Advances in biology through agronomy, aquaculture, coastal and environmental sciences

Leandris Argentel Martínez
Ofelda Peñuelas Rubio
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Prologue

Advances in biology through agronomy, aquaculture, coastal and environmental sciences is an electronic book, edited by Pantanal Editora, based on the compilation of research papers where the authors of the different chapters have used highly current scientific methodologies and research equipment.

The biological sciences as the main object of research in agriculture, aquaculture, coastal and environmental sciences generate every day an understanding of knowledge that allows raising the scientific level of society as part of universal access to knowledge.

This book mainly addresses issues related to the use of plants extracts as sustainable alternatives for biocontrol of pests and bacterial diseases. It also brings together information on viruses and other diseases in aquatic organisms. In addition, studies of mangroves structure and their contribution to carbon sinks in experimental sites in northwestern Mexico are presented. Finally, an analysis on educational strategies for environmental education based on plant biology is carried out.

Editors appreciate the participation of the authors who have come from higher education institutions and research centers of great scientific prestige in Mexico. The majority of them are members of the National Research System of CONACyT, Mexico.

The authors

Summary

Chapter 9

Plant galleries as a strategy for environmental education in México

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ABSTRACT

There is a global crisis in environmental education, hence, educational institutions at all levels must commit to fostering a paradigm shift in their students by creating proposals that help prevent and/or mitigate the environmental impact generated by economic activities. In this sense, this contribution is made on the use and benefit of vegetable galleries as a basis for conscious agricultural practices, and concomitantly, as a strategy for soil recovery, water use, and environmental conservation. Thus, creating social and economic well-being for thecommunities, an objective pursued by education.

Keywords: agricultural practices, environmental conservation, education, soil recovery.

INTRODUCTION

The Food and Agriculture Organization of the United Nations (FAO) is a technical organization created by the United Nations (UN) with the purpose of combating hunger and poverty in the world;

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however, by 2055, it foresees a world population of 10,000 million people (FAO, 2020). The World Bank reports that as of 2019, 8.9% of the world's population was undernourished, facing unprecedented pressures and challenges while suffering strong economic impacts (World Bank, 2022). Under this chaotic scenario, solutions must be created from education based on the concept of sustainability, favoring food production and planet health (FAO, 2021). Sustainable agriculture is an approach in which the use of resources is balanced with productivity, which is achieved through the capacity to innovate, coordinate, and manage soil, water, and organisms within the climatic and economic limits of the environmental system (Quam et al., 1999). For this reason, paradigms must be broken, and stakeholders must work as true agents of change. This can only be achieved through comprehensive environmental education, in which well-structured and innovative strategies must be proposed and applied to lay the foundations for true sustainability. These goals can be accomplished by starting in regions implementing small changes in food production and increasingly gaining a foothold in all economic activities.

The success of bioeconomics, whose main task is to investigate the impact of human enterprises on the environment (Mohammadian, 2000), is supported by biotechnology. Biotechnology plays a fundamental role in solving production and processing problems in agricultural and livestock products in a sustainable manner through the creation of new production techniques aligned with the concept of sustainability. In this way, an increase in yield and profitability in production is achieved by reducing or mitigating pests, improving adverse abiotic conditions such as drought and cold, and taking better advantage of food production areas. All the above are the basic foundations of agroecology, which also promotes the reduction or prohibition of the use of agrochemicals to develop a rational use of the environment, thus favoring the conservation of biodiversity (Muñoz; Montico, 2021; Bravo, 2013; Gazó, Sharry, 2015). As part of agroecological education, the reuse of nutrients, with the use of organic fertilizers and/or biofertilizers from bioprocesses, is proposed as an effective measure to achieve rural sustainability (Gálvez; Huerta, 2017). World organic production statistics show that in Mexico, 1,853,653 hectares (Ha) are registered as organic spaces where the wild harvesting of medicinal and aromatic plants, diverse fruit species, silvopastoral systems, and beekeeping are used in natural conditions. However, hard data only report 215,634 Ha as organic production systems with 45,954 producers and 544 processing plants (Wille et al., 2022). In this sense, while training as part of an environmental education process has a long way to go worldwide, it is important to highlight the educational activity in this aforementioned panorama, and with this, a question arises: What would be the educational strategy to make food production truly sustainable?

