Biological Control: lessons learned for agroecological transition in Uruguay

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Control biológico: aprendizajes para la transición agroecológica en Uruguay

Controle biológico: aprendizados para a transição agroecológica no Uruguai

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Abstract

Agroecology proposes to mobilize the scientific and practical, traditional and local knowledge of producers to develop jointly new production systems. This article presents the results of research on biological control carried out since 2003 in the north of Uruguay. Experiences were conducted by different organizations of family farmers and by BIO-Uruguay (Batoví Instituto Orgánico), a social organization founded by family farmers and rural inhabitants. The results of the analyzed experiences are technical, methodological and social, focusing mainly on the biological fight against pests and diseases of agricultural and livestock production. The different stages of the co-innovation process are presented to obtain biological solutions from the recognition and use of native pathogenic fungi to control pests of economic importance. The objectives of this study were to restore biological balances, to contribute to the agroecological transitions of the productive systems, and to enforce the collective learning, necessary among the actors, for co-innovation. These learnings contribute to the development of the individual and institutional capacities needed to "build agroecology" in Uruguay.

Keywords: bioinputs, action-research, native organisms, participation

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Resumen

La agroecología propone movilizar los conocimientos científicos y prácticos, tradicionales y locales de los productores para coconcebir nuevos sistemas de producción. En este artículo presentamos los resultados de trabajos sobre el control biológico desarrollados a partir de 2003 en el norte del Uruguay. Las experiencias son realizadas por diferentes organizaciones de productores familiares y por BIO-Uruguay (Batoví Instituto Orgánico), una organización social fundada por productores familiares y pobladores rurales. Los resultados de las experiencias analizadas aquí son técnicos, metodológicos y sociales. Se trata principalmente de la lucha biológica contra plagas y enfermedades de la producción agrícola y pecuaria. Se presentan las diferentes etapas del proceso de coinnovación para la obtención de soluciones biológicas a partir del reconocimiento y el uso de hongos patogénicos nativos para controlar plagas de importancia económica. El objetivo fue restituir equilibrios biológicos, contribuir a las transiciones agroecológicas de los sistemas productivos y a implementar los aprendizajes colectivos, necesarios entre los actores para la coinnovación. Estos aprendizajes contribuyen al desarrollo de las capacidades individuales e institucionales necesarias para "fabricar la agroecología" en Uruguay.

Palabras clave: bioinsumos, investigación-acción, organismos nativos, participación

Resumo

A agroecologia se propõe a mobilizar o conhecimento científico e prático, tradicional, local dos produtores para co-conceber novos sistemas de produção. Neste artigo apresentamos os resultados dos trabalhos de controle biológico desenvolvidos a partir de 2003 no Norte do Uruguai. As experiências são realizadas por diferentes organizações de produtores familiares e Batoví Instituto Orgânico (BIO-Uruguai), que é uma organização social fundada por produtores familiares e habitantes rurais. Os resultados das experiências aqui analisadas são técnicos, metodológicos e socais. Trata-se principalmente da luta biológica contra pragas e doenças da produção agrícola e pecuária. São apresentadas as diferentes etapas do processo de co-inovação para a obtenção de soluções biológicas a partir do reconhecimento e uso de fungos patogênicos nativos para controlar pragas de importância econômica. O objetivo era restaurar os equilíbrios biológicos; contribuir para as transições agroecológicas dos sistemas produtivos e implementar a aprendizagem coletiva, necessária entre os atores, para a co-inovação Essas aprendizagens contribuem para o desenvolvimento das capacidades individuais e institucionais necessárias para a "fabricar a agroecologia" no Uruguai.

