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Sustainable Development of Microbiological Products. A Challenge during the Agroecological Transition

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Abstract

There is a need to transit towards sustainability in the production and use of bio products. To contribute to this, the agroecological transition is addressed in the development of microbiological products. It focuses on the importance of the decentralization of bio products towards local food systems. It is argued that the sustainable development of bio products involves facilitating functional interactions and improving the quality of the habitat where they will be used. Also adopt new criteria to assess its sustainability.

Keywords: Microbiological products; Decentralization; Interactions; Habitat; Sustainability

Introduction

The history of technical products for crop nutrition and health has been contrasting: those of mineral origin and natural bio preparations, which predominated until the middle of the last century, were displaced by agrochemicals. These have had a rapid development during more than 70 years of intensive conventional agriculture (products, decision system and utilization technology); however, its accumulated negative effects have put social and scientific pressure in favor of the development of microbiological products (MBP). The use of the latter, which have initially been valued as an alternative with the same approach as the conventional product, is moving towards their functional integration and the decentralization of production, which is why they are considered sustainable biotechnologies for the food future. The integration of MBP, which involves facilitating the synergy between bio pesticides, bio fertilizers, bio stimulants and mycorrhizal inoculants, is in high demand and puts scientific pressure on the methodological innovations necessary to achieve their sustainable use, mainly to determine the compatibility between the microorganisms used to develop them and their interactions with the populations that cohabit in the rhizosphere and phyllosphere of cultivated plants, as well as develop appropriate technologies for their integration into crop practices and transform the design of the agroecosystem as a quality habitat for these microorganisms [1]. Bio products are a basic component of sustainable systems due to their contribution to reducing external inputs, improving the quality and quantity of internal resources, and their safety; furthermore, they can be generated from local resources and promote endogenous regional development [2,3]. The agroecological transition in the integration of MBP is a progressive process, which is justified by contributing to the following functions: (a) reducing the toxic load in agroecosystems, by replacing agrochemicals with bio products; (b) facilitate the regeneration of the soil and crop microbiota, which was depleted during intensive conventional agriculture and (c) contribute to the ecological self-regulation capacity of the systems, through functional integration. Based on recently published articles on decentralized biotechnologies and functional integration of bio products, the current objective is to draw attention to the need to move towards the sustainable development of MBP, in contrast to the reductionist tendency to consider them simply as substitute products or components of conventional technology packages.

Sustainable Development of Microbiological Products

The different scientific and development institutions have their own research and innovation systems to generate new bio products, position them in the markets and achieve their use in agricultural production. However, although the demand is still not satisfied and is growing, the progress made in recent years suggests the need to move towards sustainability in the processes of mass production and use by farmers. For intensive conventional agriculture, the development of agrochemicals aimed to achieve their effectiveness in the nutrition and health of crops; with the emergence of bio products during the rise of organic agriculture, the purpose has been to replace agrochemicals with biological products; however, the agroecological transition towards sustainable agriculture conceives the decentralization of production processes and the functional integration in their use, to facilitate the capacity for self-management, the restoration of degraded natural resources and ecological self-regulation in agroecosystems. The technological development of MBP (Figure 1) has two basic components: (a) mass production technology and (b) techniques for use in agricultural production. As innovations advance towards validation tests of the production process and its use in the soil-crop system, biotechnologists and agricultural technicians are integrated into teams to establish the characteristics of mass production and use, processes in which adjustments are needed to different contexts with the participation of farmers. This implies that the research and innovation processes for the development of MBP are complex and require various scientific methodologies to carry out transdisciplinary innovations. Mass production, which generally begins in centralized facilities and is subsequently decentralized to territorial production, also moves towards the adaptation of said technologies to different socioeconomic contexts, a characteristic that leads to the generation of different technological forms, be they industrial, semi-industrial and artisanal. The generation of biotechnological products considers upward scaling during the development process of a new product or technology, based on the results of a smaller scale while, in decentralized biotechnologies, the production process and the utilization system are scaled up in the territories [4,5]. The sustainable production of fresh foods is moving towards contextual self-management, a process that demands the decentralization of appropriate biotechnologies; in turn, interactions are facilitated between actors who obtain and use said products [6]. The practical use of bio products begins with the substitution of chemical inputs, which is why the tendency is to use them in the same way; however, due to their different characteristics (agrochemicals are products of chemical synthesis and bio products are obtained through the massive multiplication of microorganisms), they require integration into the soil-crop system, achieving synergies between the different types of bio products and moving towards habitat management (cropping and production system) because they need certain conditions for their functioning as living organisms.