The Mexican Ministry of Public Education (SEP) in its 2022 curriculum framework and syllabus of Mexican basic education for children and adolescents encompasses new content related to environmental and financial education (favoring one type of economy over others, such as the popular and solidarity economy) and the use of digital information and communication technologies. It also highlights forming part of various educational processes linked to the community-territory to develop projects aimed at social justice and solidarity with the environment (SEP, 2022), a consideration that often remains only in the inkwell and in the trunk of good intentions.

In Mexico, the specific subject concerning plant galleries as an ecological strategy is rarely considered in environmental education or training programs. Nonetheless, our contribution presents the benefits of these systems with the purpose of promoting their development to a greater extent, not only for regions that need the effectiveness of windbreaks against erosion or protection but also to understand the integration of tree coverage in a holistic manner. The resultant creation of vegetation corridors with different strata can serve as settlement areas for diverse organisms; they have the capacity to regulate soil temperature and create a single system through the agroecological matrix (Martínez, 2018; Griffon et al., 2010). The objective this document is encourage on the use and benefit of vegetable galleries as a basis for conscious agricultural practices, as a strategy for soil recovery, water use, and environmental conservation.

MATERIALS AND METHODS

A compilation of information in the databases of the Worldwide Web was carried out using scientific articles published in indexed and refereed journals as sources of consultation, as well as national and international library resources and repositories (Michán, 2011). Subsequently, a structured and systematic interpretation and integration of the information was carried out, followed by the drafting of this document (Tinto, 2009).

RESULTS AND DISCUSSION

Environmental education must play a decisive role in food production to reduce the environmental impacts created. An example of this scenario is the case of Central America, where almost all agricultural systems are managed alternating trees, crops, and/or pastures as agroforestry or agrosilvicultural systems. This integration favors the producer since it provides timber, forage, and fruit, in addition to offering shade and windbreak protection. It also increases the biological diversity of the area since its foliage, roots, and leaf litter form ecological niches for a great variety of macro- and microorganisms, in addition to improving soil fertility by increasing organic matter (Beer et al., 2003; PASOLAC, 1999). It is worth mentioning the various benefits of living barriers in environmental training programs, emphasizing that they function as a natural repellent by being a biological control against various pests and parasites (Smith; Liburd, 2012; San Román; Cárdenas, 2016). Among the precedents that reinforce these practices are those carried out by González et al. (2006), who evaluated marigold (*Tagetes erecta*) and sorghum (*Sorghum spp.*) as an alternative for biological and physical control against the white fly (*Bemisia spp.*) in eggplant (*Solanum melongena L.)* crops. They resolved that this barrier was highly effective in reducing whitefly populations and that it should be promoted as an alternative within integrated pest management practices. The efficiency of the combination of four live barriers, corn (*Zea mays*), sorghum (*Sorghum bicolor*), sunflower (*Helianthus annuus*), marigold (*Tagetes erecta*), and the entomopathogenic fungus (*Paecilomyces farinosus*), was evaluated on vegetable crops in Oaxaca with the same pest (*Bemisia tabaci*) to propose integrated management. The results indicated that the combination of *P. farinosus* with corn barriers produced a yield of 4,721 kg ha^{-1} in chili crops (*Capsicum annuum L.*) and 7,227 kg ha^{-1} saladette tomato *(Solanum lycopersicum*) without being significantly different from the control treatment with a commonly used endosulfan pesticide (Ruíz; Aquino, 1999).