Palavras-chave: bioinsumos, investigação-ação, organismos nativos, participação

1. Introduction

Agroecological systems rely on a great plant and animal biodiversity to develop production systems independent of agrochemicals. In Uruguay, agroecology began to develop more than 30 years ago as a way of revaluing nature and as a source of solutions to the problems of pests and diseases generated by the technological packages that were spreading in the Uruguayan countryside. Family producers in the south of the country, devoted to horticultural items[1], were pioneers in experimenting with agroecological solutions. From 2003 and 2004 a focal point was created to promote agroecology in the northern livestock area of Uruguay (Tacuarembó), promoted by BIO Uruguay (Batoví Organic Institute), which has consolidated over time. The initiative arises from associations of family producers and rural inhabitants with the common objective of preserving and promoting the culture of rural life in the area, and sustainable production systems that do not pose risks to health or the environment[2].

Agroecology is based on territorial and grassroots processes and therefore can provide situated or contextualized solutions to local problems. It also proposes participatory methodologies that allow the development of new technologies carefully tailored to the needs and circumstances of specific rural communities[3-4]. The regenerative agricultural techniques, in this case, through the development of biological control alternatives (BC) using native fungi[5], allow processes of substitution of inputs and ecological restorations. These are ways of social activation and empowerment that are built on traditional knowledge for the ecological control of pests, compatible with rural culture and the mentality of the local population.

However, these changes and improvements in production systems must be thought of in the long term, understanding that they are biological processes that evolve together with mental processes to deconstruct imposed systems, of devaluation of inherited techniques. This implies at least two challenges for agronomic science: the first is how to deal with the complexity of the phenomenon, and the second

is how to associate producers in the production of new solutions and new knowledge. It should be generally remembered that scientists produce the knowledge mainly in experimental stations and laboratories away from producers. Incorporating this new perspective into the agronomic sciences, both in the co-creation of new knowledge and in the training of technicians and scientists, is one of the greatest challenges nowadays[6].

Picture 1. Agroecological vegetable producer in Tacuarembó

Source: Photograph taken by Álvaro Scarone, March 2021

The four BC experiences presented in this article have their starting point in the recognition of the diversity of native life, in particular of the beneficial soil fungi present in more conserved or less disturbed agroecosystems[7-8]. The common objective is the search for solutions, from agroecosystems to health problems economically important for the country[9]. To this end, it is necessary to develop the ability to identify, isolate, multiply, conserve and use native pathogenic fungal agents for BC. But for individual solutions to generate innovations, that is, new techniques and practices that allow solving problems and producing quality food, they need to be "socially" validated. Some authors, such as Flichy[10], talk about creating a "sociotechnical framework" that allows the implementation of these techniques. This means that, collectively, the actors involved in innovation set the rules, define internal and external relations, and above all, define the way to solve problems, review the operating conditions, the reproduction and how to share it (disseminate it) with other producers.

The hypothesis of this article is that to innovate the innovation must be "manufactured" by a network of producers, technicians and state and non-state institutions[11-12]; and that the real protagonism of producers generates empowerment and social capital in organizations to support the experiences[13]. The purpose of this study is, on the one hand, to provide knowledge about this process of innovation or sociotechnical co-innovation; and on the other hand, to characterize the contribution of the BC to the agroecological transition and, in particular, in the way that the actors appropriate and redefine concepts and roles[4]. It seeks a comprehensive view and to generate contributions to understand and reflect on different roles, including research and technical advice in the agricultural sector[14].

2. Material and methods

The four experiences and projects presented are part of a spiral of innovation that generated knowledge and enabled the identification of contributions of BC to agroecological transition. The experiences were imagined and executed by producer associations, different institutional programs and the BIO. The main objective was to obtain solutions to pest problems of economic importance for the country. The studies were carried out in producers' properties, scaling in areas and productive units, and giving special value to the ability of the tools developed to restore productive systems, contribute to the national productive system, and recognize and value the conservation of biodiversity. The new practices resulted from feedback, adjustments, relinquishment, redefinition, alliances and learnings (both technical and organizational and social), through continuous adaptive adjustments that emerge from the reality of resources and capacities. Knowledge is not only built for the BC of pests with native pathogenic fungi, but also on the management of biodiversity and methods of co-innovation of agroecological production systems.