An interesting example is the biocontrol of harmful organisms in the soil, where it is necessary to promote synergism to make the most of the benefits of microorganisms, as shown by the results of the compatibility study between the different bioregulators that are applied, such as: Trichoderma spp., Rhizobium sp., Azotobacter, T. paurometabola, and Glumus clarum, suggests the possibility of the combined use of some of these agents in the management of root-knot nematodes [7,8]. Likewise, to control phytopathogenic fungi, bio preparations are used from native strains of Trichoderma, previously selected as effective, under preventive forms of use and established doses, according to the nature of the pathogen and the type of crop compatible with bio fertilizers and biostimulants [9-11]. It was determined that organic matter enhances the action of the bio product, with higher yields due to the stimulation of plant growth and protection against pathogens above 80-90% [12]. The synergistic integration of microbiological biopesticides, bio fertilizers, biostimulants and mycorrhizal inoculants is in high demand and puts scientific pressure on the methodological innovations necessary to achieve their sustainable use, mainly to determine the compatibility between the microorganisms used to produce them and their interactions with populations. That cohabit in the rhizosphere and phyllosphere of cultivated plants, as well as develop appropriate technologies for their integration into crop technologies and transform the design of the agroecosystem as a quality habitat for these microorganisms. The functional interactions of MBP in the cropping system (phyllosphere and rhizosphere) are closely related to the design and management of the cropping system and the integration of auxiliary vegetation structures, due to their contribution to the regulation of the microclimate and pedoclimate. That is, the cultivation system is the new habitat where these microorganisms will function for the nutrition, growth and health of the crop, which is why it is important for its integration to be sustainable [13]. Innovation for the adoption of agrobiotechnologies requires a holistic approach in their integration into agricultural production systems, so that synergies and functional interactions are facilitated that also contribute to the economic rationality of the transition towards sustainable systems. The strategy of decentralized biotechnologies for the transition towards sustainable agriculture and food means that the processes of obtaining and systems of use of these products are appropriate for the different socioeconomic and ecological-environmental contexts where they will be used.

Decentralization of Bioproducts to Local Food Systems

During the agroecological transition towards local food systems, MBP are valued in three dimensions: (a) articulated local production, whether industrial, semi-industrial and artisanal, carried out by local entities; (b) its contribution to sustainable

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nutrition and the regeneration of natural resources degraded by conventional agriculture and (c) the role of the local agroecological knowledge management system, to achieve its sustainable integration. The strategy of decentralized biotechnologies for the transition towards sustainable agriculture and food means that the processes of obtaining and systems of use of these products are appropriate for the different socioeconomic and ecological-environmental contexts where they are going to be used, so that they are feasible to create capacities so that these agro biotechnologies are integrated into local value chains. These can be obtained through industrial, semi-industrial and artisanal processes, in decentralized facilities at different levels in the territory. Adopting agro biotechnologies has various logistical, legal, financial, knowledge management, innovation, biosecurity implications, among others; In turn, the territorial scaling for obtaining and using it must be designed as an incremental transition process (Vázquez 2023). Some agro biotechnological products are imported or obtained by national entities, so that access through local agricultural production depends on various external actors; however, decentralized biotechnologies mean an approach to the places where primary agricultural production is carried out, whose main advantages are: (a) facilitation of access by farmers; (b) greater possibilities of exchange between biotechnologists and users; (c) production planning according to crops and seasons of the year; (d) possibilities of using elements of the local biota in some bio products (example: microbiological biopesticides); (e) feedback on effectiveness to improve product quality; (f) greater contribution to the transition process towards sustainable systems. Despite the international crises that have an impact on agricultural production, mainly economic, energy, climatic and technological, the approach of "protecting" and "enhancing" cultivation with agrochemicals (fertilizers, pesticides and others) still predominates as the only option and, sometimes replacing these with other products with a lower environmental impact (organic fertilizers, biopesticides, botanical pesticides, etc.), which also contributes to the product approach that characterizes what is known as "green revolution syndrome" [14].which was later popularized as a "technology package", a reflection of the reductionist approach that has led to the technological crisis of contemporary agriculture. These narratives, which still predominate in agrarian socioecosystems, constitute a factor that slows down the integration of MBP and other appropriate technologies to move towards sustainable agriculture.