Repellent plant barriers have an unpleasant odor for some insects, and some of these plant species are borage (*Borago officinalis*), sage (*Salvia spp*), marjoram (*Origanum majorana*), thyme (*Thymus spp*), nettle (*Urtica dioica*), milfoil (*Achillea millefolium*), wormwood (*Artemisia absinthium*), basil (*Ocimum basilicum*), buttercup (*Ranunculus acris*), calendula (*Calendula officinalis*), dandelion (*Taraxacum officinale*), and mint (*Menta spp*) (Cucchi, 2020). In the state of Hidalgo, Mexico, 124 plant species are used, from which 186 products are obtained in the form of infusions and fumes to combat 29 types of pests of both vertebrates and invertebrates (Villavicencio et al., 2010). Other vegetable crops also share this anti-pest action, some of them being chard (*Beta vulgaris* var. *Cicla*), garlic (*Allium sativum*), celery (*Apium graveolens*), coriander (*Coriandrum sativum*), chives (*Allium schoenoprasum*), spinach (*Spinacia oleracea*), turnip (*Brassica rapa rapa*), parsley (*Petroselinum crispum*), leek (*Allium ampeloprasum* var. *Porrum*), radish (*Raphanus sativus*), and carrot (*Daucus carota*) (Cucchi, 2020). The dried flowers of the pyrethrum daisy (*Chrysanthemun cinerariaefolium*) contain active components such as pyrethrins, cinerins, and jasmolins as natural insecticides. The canary bird bush (*Crotalaria agatiflora*), turmeric (*Curcuma domestica*), and neem (*Azadirachta indica*) are some other species that have insecticide, fungicide, nematicide and repellent qualities, as well as herbicide power (Castro et al., 2018). However, there are plant species that function in an opposite manner, hosting pests. Such is the case for leguminous plants such as gliricidia (*G. sepium*) and the river tamarind (*Leucaena leucocephala*), which can host the green leafhopper (*Empoaska kraemeri*). This leafhopper is considered a pest that greatly affects bean crops; therefore, in places where it is present, these trees should not be included as living barriers (Pérez, 2009). In general, applications of agroecological systems favor the producer; however, it is also necessary to point out that the added value of lands with these systems increases between 23 and 52% over any traditional land or plot, even considering suburban land (Giraldo; González, 2018). Figure 1 shows an agroecological model based on an environmental education and sustainable production strategy that generates economic, social, and environmental benefits by integrating forestry systems (windbreaks with different strata and timber or fruit tree species), aromatic plants, vegetables, apiaries, and other livestock production systems (tilapia farming and sheep rearing). This system is not utopian, and its creation and functioning are possible if it is considered a "living organism", characterized by a structural conformation where all representatives and their dynamics are controlled through self-regulated biological mechanisms (Muñoz; Montico, 2021).