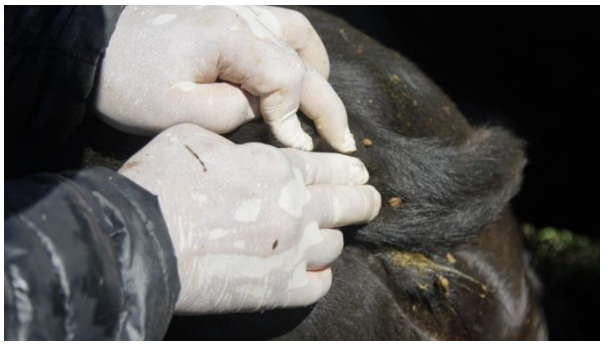
Experience 1: Agroecological centers

This experience was developed between 2004 and 2008 together with the Association of Family Producers from Sauce de Batoví (Batoví Productivo) through the project "Agroecological Centers", supported by the Small Grants Program of the United Nations Development Program. The aim was to contribute to the analysis and dissemination of local agro-ecological practices, including the research of the diversity of beneficial organisms in the different soils, associated with their management. A strain collection was prepared with promising native fungi for the control of cutting ants (genera *Atta* and *Acromirmex*)[15-16]. This process generated a biopesticide for ants that was registered and is currently in the process of renewal with improvements in its formulation, with the support of FAO (Food and Agriculture Organization of the United Nations).

Experience 2: Biopesticide for ticks

This experience was developed between 2015 and 2020 and involved a group of family producers from the Cooperative of Milk Producers of Tacuarembó (COOPLT by its Spanish acronym). The aim was to isolate and reproduce pathogenic fungi at small scale for their use in tick control in livestock. This experience was supported by the program +Tecnología of the National Institute of Agricultural Research (INIA by its Spanish acronym), Ministry of Livestock Agriculture and Fisheries (MGAP by its Spanish acronym)[2][13][15][18], and the Directorate of Rural Development (DGDR by its Spanish acronym), also of the MGAP.

Picture 2. Appearance of ticks affected by pathogenic fungi days after applying the biopesticide for ticks



Source: Photograph taken by Álvaro Scarone, March 2021

The aim was to reduce populations and damage caused by cattle ticks *Rhipicephalus B. microplus,* reducing the environmental impact of chemically synthesized acaricides and the low control efficiency due to the resistance generated by this arthropod. The results showed that the use of biopesticide for ticks decreased the levels of tick infestation, as well as the number of applications of the biopesticide, demonstrating its role in restoring natural balances.

Picture 3. Monitoring the effectiveness of biopesticide for ticks in treated animals

Source: Photograph taken by Álvaro Scarone, March 2021

Experience 3: Bioinsecticide

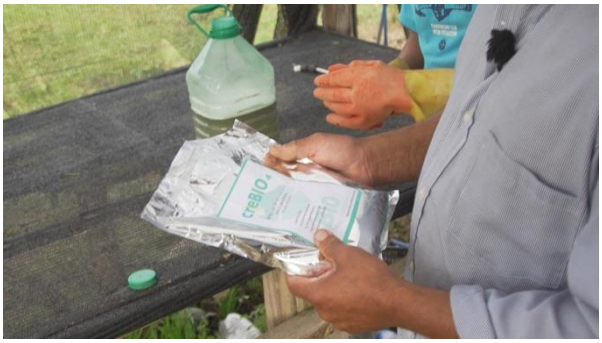
The experience began in cooperation with the Punto Verde Agricultural Cooperative in 2003[9], but with support in recent years from the MGAP and the National Agency for Research and Innovation (ANII by its Spanish acronym). The objective was to include a biological tool in the ecological management of pests in horticulture, reducing the incidence of whiteflies. Research was carried out together with identifications and the development of a bioinsecticide for whiteflies, pathogenic of *Trialeurodes vaporariorum* and *Bemisia tabacci*, which is currently registered as a commercial bioinput in the MGAP.

The main results obtained are based on the availability at national level of an efficient bioinput for the control of these pests, which is friendly to integral health and maintains and improves the beneficial biodiversity of agroecosystems[19].