Functional interactions of bio products

It is difficult to fully understand the functioning of a biological system [15]. The complexity of plant-soil-microorganisms-environment interactions is varied. A complete understanding of all the relationships involved is unlikely; however, the beneficial effects of biological interactions that stimulate crop yields and improve plant health can be evaluated and some general strategies of the interaction become evident [16]. In nature, all microorganisms live in associations and form natural consortia that are more stable than laboratory monocultures [17]. A microbial consortium is a microbial association that contains two or more microorganisms, which can be archaea, fungi, bacteria, viruses and algae [18, 19]. At a biotechnological level, they have been classified according to their construction into: I- natural microbial consortia, which are found living symbiotically in nature; II- artificial microbial consortia, made up of different wild microorganisms that can grow together symbiotically in a closed system to generate valuable products; III- semi-synthetic microbial consortia, in these consortia wild and modified microorganisms are grown together for a common purpose; IV- Synthetic microbial consortia: include the co-culture of microorganisms that are metabolically modified to increase their function and productivity [20]. There is a lot of scientific evidence in this regard. For example, studies on the rhizosphere microbiome and its interaction with the plant have revealed that plants form their own rhizosphere microbiome, coordinated by root exudates [21], a phenomenon that varies with conditions. Environmental conditions and the age of the plant [22].

The interaction of rhizosphere microorganisms, such as arbuscular mycorrhiza-forming fungi, fungi of the genus Trichoderma and bacteria of the genus Pseudomonas, usually classified as biological control agents and plant growth promoting microorganisms, depend on this type of factors to express its potential beneficial effects; however, the interactions between microorganisms are complex and synergistic effects may occur that enhance the benefits for the plant or, on the contrary, antagonistic effects or simply no effect may occur [23].

For practical purposes, the interactions that are facilitated with the technology of using MBP in the soil-crop system can be of three types, among others:

- Between bio products. When more than one bio product is mixed, with the purpose of facilitating synergies in its activity (nutrition, growth stimulation, health) or reducing the energy costs of the intervention; also, when the incorporation into the soil or sprinkling on the crop has a sequence, which is due to complementary effects between them.
- Between the bio products and the biota that inhabit the soil-crop system. Mainly due to the importance of contributing to interactions with the rhizospheric and epiphytic biota.
- Between the bioproducts and the conditions of the soil-crop system as habitat. When the soil-crop system has a temporal (crop succession and rotation) and spatial (multiple crops) design, the edaphoclimatic conditions for the activity and establishment of the microorganisms that make up the MBP are improved.

Facilitating the functional interactions of MBP constitutes a challenge during the agroecological transition, because it involves making disruptive innovations in the methods of use (treatment of seeds and seedlings, incorporation into the soil, integration into the irrigation system, integration into filial spraying, among others) and the redesign of the soil-crop system as an appropriate habitat, so that it is expressed in greater sustainability.

