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Agroecological and sustainable management of school gardens

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SUMMARY
School gardens serve as environments for learning about various topics, including agroecological cultivation, in contrast to traditional agriculture. From this perspective, a range of tools can aid in managing pests and diseases, thereby minimizing crop losses and providing alternatives to agrochemicals. This study aimed to conduct a comprehensive literature review on diverse strategies for the agroecological management of vegetables and to examine existing practices in school gardens. The goal was to propose alternative approaches for the management of arthropods and pathogenic microorganisms. The methodology involved reviewing educational materials and scientific publications addressing the ecological and sustainable management of vegetable gardens, complemented by the creation of tables for analytical and comparative purposes. The results demonstrated the availability of numerous techniques and recommendations for pest and disease management, showing promising outcomes. Additionally, some of these strategies have already been successfully implemented in school gardens. Consequently, the adoption of various agroecological tools can significantly enhance both the quantity and quality of vegetables produced in schools, fostering environmental awareness and encouraging the appreciation of ancestral knowledge integral to garden maintenance.

KEYWORDS: Agroecology. Environmental Education. Sustainability.

1 INTRODUCTION

Conventional agriculture promotes increased productivity using strategies that heavily rely on human intervention, such as intensive irrigation, mechanization, and widespread application of agrochemicals (LOVATTO et al., 2012; BECKER; SILVA, 2021). However, the use of agricultural pesticides reduces biodiversity by eliminating natural predators and beneficial microorganisms, selecting for resistant pathogens, causing harm to both animal and human health, in addition to contaminating the water, soil, and food sources (BOHM et al., 2017; ZANUNCIO JUNIOR et al., 2018).

The focus of this profit-driven agriculture disregards ecological dimensions and specificities of natural environments, resulting in imbalances and triggering disease outbreaks and pest proliferation (LOPES et al., 2016; PEREZ-ALVAREZ et al., 2019). In this perspective, the agroecological management of agricultural production requires a paradigm shift by adopting sustainable production systems with gradual changes. These changes include optimizing and rationalizing the use of fertilizers and pesticides, replacing chemical inputs with biological or alternative inputs, restructuring the production system, and establishing a producer–consumer relationship in determining agri-food priorities (GLIESSMAN, 2000; MICHEREFF FILHO et al., 2013; STRATE, 2019; BECKER; SILVA, 2021).

The control of pests and diseases in agroecological cultivation presupposes the use of various strategies that enable both good agricultural productivity and the maintenance of balance in agroecosystems, with minimal human intervention. This approach is based on natural and self-sustaining biological processes (PEREZ-ALVAREZ et al., 2019). Thus, preserving agrobiodiversity, coupled with proper soil and natural resource management, provides suitable conditions for pest and disease control affecting the majority of plants in traditional crops. It is worth noting, however, that no single strategy operates in isolation, and only a comprehensive and systemic approach allows insects, microorganisms, and plants to coexist in balance, without population increases triggered by improper environmental management (LOPES et al., 2016; ZANUNCIO JUNIOR et al., 2018). Therefore, the agroecological system of pest and disease management should focus on understanding the environment and preventing

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environmental disorders and imbalances to subsequently control populations of organisms harmful to crops (VIANNA JUNIOR, 2015).

2 OBJECTIVES

The present study aimed to perform a bibliographic review on different techniques and recommendations for the agroecological management of pests and diseases in vegetable gardens. Furthermore, it sought to review the existing literature for strategies already being implemented in school gardens, with the aim of proposing sustainable alternatives for their management.

3 METHODOLOGY

The execution of the present work was divided into three phases, with the first two being conducted through exploratory research with a qualitative approach, carried out between October and December 2021.

The first phase involved a bibliographic review of alternative and agroecological methods for managing pests and diseases in vegetables found in books and handbooks published within the last 10 years. The search was conducted on the Google Scholar and CAPES Journals databases, as well as on the websites of research and rural extension institutions (Epagri and Embrapa) and in the Agroecological Files of the Ministry of Agriculture, Livestock and Supply (MAPA). Data obtained were used to construct tables, identifying the target pests and pathogens for each strategy.

The second phase involved research of the literature on databases such as Google Scholar, ResearchGate, and Scielo, for scientific articles and abstracts, using search terms like "school gardens", "agroecological management", and "sustainable management". The search was limited to works developed and published in the country within the last five years, with refinement to exclude works that did not address the relevant topic. The data obtained were used to create a table listing the strategies for agroecological management of school gardens addressed by the authors.

Finally, in the third phase, a comparative analysis of methodologies that can be used in the management of school gardens was carried out to complement and add new knowledge to the management of these gardens. This aims to provide new tools and support for the maintenance of a sustainable agricultural model, ensuring the production of safe and healthy food.