Experience 4: Biofungicide and growth promoter

This experience, developed between 2017 and 2018 in cooperation with the Horticultural Movement of Tacuarembó, and with partial support from the National Institute of Cooperativism (INACOOP by its Spanish acronym), aimed to provide ecological tools for the management of diseases of intensive leaf crops, avoiding the use of synthetic agrochemicals. Agroecological management was generated through research of antagonistic native fungi to solve health problems that arise in intensive horticultural systems.

Picture 4. Development of packaging to maintain the quality of bioinputs for long periods: CRE BIO 4 based on *Trichoderma allelatum*



Source: Photograph taken by Álvaro Scarone, March 2021

The four experiences constitute participatory research focused on the restoration of pest control of economic importance for the region and the country. They follow the same methodological itinerary in three stages: (a) the first, characterized by the search to strengthen the cooperation and co-

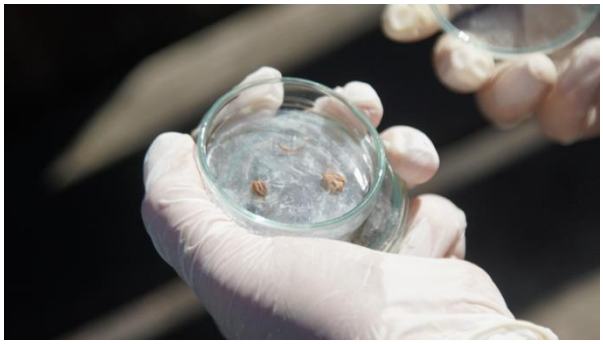
innovation abilities of the different actors, generating work agreements and roles to be developed; (b) the second, for strengthening specific work capacities (techniques) with the target pest, its interactions in the productive system according to different management techniques, the development of techniques of isolation, recognition, mass multiplication, conservation of the isolated strains and use at the field level, involving the development of appropriate and appropriable techniques and processes in real conditions, abilities and facilities available at the field level and not at experimental stations; (c) the third, for systematization of results of control technical efficiency, of the methodological processes to reach them, of the needs of development of institutional roles that allow the scaling of the experiences, and of the contribution in the development of production with agroecological bases.

3. Results and discussion

The results have been of three types: (a) technical, allowing the development of agroecological products and practices; (b) organizational, favoring cooperation between the actors of the projects, and creating a culture of collective and participatory work; and (c) political, making contributions to define the paths of the agroecological transition and also generating knowledge to develop public policies.

It can be stated that all the cases of BC tools used from this perspective, which starts from the research of native organisms and then their effect on biodiversity, have allowed the different actors to become aware and learn about agroecological management.

Picture 5. Prospecting for pathogenic fungi



Source: Photograph taken by Álvaro Scarone, March 2021

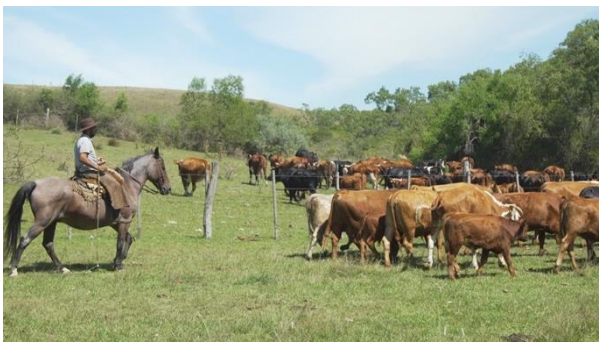
3.1 Development of effective biological solutions in the control of pests of economic importance for the region

Viable and efficient alternatives have been developed for the control of cattle ticks (*Rhipicephalus microplus*), the control of main horticultural pests (*Trialeurodes vaporariorum* and *Bemicia tabacci*), cutting ants (genus *Atta* and *Acromirmex*), fungi and bacteria that cause diseases in crops (*Botrytis*, *Phitium*, *Peronospora* and *Sclerotinia*, among others). This has led to obtaining more than 20 native isolates of pathogenic fungi and their use applied and systematized in more than 100 productive systems in different regions and ecosystems of the country, showing a viable path from the ecological, economic and social, and replacing chemically synthesized inputs. In addition, experiences and results of ecosystem restoration have been obtained in all areas, mobilizing the application of agroecological practices of conservation and restoration of natural ecosystems.

