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STUDY OF THE AGROECOLOGICAL TRANSITION IN EXTENSIVE AGRICULTURE IN THE SEMIARID REGION OF CÓRDOBA, ARGENTINA

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ABSTRACT

Extensive agriculture in the semi-arid region of Córdoba, Argentina, generated an intense degradation of the biophysical environment, a decrease in ecosystem self-regulation mechanisms, a considerable reduction of agrodiversity and the loss of associated environmental services. The physical-biological responses of different agroecological practices were evaluated for ten years in permanent macroplots located in three agricultural systems in order to study the transition towards more sustainable systems, which can be extrapolated to the rural area of central Córdoba. This process generated local information compatible with the farmers' technology. The results showed that *winter cover crops* allowed good weed control. Although they affected the soil water content, they did not produce significant differences in summer crop yields and they increased the level of surface organic carbon, thus mitigating the edaphic densification processes caused by no till farming in the medium term. *Crop rotation* contributed with more organic carbon to the system. *Open-pollinated maize varieties* produced a good yield of grains and biomass, even in years of marked water deficits, showing their adaptation to semi-arid conditions and their good plasticity. *Fertilization with vermicompost* in reduced doses increased grain yields and biomass production. The integrated management of these practices improved the balance and biological interdependencies that favoured biotic regulation between phytophagous and predatory arthropod populations as well as the regulation of spring weed populations.

Keywords: *permanent macroplots, agroecological practices, semi-arid environment, extensive crops.*

INTRODUCTION

In the last three decades, the extensive agricultural systems of the central region of Cordoba, Argentina, underwent transformations in their structure and function due to a process of productive simplification, which generated an intense degradation of the biophysical environment and a general decrease of the mechanisms of self-regulation. The agriculture specialized in commodity production, the adoption of transgenic materials in association with no-till farming (NT) and the use of chemical inputs contributed to this modification (Manzanal, 2017). The technological package (GMO soybean, NT and Glyphosate) favored the expansion of the agricultural frontier, replacing livestock and natural vegetation areas and traditional crops (maize, peanuts, sorghum and beans); this resulted in a drastic reduction of technological and biological diversity that caused the loss of environmental services associated with biodiversity (Alessandria, 2001). For example, the exclusive use of chemical supplies prevails as the pest control method, increases selection pressure on weeds and insects, and contributes to weakening regulatory mechanisms (Nicholls, 2006). Soybean monoculture negatively affects soil biophysical and chemical fertility due to its low residues contribution andit is considered an extractive crop because it does not generate surplus nitrogen (Zamar, 2004). Agroecology proposes process technologies with different practices that contribute to increase spatiotemporal biodiversity of agricultural ecosystems to provide ecosystem services, such as nutrient cycling, biotic regulation, genetic conservation and water regulation, which are linked to sustainability (Sarandón and Flores, 2014). Therefore, the favorable properties of the following agro-ecological practices are these:

The incorporation of *winter cover crops* (CC) provides an additional source of living cover and a significant amount of residues, improves soil organic carbon balance (Metay *et al.*, 2007, Basanta *et al.*, 2008), improves the soil physical condition increasing water aggregate stability, infiltration, total porosity and decreasing compaction (Villamil *et al.*, 2006). In addition, grasses and legumes CC contribute to the input, recycling and availability of nutrients (Kuo and Jellum, 2000), inhibit the emergence of weeds (Kruidhof *et al.*, 2009; Zamar *et al.*, 2000), stimulate diversity (Ferreira *et al.*, 2010) and provide food and shelter to predatory insects, parasites and parasitoids (Altieri, 1999). *Crop rotations* reduce the proliferation of pathogenic pests and microorganisms by disrupting their biological cycles when changing the plant species sequence (Altieri and Nicholls, 2012). They also modify the composition of weeds associated with each crop, reducing its effects and the development of resistance to chemical control. *Open-pollinated maize in the crop sequence* has better adaptation to the limiting conditions of the semi-arid zone, provides higher biomass volume, and decreases seed and feed supply costs for animal production (Kutka, 2011). The application of biofertilizers contributes to biological diversity and allows to restock nutrients extracted by the crops and to enhance the synergy among beneficial microorganisms ableto stimulate plant growth (Boraste *et al.*, 2009). The use of *reduced doses of*