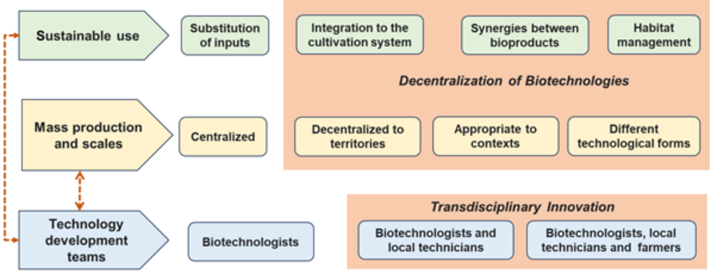

Figure 1: *Agroecological transition in the sustainable development of microbiological products for crop nutrition and health.*

Agroecological Redesign of the System to Improve Habitat Quality

Although the specific habitat where MBP interact is the soil-crop system, they also receive influences from the rest of the production system, mainly from the structural design of the crop composition and the integration of auxiliary vegetation structures. Conventionally, the habitat is studied and managed according to the species or groups of biodiversity, considering their conservation and the ecosystem services they must provide; while, socioeconomic development occupies vast territories in urban and rural areas, with increasing artificiality and the consequent generation of pollutant emissions, among other negative externalities that, as a whole, reduce the quality of the habitat for biodiversity in general, including human settlements [24]. However, this approach has proven insufficient and, today, attention is turned towards a more functional approach, which tries to establish causal relationships between the characteristics of the organisms present and the processes and services of the ecosystems [25,26]. The quality of the agroecosystem as a habitat facilitates the functions of the associated biodiversity and the synergies in the use of bio products, which is evident in its capacity for ecological self-regulation, because multiple cumulative effects occur that contribute to the regeneration and conservation of the biota in the environment. Soil, recovery and conservation of the associated biota (rhizospheric, epiphytic, natural enemies, pollinators) and higher quality of food, with lower environmental impact, among others [27]. The multifunctionality of microorganisms in agricultural systems is expressed according to a series of biotic factors, such as competition with other microorganisms, the biological composition of the soil, plant-microorganism recognition and vice versa. Likewise, abiotic factors, such as climate, physical and chemical characteristics of the soil, which directly influence the type of interaction of these organisms and the expression of beneficial or detrimental effects, determining the development of plant species [28,29]. Several ecological theories argue that the efficient functioning of agricultural production systems does not depend only on the elements of biodiversity that are introduced and inhabit it, since diversity is not always something inherent to stability pointed out, connectivity and habitat quality are essential [30-32].

In recent years, the need to pay greater attention to the effects of diversity on the stability [33], and the occurrence of harmful organisms and their natural enemies in agroecosystems [34] has been widely documented, as well as promoting interactions that contribute to the ecological services of functional biodiversity [35], including connections between production systems and natural ecosystems [36]. The level of internal regulation of agroecosystems depends greatly on the degree of diversity of plants and animals, and furthermore, this agro diversity is the result of the interaction between the environment, genetic resources and management, which modifies their functioning and allows greater adaptability to extreme situations [37]. Property redesign attempts to transform the structure and function of the agroecosystem by promoting diversified designs that optimize key processes. The promotion of biodiversity in agroecosystems is the key strategy in farm redesign, since research has shown that [38]: (a) greater diversity in the agricultural system leads to greater diversity of associated biota; (b) biodiversity ensures better pollination and greater regulation of pests, diseases and weeds; (c) biodiversity improves nutrient and energy recycling; (d) complex and multispecific systems tend to have higher total productivity. Agroecology is a science that studies the agroecosystem as a whole (holistically) and considers it as a complex system [39], achieving a comprehensive approach to the processes that occur in it and in this way, overcoming the simplistic view of industrial agriculture [40]. A complex system can be described as a system composed of multiple elements that interact in multiple ways, in which many properties depend on these interactions and are known as emergent properties, of which the stability (homeostasis) of an agroecosystem is a classic example and it does not depend only on the identity of the components of biodiversity. The scaling of biological control in Cuban agriculture has been fundamental in the agroecological transition and greater sovereignty in pest management. Furthermore, it has contributed to valuing the multifunctions of biodiversity in the design and management of agricultural production systems, thus generating new territorial dynamics and territorial governance [41].

