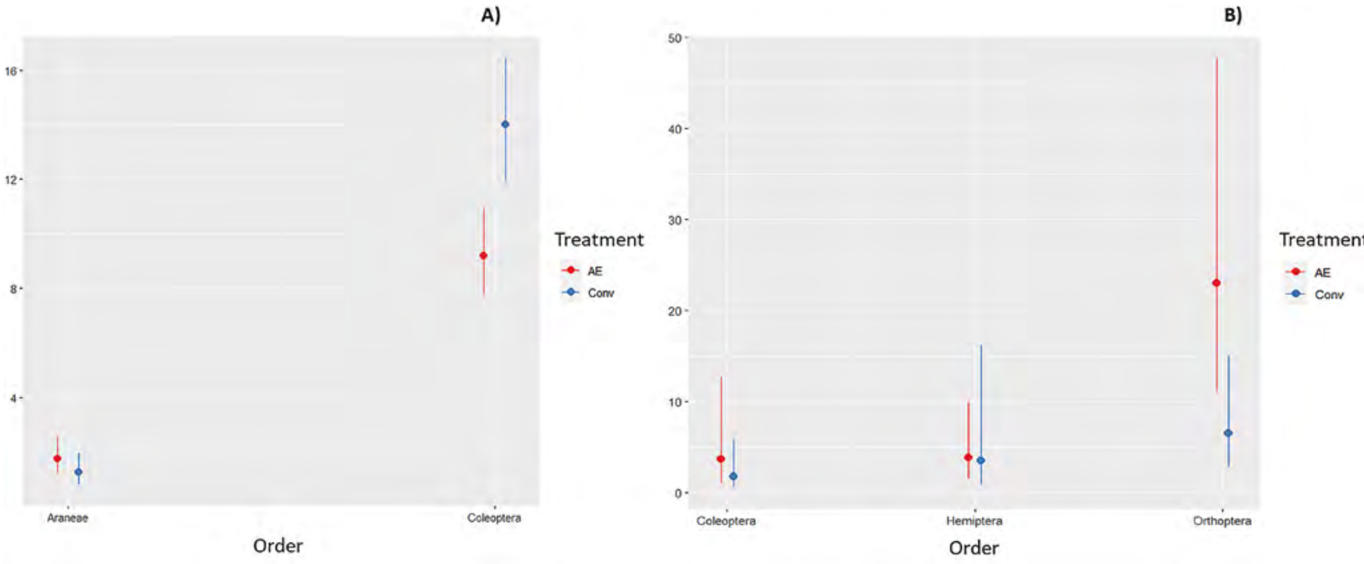

Figure 2. A) Predicted values for the abundance of the most representative groups of predators and B) abundance of phytophagous in the two systems evaluated. Points are means; bars are confidence intervals. Plots were estimated using a negative binomial GLM.

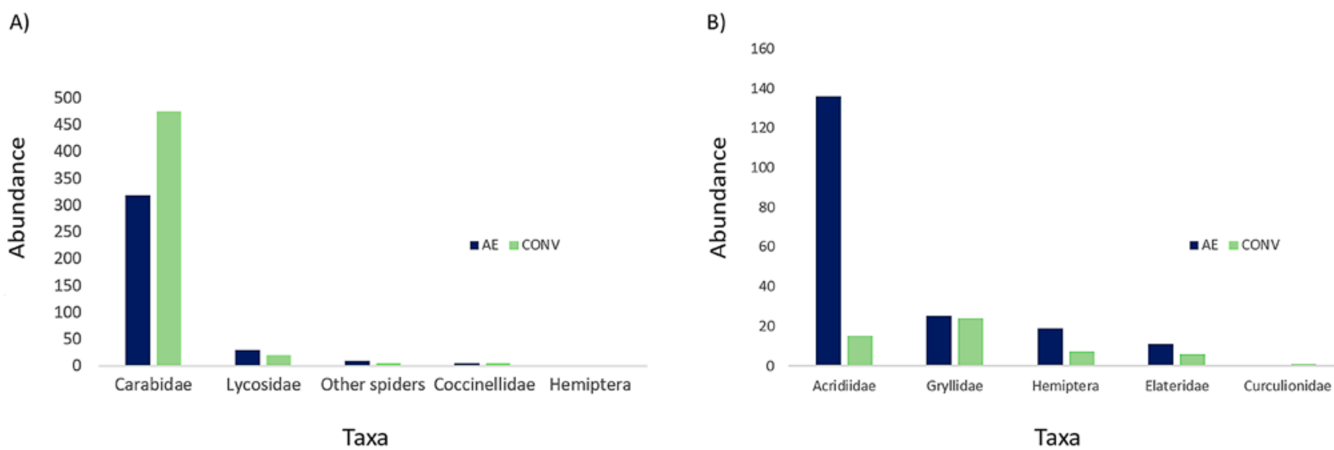

Figure 3. Abundance of the main families found in the crops of A) predatory and B) phytophagous arthropods found in cotton crops with agroecological (AE) and conventional management (CONV).