*vermicompostin extensive crops*is an incipient practice in no-till farmingthat contributes to root development and biomass production (Alessandria, 2013).
These practices were applied with the objective of evaluating the agroecological transition of extensive agricultural agroecosystems from the semi-arid zone of Córdoba, Argentina, in order to improve biophysical conditions, increase agrodiversity and reduce the incorporation of supplies. The transformations were proposed in close interaction with farmers to recover the local information and generate an adequatetechnological management and one that is compatible with the local socioeconomic conditions.

MATERIAL AND METHODS

The experience was developed in predominantly agricultural production systems in the town of Lozada (Santa Maria Department, Córdoba, Argentina). The studied farms are located in a geomorphological region of the Rafael García-Lozada basin called Central Planicie, with a complex of soils classified as typical argiustoles, with mostly silt loam texture (Zamar, 2004). The climate corresponds to that of semi-dry, semi-humid domain with water deficit, without thermal winter (Capitanelli, 1979), with an annual mean precipitation of 686 mm and

Figure 1. Map of Argentina with situation of the Province of Cordoba (left) and with designated locality of investigations (Department of Santa Maria) (right)

evapotranspiration of 850 mm annually, which determines the existence of periods with soil water deficiency (Vettorello, 2008).The experimental macroplots of 1500 square meters were established since 2005 to 2014 in three farms. A completely randomized block design (three production systems) was developed. The treatments were: consociated winter cover crop (poaceae and fabaceae), corn-soybean rotation and application of 200 kg / ha of vermicompost at the time of sowing (agrodiverse treatment) and soybean monoculture with chemical fallow without biofertilizer (control treatment).

The following biophysical variables were measured in both treatments:
Edaphic variables: bulk density (DA) at 0-5 and 10-15 cm depth (cylinder method); penetration resistance (with impact penetrometer); infiltration (single ring infiltrometer); organic carbon content and water-aggregate stability (Walker and Reuter, 1998) at depths of 0-5 and 5-20 cm. The water content was measured for the 0-100 cm profile at CC sowing, in its drying and at the time sowing of the summer crop.
Biological variables: aerial biomass of cover crop and summer crop; grain yield of crop; records of richness (R) and specific abundance of spontaneous plant species; richness of phytophagous arthropods and predators in summer crops with the vertical cloth method (Drees *et al*., 1985). We calculated an index that relates the richness of predatory and phytophagous arthropods (index: R predators / R phytophages) at different times of the summer crop cycle.

RESULTS AND DISCUSSION

The results obtained from the experiment are presented in Table 1 where we compare the average data of the initial situation (year 2005) of the biophysical conditions of the production system studied and the data of the treatments applied after ten years of experience.

Table 1. Average data of edaphic conditions in three macroplots in different farming systems

Soil dept (cm)	Organic carbon (%)	Bulk density (gr / cm3)	Water-aggregate stability (%)	Infiltration (mm/h)	Penetration resistance (Mpa)	Water Content (mm)
	Before start of the experiment (2005)					
0-5	1.08	1.23	39			
5-20	0.74	1.43	30			
				23.87	1.623	
	Status in year 2014: control					
0-5	1.39	1.47	46.6			
5-20	0.92	1.65	33.4			
				19.22	1.850	
	<u>Water contents (mm) in 100 cm of soil depth</u>: Cover crops sowing					152.67
	Cover crops drying					183.75
	Crop Summer Sowing					250.24
	Status in year 2014: agrodiverse treatments					
0-5	1.85([a])	1.38([a])	73.4([a])			
5-20	0.98	1.63	40.0([a])			
				24.44	1.598	
	<u>Water contents (mm) in 100 cm of soil depth</u>: Cover crops sowing					159.47
	Cover crops drying					101.06 ([b])
	Crop Summer Sowing					229.81

(a) Indicates significant differences with the initial situation (p<0,10); (b) Indicates significant differences with respect to the control (p<0,10).