Sustainability in the valorization of microbiological bio products

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After the Second World War, agricultural production underwent a transcendental technological change, which became the paradigm of productivism, based on the intensive exploitation of land. This consisted of an accelerated process of development of new technologies, mainly machinery and various implements, fertilizers, pesticides and other agrochemicals, as well as technologies for soil preparation and crop management, including genetic improvement to achieve varieties with high response productive [42]. This hyper-technical technological model established the limiting factors of its productive efficiency, including the technical products that were needed for the growth and health of the crops. Indeed, the intensification of agricultural production implied greater productive efficiency and this was possible by subsidizing crops with nutrients and eliminating harmful organisms that increased as a consequence of the massive multiplication of their host plants. That is, it was economically established that the main effect expected from technical products is to increase the effectiveness of crop nutrition and health. These criteria, established by agrochemicals, maintain their validity in the development of bio products; because, the soil, the agricultural species and varieties and the technologies of the cropping systems, which were generated during the rise of conventional agriculture, are the same when the agroecological transition begins. Therefore, they are farming systems that need these technological subsidies. However, with the development of MBP, new decision-making and application technology systems have been established, whose evaluation with sustainability criteria considers the following criteria: (a) technical efficiency in the control of populations of harmful organisms and nutrition of crops; (b) synergistic integration between different bio products (effects, energy savings); (c) its contribution to the reduction or elimination of the toxic load caused by agrochemicals; (d) the facilitation of the functions of the associated biota that inhabit the plant organs and the soil and (e) the local capacity in access.

Unlike agrochemicals, which are composed of specific molecules and additives, MBP have reproductive structures of species or communities of microorganisms and the substrate where they are preserved, which when used interact with the biota of the agroecosystem, both to achieve greater effectiveness (nutrition, plant growth, health), as well as to facilitate its persistence or establishment and continuity of its positive effects. The recovery of soil biota (organic matter decomposers, phytopathogen antagonists, rhizospheric biota, others); the activity of the epiphytic microbiota that lives on the surface of leaves, fruits and other aerial organs of plants; the activity of natural enemies of pests (entomopathogens, antagonists, nematodopathogens), among others, with evidence of sustainability in the integration of MBP. Several factors, which are not important in the use of agrochemicals, negatively influence the effectiveness of bio products, which in turn are determining factors in the sustainability of the use of these biotechnologies [43], mainly the following: (a) productive specialization, including monoculture; (b) simple cropping system designs (uniculture); (c) the integration of bio products and agrochemicals with application substitution criteria; (d) direct exposure of the bio product to direct solar radiation; (e) direct exposure of the bio product to surface air currents; (f) low relative humidity in the soil and microclimate; (g) poor quality of the bio product with respect to the concentration and viability of the microorganisms that comprise it; (h) poor quality of water used to prepare and apply suspensions; (i) prolonged exposure of the bio product to excess heat before its use (transportation and preparation). Scientific centers and their MBP development project teams generally focus on the same effectiveness criteria of their similar agrochemicals, a situation that is logical because the substitution of inputs demands this competition in effects [44]; however, the research itself, mainly when it is transdisciplinary, incorporates new sustainability criteria in its assessment by biotechnologists, technicians and farmers.