3.2 Production of actionable knowledge and innovation capacities

We talk about actionable knowledge when this serves to solve problems (action) and is recognized and validated by the scientific communities. The process, conceived from a possible escalation of similar experiences, generates needs for the development of capacities and new roles in the country's organizations and institutions in the field of rural development and food security[6]. Capacities have been developed to support the recognition and identification of new isolates generated by new productive groups, mass multiplication, monitoring techniques and conservation, considering the importance of having a national germplasm of native fungi.

Picture 6. Plant biodiversity of livestock systems in northern Uruguay



Source: Photograph taken by Álvaro Scarone, March 2021

3.3 Country-level development of the registration system of bioinput with native organisms

The bioinputs generated in this process have acted for the generation of legal frameworks and the adjustment of the associated processes for their registration (Decree 170/007) by the competent authorities (MGAP). This has its own value given its intrinsic characteristics to the process of isolation and multiplication, which increase its genetic richness and value for the conservation of biodiversity with the potential to adapt to field conditions and, therefore, its function as restorers of natural balances. This process is generating country-level discussions on what development approaches are wanted as a society, what capacities should be generated at the level of authorities, regulatory institutions, research and training of technicians. In the face of the constant increase in demand for bioinputs, in a country that has very few of these products commercially available, questions arise whether this commercial growth of bioinputs will follow the same logic of importation of chemically synthesized inputs, or if we will have the capacity to develop our own based on native organisms that manage to reimplant in agroecosystems and regenerate them. It is the registries that make them effectively marketable and available to the national productive sector. But this not only implies that legal results are achieved or products become marketable, but it also represents a model for working with native organisms that are genetically biodiverse populations, locally adapted containing knowledge of local biodiversity and its associated benefits.

There are currently five formulated products in an advanced or completed registration process for different health problems of the country's agricultural production: CREBIO 1 for cutter ants (based on *Beauveria bassiana* and *Trichoderma harzianum*); CREBIO 3 for thrips, stink bugs and cutworms (based on *Metarhizium* anisopleae.); CREBIO 4 growth promoter and antagonist of crop diseases (based on *Trichoderma allelatum*); CREBIO 5 insecticide of white flies (based on *Cordyceps javanica*); CREBIO 7 bioinsecticide for ticks (based on *Beauveria bassiana*, *Akanthomyces lecanii* and *Metarhizium anisopleae*).

3.4 Contribution to agroecological transition processes and definition of agroecology in Uruguay

Agroecology needs to enhance animal and plant biodiversity to produce goods and services that allow the sustainability of rural systems, territories and families, offering quality products. Biocontrol is one of the main instruments in the development of new, more agroecological production systems. The use of native pathogenic fungi generates new practices that suggest new paths in agroecological transitions, promote recognition and care to enhance ecosystem services of biodiversity, and contribute to restoring natural balances. Systems in transition have biological pest control alternatives that minimize economic losses and promote knowledge of biological interactions. They also raise awareness and bring nature and knowledge together, activating more conservationist and careful management (practices) of life and natural resources. This allows defining the role of BC in the agroecological transition not as a traditional input, but as a restorer of natural control. These practices must be accompanied by soil improvement practices and system diversification, including native species for their role in the balance, composting and recycling organic waste, avoiding management that destroys the soil or the biodiversity, taking care of water and promoting practices that contribute to health.

Every day is a new challenge to move from the logic of “exploitation” to the logic of “regeneration”. It was seen in all the cases and experiences developed by Bio-Uruguay, in the control or fight against different pests, that BC made with native fungi requires frequent applications at the beginning, which are then spaced in time and that, even in those highly affected by the pest, they achieve the restitution of natural control after three to four years. This implies that there is no need to use preparations with pathogenic fungi or biopesticides, given the high adaptability of these organisms to their own environments from where they were isolated.