In the agrodiverse treatment, organic carbon content and water aggregate stability were improved due to the contribution of carbon by the inclusion of grasses (maize and CC) (Basanta *et al*., 2013, Villamil *et al*., 2006). However, the values of bulk density, infiltration and penetration resistance did not show favorable changes due to the compression exerted by the continuous agricultural machinery traffic. This is common in the management of no-till practices, which produces soil densification (Schmidt and Amiotti, 2015) in extensive areas of the central region of Córdoba.
The results of the effects on the water content of the soil up to one hundred centimeters of the profile by the winter CC showed that the control treatment presented higher accumulated water content than the treatment with CC at the time of its cycle cut. This result coincides with that observed by Restovich *et al*. (2012) and Basanta *et al*. (2008) and the reason of it is that CC utilized much of the profile water for biomass production, which averaged 1255.2 kg / ha. In the first forty centimeters of the profile, there were no significant differences at the time of sowing of the summer crop between the two treatments, caused by a recharge of the profile between the drying time of the CC and the moment of the sowing of the summer crop due to the precipitation occurrence.

Table 2. Average data of the biological conditions in three macroplots designed in different agricultural systems

Final conditions after ten years of the experiment			
Control treatment (soybean monoculture)		Agrodiverse treatment	
Biomass accumulated over 10 years (Kg MS / ha summer crops + winter cover crops)			
49513.8		95617.3(*)	
Soybean (2013)	Maize (2014)	Soybean (2013)	Maize (2014)
Reproductive biomass (Kg MS / ha)			
2214.9	2955.6	3241.7(*)	6714.3
Vegetative biomass (Kg MS/ha)			
3990.2	5178.6	5712.5(*)	16376.3
Spontaneous spring-summer vegetation			
Coverage (%)	Richness	Coverage (%)	Richness
18.3	10.3	2.1(*)	2.0(*)
Arthropods in soybean crop in different phonological stages (year 2013): Richness (Predator / phytophagous index)			
R2 stage: 0.64	R6 stage: 1.27	R2 stage: 1.44(*)	R6 stage: 1.67

(*)Indicates significant differences with respect to the control (p<0,10)

The accumulated aerial biomass production of the agro diverse treatment during the experiment was significantly higher (93.11%) than in the control. Both reproductive and vegetative biomass show significant differences in favor of the agro diverse treatment. Rotation and CC increased the amount and diversity of residues, favoring the temporal distribution of their inputs and contributed to improve the biological activity of the soil. This can be attributed to the fact that longer periods of active root growth would provide an environment that is more favorable to the development of microbial populations (Ferreras *et al*., 2010). Maize varieties produced grain yield and biomass volume similar to those of regional averages, even in years with marked water deficits, indicating their adaptation to semi-arid conditions and adequate plasticity (Kutka, 2011).

The consociation used as winter cover crop significantly reduced the spring weed community coverage and richness (Kruidhof *et al*., 2009).

In the last two years of the experiment, it was observed that soybean crop in the agrodiverse treatment maintained the best values of the predator / phytophagous richness index in relation to the control treatment during its reproductive stages (R2 and R6). The following year, when maize was introduced into the sequence, a significant drop in the abundance and richness pattern of both arthropod groups occurred in this crop; these results could be explained by a temporary disruption of the biological cycles that could affect the presence of specific pests (Altieri and Nicholls, 2012).

CONCLUSIONS

The agroecological transition process for extensive agriculture proposed in this work together with the implementation of a set of suitable practices to the semi-arid environment provided greater biodiversity and reduced the intensity of external resources´ use. The soil biophysical conditions were modified with a better water-aggregate stability and an increase of the organic carbon that contributed to progressively mitigate the processes of soil degradation due to monoculture. The summer crops yields and their contribution of residues to the soil were increased. The equilibrium and biological interdependencies of phytophagous and predatory populations were improved as well as the regulation of spring weed populations.

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