References

1. Vazquez LL. Agroecological transition in the integration of bioproducts. J Appl Biotechnol Bioeng. 2022; 9: 225-227.
2. Jay SS, Chandra PV, Singh OP. Efficient soil microorganisms: A new dimension for sustainable agricultura and environmental development. Agricul Ecosystems and Environ. 2011; 140: 3339-353.
3. Doyle PM, Erickson CM. Opportunities for mitigating pathogen contamination during on-farm food product. lnter J Food Microbio. 2012; 152: 54-74.
4. Stamenkovic S, Beskoski V, Karabegovic I, Lazic M, Nikolic N. Microbial fertilizers: A comprehensive review of current findings and future perspectives. Spanish J Agricult Res. 2018; 16.
5. Vazquez LL. Decentralized biotechnologies in production-use networks of biological control agents. J Appl Biotec Bioeng. 2021; 8: 65-66.
6. Vazquez LL. Decentralized biotechnologies in the transition towards sustainable agriculture. J Clinical Labor Res. 2023; 6.
7. Mena J. HeberNem bionematicide application manual. 1er Seminario Tecnico sobre Sanidad Vegetal en Cultivos, Protegidos, 25 al 28 de septiembre, La Habana. 2007.
8. Puertas A, de la Noval B, Martinez B, Miranda I, Fernandez Fy, Hidalgo-Diaz L, et al. Interaction of Pochonia chlamydosporia var. catenulata with Rhizobium sp, Trichoderma harzianum and Glomus clarum in the control of Meloidogyne incognita Rev, Proteccion Veg. 2006; 21: 80-89.
9. Sandoval I, Stefanova M, Lopez MO, Neyra M, Garcia D. Use of a Trichoderma biopreparation to control diseases in tomato and pepper. (Summaries) Earth Conference on Biomass for Energy, Development and the Environment, La Habana, Cuba. 1995; 136-137.
10. Stefanova M, y Sandoval I. Effectiveness of biopreparations of Trichoderma spp. in the control of phytopathogenic soil fungi. Boletín Tecnico No. 2, 22, CID-INISAV (La Habana). 1995.