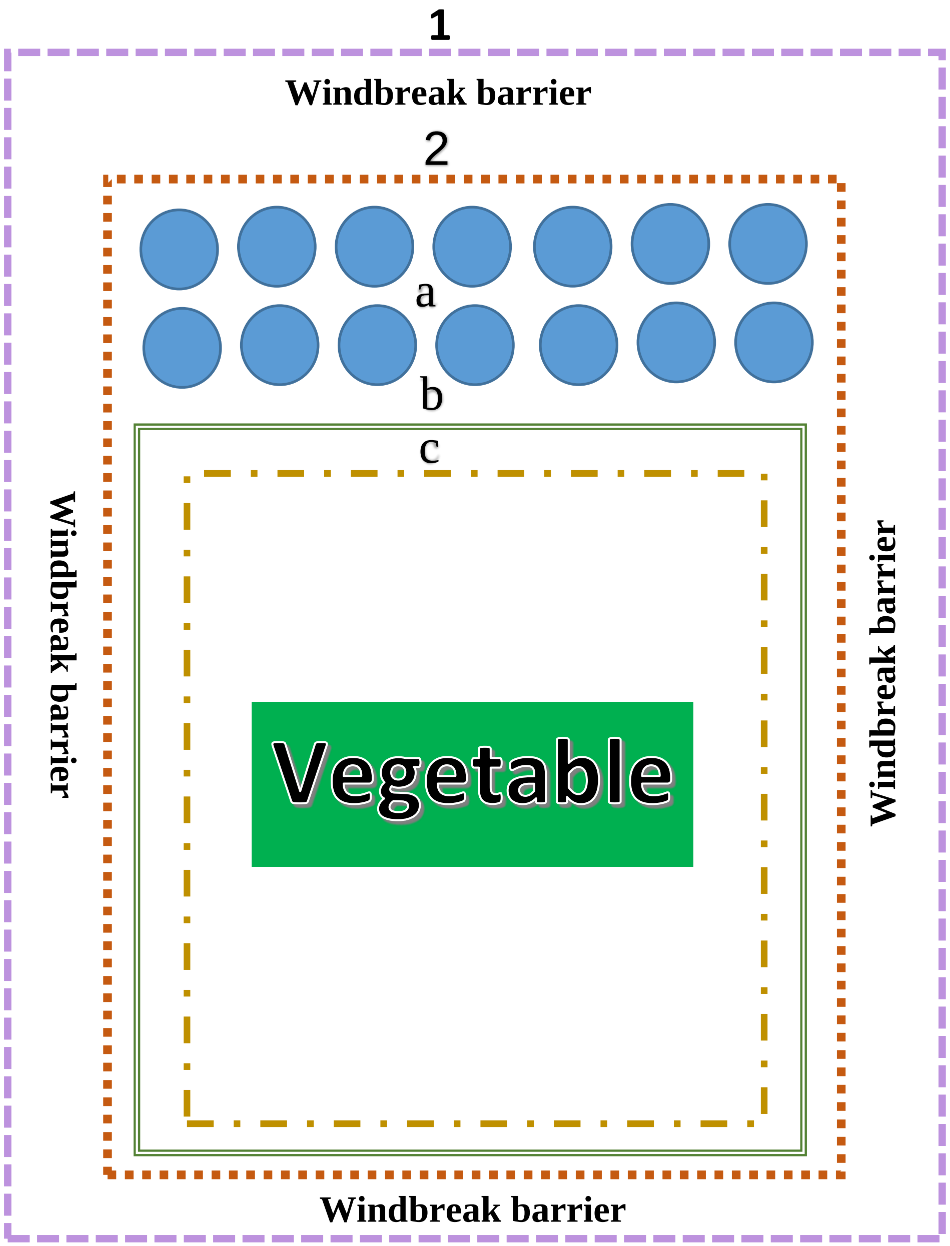

Figure 1. Integrated sustainable production system (without scale). Drawing own design

1. First stratum as a windbreak barrier of trees with an average height of 10 m; some species may be: rosy trumpet tree (*Tabebuia rosea*), cypress (*Cupresuss spp*), cottonwood (*Populus spp*), and barcino (*Cordia spp*).

2. Second stratum is a barrier of trees with an average height of 5 m; these can be citrus (*Citrus spp*), mango (*Mangifera spp*), mesquite (*Prosopis spp*), and acacia (*Acacia spp*)

a: Cultivation of tilapia (*Oreochromis niloticus*) in an open system to irrigate the entire agroforestry system with surplus water from water replacement.

b: Barrier of anti-pest plants or shrubs: basil (*Ocimum spp*), lavender (*Lavandula spp*), citronella (*Cymbopogon spp*), and sage (*Salvia spp*).

c: Organic agricultural crops (Vegetables)

Notes:

- The entire premises have common grass (Cynodon spp).
- Barriers 1 and 2 can be fenced with barbed wire and can be used for raising sheep (*Ovis spp*).
- In addition, apiaries, and hummingbird nests (*Colibri spp*) can be implemented to promote pollination in the area.