significant number of habitats, and therefore can increase predator diversity (Quispe et al., 2017), therefore it would be important in further studies to compare this parameter between AE and CONV systems. Successful agroecological transitions have been described as those that tend towards higher spatial connectivity and heterogeneity and self-regulation in ecological terms supported by functional and response diversity (de la Riva et al., 2023). The diversity of elements provides buffer capacity through duplication or redundancy functions, and the construction of natural capital through vegetation structure and cover diversity, also contributes to the conservation, resilience, and adaptability of the system (Tittonell, 2020).

In the case of predators found, these are common groups in crops. For example, the marked abundance of carabids can be explained since these are common soil predators in crops (Lang et al., 1999), and although some studies have shown that these can be found in high numbers in conventional agriculture systems, in our study the marked heterogeneous space and prey availability can explain the marked abundance and diversity of this group (Closs et al., 1999), which was high for the AE crop. In the case of spiders, we observed a similar trend, particularly in the case of wolf spiders which are common in crops. The lower abundance for other groups such as flying insects and web-building spiders, might be explained by the fact that samples were taken in the soil, which might have biased the results. Nevertheless, the lower abundance of predators in AE crops, might be explained possibly by the marked dominance of some carabid and spiders groups which might be better adapted to the crop conditions, agreeing with the agrobiont traits of these families (Michalko et al., 2021). Considering that spiders and carabids are commonly used as bioindicators, their presence could indicate the health status of the evaluate system (Castiglioni et al., 2017)

Regarding the phytophagous arthropods, we found an opposite trend than expected. In the case of richness, although we expected higher values for the AE system, both crops had similar values, while the diversity was higher in the CONV system. Possibly this might be explained by the fact that our samples correspond mostly to soil arthropods, which might have biased the results. In addition, and similarly, as it occurs in the case of predators, the higher number of refuges possibly might have increased the diversity of this group, as it has been shown in other studies (Lang et al., 1999). A complementary explanation, is that lower abundance in CONV management might be a consequence of a higher predator abundance, higher pesticides pressures in CONV management and differences due to vegetal heterogeneity of the plot, simplified in CONV (Krauss et al., 2011; Sattler, 2020).

Although our study presents some flaws, like the lack of replications given the poor local implementation of AE system in cotton, it highlights the potential effects of chemical control as one of the most important external factors in the reduction of arthropod fauna when comparing both production systems, since cotton crops often require the application of biphrentrin, a pyrethroid insecticide used to control insects of the order Lepidoptera, Hemiptera (including aphids and whiteflies), spider mites, thrips and is also used preventively against the appearance of weevils (Ahamad & Kumar, 2023; Vidal et al., 2020). Nevertheless, the systematic application of biphrentrin during cotton cycle increases the load of pollutants in the environment, threatening the local diversity of natural enemies. Further studies should explore the negative effects of this pesticide.

In conclusion, although preliminarily, our study highlights the importance of the AE system as an alternative to maintain the diversity of population of natural enemies, particularly groups as carabids and spiders which might constitute locally the most representative group of soil predators, such as it has been shown in other crops; in addition, the pressure that natural enemies exert on phytophagous insect populations in this crop should be explored. Further studies will explore too if this trend occurs in other cotton crops with AE management and if the same trend applies to other groups of natural enemies such as parasitoids.

Conclusions

AE system showed higher diversity and richness of predators compared with CONV. Phytophagous presented higher diversity and richness in the CONV system. Predator abundance was lower in AE. According to these preliminary results, the agroecological systems of cotton and food production system can be a tool to favor conservation biological control and therefore an alternative for small areas where planting, tillage, and harvesting are manuals and therefore it is a priority to protect the health of farmers and the ecosystem.

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Author Contribution

JMR participated in the sampling and taxonomic identification of arthropods, contributed to the analysis of the data and writing the final document.

MVS participated in the sampling and taxonomic identification of arthropods, contributed to the analysis of the data and writing the final document.

JRG participated in the taxonomic identification of arthropods, contributed in the analysis of the data and writing the final document.

ML actively contributed with the writing of the final documents, sampling design and databases for material processing.

LFG stated the objectives of the research, obtained funding, contributed to the analysis of the data and writing of the final document.

Conflict of Interest

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