11. Stefanova M. Introduction and technical effectiveness of biocontrol of phytopathogens with Trichoderma spp. Cuba: Fitosanidad. 2007b; 11: 75-79.
12. Stefanova M. Development, scope and challenges of biocontrol of phytopathogens in Cuba. Summa Phytopathol, Botucatu. 2007a; 33: 104-160.
13. Vazquez LL. Functional biodiversity and sustainable integration of microbiological bioproducts in agroecosystems. J Appl Biotechnol Bioeng. 2024b; 11: 60-62.
14. Vazquez LL. “Protect" and "enhance" cultivation with agrochemicals: an old paradigm inherited from the "green revolution" period, which must be changed. Rebelion. 2011b; 3.
15. Brimner TA, Boland GJ. A review of the non-target effects of fungi used to biologically control plant diseases. Agric. Ecosyst. Environ. 2003; 100: 3-16.
16. Sturz AV, Christie BR. Beneficial microbial allelopathies in the root zone: the management of soil quality and plant disease with rhizobacteria. Soil Tillage Res. 2003; 72:107-123.
17. Bhatia SK, Bhatia RK, Choi YK, Kan E, Kim YG, Yang YH. Biotechnological potential of microbial consortia and future perspectives. Critical Rev Biotechnol. 2018; 0: 1-21.
18. Paerl HW, Pinckney JL. A mini-review of microbial consortia: their roles in aquatic production and biogeochemical cycling. Microbial Ecol. 1996; 31: 225-247.
19. Zhang S. Minireview interkingdom microbial consortia mechanisms to guide biotechnological applications. Microb Biotechnol. 2018; 11: 833-847.
20. Bernstein HC, Carlson R. Microbial consortia engineering for cellular factories: in vitro to in silico systems. Computational Structural Biotechnol J. 2012; 3: 1-8.
21. Spence C, Alff E, Johnson C, Ramos C, Donofrio N, Sundaresan V, et al. Natural rice rhizospheric microbes suppress rice blast infections. BMC Plant Biol. 2014; 14: 130-147.
22. Chaparro JM, Badri DV, Bakker MG, Sugiyama A, Manter DK, Vivanco JM. Root exudation of phytochemicals in Arabidopsis Follows Specific Patterns That Are Developmentally Programmed and Correlate with Soil Microbial Funct. PLoS ONE. 2013; 8: 1-12.
23. Cano MA. Interaction of beneficial microorganisms in plants: Mycorrhizas, Trichoderma spp, Pseudomonas spp, a review, Rev, U.D.C, A Act, Div, Cient. 2011; 14: 15-31.
24. Vazquez LL. Multifunctions of the auxiliary vegetation structures on conservation habitat quality. A challenge for the agro and socio ecosystems redesigns. J Appl Biotechnol Bioeng. 2024a; 11: 10-13.
25. Hooper DU, Chapin III FS, Ewel JJ, Hector A, Inchausti P, Lavorel S. Effects of biodiversity on ecosystem functioning: a consensus of current knowledge. Ecol Monographs, 2005; 75: 3-35.
26. Diaz S, Tilman D, Fargione J, Chapin III FS, Dirzo R, Kitzberger T, et al. Biodiversity regulation of ecosystem services. In: Ecosystems and human well-being: Current state and trends. (Eds. Hassan R., Scholes R. y Ash N.), Island Press, Washington DC. 2005; 297-329.
27. Matienzo Birto Y, Vazquez LL, Alfonso-Simonetti J. Quality of Agroecosystems as Habitats to Natural Enemies and Biological Control Agents. 2019; 3: 27-24.
28. Marschner P, Timonen S. Interactions between plant species and mycorrhizal colonization on the bacterial community composition in the rhizosphere. Applied Soil Ecol. 2005; 28:23-36.
29. Siddiqui ZA, Akhtar MS. Synergistic effects of antagonistic fungi and a plant growth promoting rhizobacterium, an arbuscular mycorrhizal fungus, or composted cow manure on populations of Meloidogyne incognita and growth of tomato. Biocontrol Sci Techn. 2008; 18: 279-290.
30. Tilman D, Lehman CL, Bristow CE. Diversity-stability relationships: statistical inevitability or ecological consequence. Ame Naturalist. 1998; 151: 264-276.
31. Odum EP, Sarmiento FO. Ecology: the bridge between science and society. Mexico DF: McGraw Hill Interamericana de Mexico. 1998.
32. Bennett AF. Linking the landscape. The role of ecological corridors and connectivity in wildlife conservation, UICN-Mesoamerica, San José, Costa Rica. 2004.
33. Landis DA, Wratten SD, Gurr GA. Habitat management to con¬serve natural enemies of arthropod pests in agriculture. Ann Rev En¬tomol. 2000; 45: 175-201.
34. Nicholls CI, Parrella MP, Altieri MA. Effects of a Vegetational Corridor on the Abundance and Dispersal of Insect Biodiversity within a Northern Californian Organic Vineyard, Landscape Ecol. 2001; 16: 133-146.
35. Altieri MA. The state of the art of agroecology: reviewing advances and challenges. En: T Leon y MA Altieri (Eds.). IDEAS No. 21. Instituto de Estudios Ambientales. Universidad Nacional de Colombia. Bogota. 2010; 77-104.
36. Perfecto I, Vandermeer J, Wright A. Nature’s matrix: linking agriculture, conservation and food sovereignty. Earthscan. 2009; 1st ed. UK. ISBN: 978-1- 84407-781-6 (hardback), 978-1-84407- 782-3 (paperback). 25.
37. Almekinders C, Fresco L, Struik P. The need to study and manage variation in agroecosystems. Netherlands J Agricul Sci. 1995; 43: 127-142.
38. Power AG. Cropping systems, insect movement and spread of insect transmited diseases in crops. In SR Gliessman (ed.). Agroecology: researching the ecological basis for sustainable agriculture. New York. 1990; 47-69.
39. Griffon D. Biodiversity estimation in agroecology. Agro¬ecologia, 2008; 3: 25-31.
40. Altieri MA, Nicholls C. Agroecology, theory and practice for sustainable agriculture. Mexico DF: PNUMA. 2000
41. Chia E. Agroecology new paradigm for family farming and territorial development. Contribution of the virtuous triptych of innovation, learning and governance. Revista Cangue, marzo. 2018; 1-5.
42. Vazquez LL. Agricultural production with technological packages called "state-of-the-art", a myth similar to the mirrors of the colonizers. Rebelion. 2011a.
43. Vazquez LL, Alvarez JM. Ecological control of pest populations. Ed CIDISAV (La Habana). Instituto de Investigaciones de Sanidad Vegetal. 2011; 136.
44. Nicholls CI. Agroecological bases to design and implement a habitat management strategy for biological pest control - Ideas No. 21.

Instituto de Estudios Ambientales. Universidad Nacional de Colombia, Bogota. 2010; 203-225.

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