To successfully develop this activity, it is essential to carry out training in agricultural and forestry practices in the region combined with the criteria used by local farmers without creating conflict in social, cultural and/or economic aspects. Agroecology, as the basis of environmental education, generates transformations in soil management, ensuring suitable scenarios that maintain productive capacity (León; Acevedo, 2021). Additional factors must be balanced to avoid competition among all species (Beer et al., 2003); these factors include sources of water to maximize its availability, nutrients, and light.

Within the environmental education programme, it is very important to consider the agro-ecological requirements of the site, such as plant characteristics, soil preparation, planting seasons, planting and density systems, design, and layout of the production system (Martínez; Padrón, 2009). The target market to which the products are directed must also be very clear given the functional classification of trees based on the use product in agroforestry systems, such as timber trees, service trees, fruit trees, fodder trees, firewood, and charcoal trees (Beer et al., 2003). In the environmental education program, students should be instructed to design a well-planned integrated system. Windbreaks should not be considered simple rows of trees or bushes of different heights arranged in the opposite direction to the wind direction but as preventive systems against the loss of soil fertility due to wind erosion (Amargos, 2015). Moreover, windbreaks can also be viable as sources of fruit and bee keeping, promoting sustainable agricultural production with benefits to both biodiversity and landscape (Mekonnen, 2016). The following species are considered ideal for this purpose: common poplar (*Populus x canadensis*) and columnar poplar (*Populus nigra 'Afghanica'*), which are the most effective due to their growth rate, environmental tolerance, and low costs (Hansen et al., 2022).

Environmental training programs carried out in Kyrgyzstan, Central Asia, demonstrate the implementation of agroecological production systems with the integration of rows of poplar trees (*Populus nigra* var. *pyramidalis*) as windbreaks protecting cotton (*Gossypium hirsutum* L), corn (*Zea mays* L), and rice (*Oryza sativa* L), where crops achieve higher production rates with a more efficient use of water than in traditional agricultural systems (Thevs et al., 2021).

In training programs on integrated agricultural production systems with the use of living barriers as a strategic potential for landscape restoration, three factors are considered: a) the species must be native to the area, since they have better survival and development under local environmental conditions, b) adequate spatial configuration of the galleries, since these systems can act as structures that can retain the soil, favor the formation of terraces, and reduce surface runoff, in addition to favoring infiltration in low-lying areas, and c) adequate management (irrigation, pruning) to promote greater survival and development by mitigating the stress to which these living barriers are naturally subjected (12). On the other hand, wind erosion rates are determined by the following factors: a) soil classification, b) climatic conditions of the site, c) the windward disposition of the terrain, d) the amount and type of vegetation cover, and e) terrain dimensions (Brandle et al., 2009).

The importance of education on the benefits of this system makes it very versatile; for example, in very cold places, windbreaks provide valuable protection in autumn and winter by reducing soil erosion, abrasion, and desiccation of crops due to low temperatures and snow (Quam et al., 1999). On the other hand, in temperate to tropical zones, living barriers favor the creation of microclimates by reducing wind speed, achieving heat exchange in the form of a balance in radiation, water vapor and carbon dioxide between the soil, vegetation and atmosphere (Golberg et al., sf). Windbreaks are key structural elements in the rural environment and influence the functionality of landscapes in multiple ways, for example, the strategic use of green curtains for odor mitigation in livestock production (Brandle et al., 2009). Vargas (2020) carried out an investigation with living barriers using elderberry trees (*Sambucus nigra L.*) with a barrier distance between trees of 5 m and a distance between rows of 10 m to mitigate the effects of odors, insects, and noise from the development of pig farming activities. Thus, the effectiveness of living barriers in counteracting harmful effects on the human population in the vicinity of such farms was confirmed.