3.5 Critical mass formation

Conceived as an engine for the development of a new paradigm of production and life for the region, where the same actors are authors of a socio-technical process that is generated through continuous adaptive adjustments that emerge from the reality of resources and the actors' own capacities. In this line, more than 80 family producers and 30 technicians have been trained, as well as teachers and students of different levels. Experiences show positive common results, such as the shared definition of the object of study and the generation of solutions tailored to local capacities. Also, the involvement of actors, which allows mobilization and participation of different members of society, with a central role in the experience and rural culture of family producers, founding, participating and disseminating experiences, with a continuous flow of dialogue between scientific and empirical knowledge with equal value,

activating applicable and appropriate solutions in that context.

The entire process of co-innovation of new BC techniques shows a first set of results strictly related to the efficiency of use and the management of the proposal. Guidelines and advances of an **innovative methodology** were generated to promote the recognition and use of native beneficial organisms present in our agroecosystems and their reproduction *on farm* as a tool in pest management. The proposal addresses the bases of agroecology as it is technically and economically feasible, effective, environmentally sound, carried out with resources easily available at the level of family production and decreasing dependence on off-farm inputs.

A second set of results is related to the **technical and agronomic reflection** of future production systems appropriating the proposal. The area designed for monitoring has played a very important role in this, allowing the inclusion of all the parts, promoting a technical and agronomic reflection not only of what is strictly related to the alternative of pest control but with all those factors that must be developed in the future for the effectiveness of the proposal. This promotes an activation, a rethinking of collateral actions that are part of the necessary changes beyond the strictly technological. This process has to do with a multidisciplinary "geography of intervention" that contributes to analyzing the processes and accompanying local actors on the path of territorial innovation and agroecological transition.

Finally, a third set of results has been the **creation of spaces** for the discussion and exchange of experiences. They are all opportunities for knowledge, analysis and the formation of a social critical mass that helps to think and develop national agroecological systems. The learning generated in the co-innovation process is, firstly, organizational. Actors have learned not only to work together and develop common goals but also to develop devices and instruments that support co-innovation. Secondly, the learning is technical, relative to the recognition of fungi, the process of manufacturing bioinputs, and also how to use them according to the situations, which allows generating biodiversity management devices both at territory and property levels.

4. Conclusions

Research carried out on BC since the beginning of 2003 shows that Uruguay has an important diversity of fungal species that offer wide possibilities to manage pests with native organisms. It also indicates that this is only the beginning of a deeper understanding of the complexity of nature and the necessary integration of technical solutions and innovations with associated social processes.

From a methodological point of view, the experience of BIO Uruguay shows that it is not only possible to work with producers in the identification-diagnosis of pest problems, but also to design a methodological itinerary that allows transforming local resources into pest-control products. This increases the capacity for innovation and, therefore, resilience of the producers. The regional scaling up of this type of experience should be developed in the coming years in Uruguay.

BC is a real alternative to the use of chemicals and an excellent tool for maintaining and restoring biodiversity. Therefore, it is one of the main tools to implement agroecology. The positive results of the use of native fungi, which are valued from all points of view, are not only due to their technical effectiveness, but also the social appropriation of a culture of closeness to nature that is still maintained in the north of the country. Academia, in particular, agroecological academia, must be part of the co-innovation spiral in order to take position and redefine techniques such as biological control from this perspective.

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To the producers of the different associations that participated in this process, to the members of BIO-Uruguay, and the representatives of the different institutions that, from practice, contributed to generate paradigm shifts.

Authors contribution

Alda Rodríguez was responsible for the execution and systematization of the experiences analyzed. Eduardo Chia and Virginia Rossi contributed to the discussion of conceptual frameworks for the analysis of experiences. All authors contributed equally to the writing of the article.

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