Another benefit of these techniques, which makes their promotion very necessary, is the positive effect they have against loud sounds. This has been investigated mainly in urban areas, where it was observed that there is a significant reduction in noise (>40 dB) thanks to the implementation of broadleaf shrub barriers in combination with coniferous trees (50 to 100 m) (Karbalaei et al., 2015). In other areas, such as cemeteries, a windbreak curtain of native species can be placed around the periphery (Higgins, 2013), as it minimizes the presence of odors and floating particles. These windbreak curtains are also beneficial in the sense that they have the capability of regulating temperature by capturing carbon dioxide (CO_2) to transform it into oxygen O_2 (Dueñas; Villa, 2019). It is very common that cypress trees (*Cupressus sempervirens*) are used in such places since they are long-lived, suitable for almost any climate and soil, present a beautiful landscape and can reach up to 30 m in height (Gutiérrez, 2005). An additional strategy that is highly recommended in these funeral gardens or cemeteries is to promote the development of microorganisms such as *Mycorrhizae* and *Azospirillum spp.* as nitrogen-fixing species and stimulants of plant growth (Dueñas; Villa, 2019).

An evaluation of the capacity to retain atmospheric dust particles was implemented using four tree species, bottle tree (*Brachychiton populneus*), oak (*Quercus ilex* subsp. *Ilex*), olive (*Olea europaea*) and nettle tree (*Celtis australis*) in Valencia, Spain, due to the high atmospheric pollution in urban areas. The capacity to retain atmospheric dust varied significantly among species, with oak having the highest rate of particulate matter capture. This is probably because the species is evergreen and has an elevated abundance of trichomes (a variety of villi) on the underside of its leaves (Ferriol et al., 2014). The results of this investigation are encouraging for the implementation of such environmental strategies in all cities of the world with native species that have the aforementioned characteristics. Moreover, while the use of crop-dusting on traditional agricultural crops continues to be used, it is not the most effective, as only 1% of the product supplied fulfills its purpose. Most (99%) is lost by wind action or seepage to the subsoil, a situation that affects the environment with known contamination factors (Bejarano, 2017). One mitigation strategy against this environmental impact is the use of plant galleries, as they buffer the harmful effect of atmospheric pollution and are capable of capturing particles down to 2.5 μm (microns) through different mechanisms. One of these is the direct interception of floating particles through the stomata in their leaves, improving air quality (Mănescu et al., 2015; Hansen et al., 2022). The nature of the particles not only involves pesticides, but they may also carry suspended colloids (PM) as a complex mixture of chemicals and/or biological elements, such as metals, salts, and carbonaceous materials. In addition, they can also be volatile organic compounds (VOCs), polycyclic aromatic hydrocarbons (PAHs), and endotoxins (Billet et al., 2007).

In recent years, as an alternative to mitigate air pollution and the challenges of climate change, the innovation of green roofs, vertical gardens and organic hydroponic agriculture has been implemented in urban areas, which has efficiently improved air quality in European cities (Pava, 2020; Köhler; Kaiser, 2021).

Environmental education has been implemented in developed countries at all school levels for decades, which has generated changes in their production and environmental paradigms. However, in Mexico, this is not the case since traditional agricultural production practices are dogmas fostered by the corruption of large companies and the government.

It is expected that by 2023, the agro-food sector in Mexico will be considered a development priority, as stated by the National Agricultural Council (CNA) in its outlook for the Mexican rural area. The ongoing conflict with environmental protection is not encouraging, which is why it is essential to apply environmental education at all levels and to extend it into production chains. At the same time, the National Development Plan (2019 to 2024) must be complied with in environmental issues or at least put on track and not have it remain in the inkwell of good intentions and become demagoguery.

Undoubtedly, ensuring food for the population is a priority for the Mexican government, but this must be done under new sustainable production schemes and curricula, for which it is necessary to establish adequate and innovative public and private policies that truly guarantee and execute these programs.

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Index

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