4 RESULTS

4.1 First phase

This systematic review indicated the existence of several studies addressing the use of agroecological management strategies in domestic and urban gardens, with a predominance of recommendations for pest control, such as insects and mites. It is worth noting that pest

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control minimizes the occurrence of diseases, since arthropods are involved in viral disease transmission (BETTIOL; MORANDI, 2007; SILVA et al., 2019) and can generate entry points for the attack of various pathogens (BERNARDI et al., 2015). Furthermore, a convergence among various studies has been observed regarding the use of techniques for pest control, as can be seen in Table 1.

Table 1 – Agroecological strategies for controlling arthropod-pests according to the literature (2011-2021)

Type of control	Strategies	Targets	References
Traps	Gourd bait	Slugs, snails, and caterpillars	Branco and Liz (2009)
	Detergent bait	Soil insects	MAPA (2016)*
	Molasses + grape, peach, orange, and guava juice bait	Fruit flies	MAPA (2016)
	Sesame + neem oil + wheat flour bait	Leafcutter ants	MAPA (2016)
	Adhesive blue plates or strips	Thrips	Azevedo Filho and Tivelli (2017)
	Adhesive yellow plates or strips	Aphids, bugs, thrips, and flies	Azevedo Filho and Tivelli (2017)
	Containers with coarse salt and chayote	Slugs and snails	Branco and Liz (2009)
Alternative insecticides	Quicklime	Leafcutter ants	MAPA (2016)
	Lime sulfur solution	Mites, scale insects, and sucking insects	Azevedo Filho and Tivelli (2017) MAPA (2016)
	Eggshell	Leafcutter ants	MAPA (2016)
	Ash	Leafcutter ants	MAPA (2016)
	Ash + milk + lime or milk + wheat flour or ash + lime	Mites and aphids	Anacleto et al. (2017) Azevedo Filho and Tivelli (2017)
	Detergent or neutral soap	Mites, scale insects, and aphids	Azevedo Filho and Tivelli (2017) MAPA (2016)
	Manure + molasses or brown sugar	Leafcutter ants	MAPA (2016)
	Bone or wheat flour meal	Leafcutter ants	MAPA (2016)
	Mineral oil + kerosene	Scale insects	Branco and Liz (2009)
	Soap + alcohol + tobacco	Aphids and caterpillars	MAPA (2016)
	Charcoal powder	Leafcutter ants	MAPA (2016)
	Soap + ash	Mites	MAPA (2016)
	Salt + wheat flour	General insects	MAPA (2016)
	Salt + vinegar + soap	Aphids and caterpillars	MAPA (2016)
	Silica	Mites	Azevedo Filho and Tivelli (2017)
Animal-based insecticides	Caterpillar solution	Caterpillars	MAPA (2016)
	Beetles solution	Beetles	Anacleto et al. (2017)
Plant-based insecticides	Rosemary	Butterflies	MAPA (2016)
	Garlic, garlic/coconut soap/mineral oil	Borers, mites, scale insects, and aphids	Azevedo Filho and Tivelli (2017) MAPA (2016)
	White leadtree	Leafcutter ants	Anacleto et al. (2017) MAPA (2016)
	Rue	General insects	Anacleto et al. (2017) MAPA (2016)
	Bougainvillea or primrose	Thrips	MAPA (2016)

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Type of control	Strategies	Targets	References
	Horsetail	Aphids and mites	MAPA (2016)
	Onion and garlic	Aphids and whiteflies	MAPA (2016)
	Paradise tree	Grasshoppers, aphids, scale insects, and beetles	Anacleto et al. (2017)
	Comfrey	Aphids	Anacleto et al. (2017)
	Marigold	Mites and caterpillars	Anacleto et al. (2017)
	Tobacco or tobacco + pepper	Aphids, caterpillars, lice, beetles, and scale insects	Anacleto et al. (2017) Jorge et al. (2012)
	Sunflower	General insects	MAPA (2016)
	Mint	General insects	MAPA (2016)
	Mugwort	General insects	Anacleto et al. (2017)
	Basil	Butterflies, moths, and ants	MAPA (2016)
	Castor bean	Leafcutter ants	MAPA (2016)
	Neem oil	Caterpillars and grasshoppers	Anacleto et al. (2017) MAPA (2016)
	Neem oil + soap or ash	Leafminers, whiteflies, moths, and caterpillars	MAPA (2016)
	Pepper (cumari, chili, red, and black)	General insects	Anacleto et al. (2017) Azevedo Filho and Tivelli (2017) MAPA (2016)
	Sage	Moths	MAPA (2016)
	Fern	Mites and aphids	Anacleto et al. (2017) MAPA (2016)
	Sisal	Leafcutter ants	MAPA (2016)
	Timbó (roots)	General insects	Anacleto et al. (2017)
	Nettle	Aphids and caterpillars	Anacleto et al. (2017) MAPA (2016)
Biological control (entomopathogens)	*Bacillus thuringiensis*	Caterpillars	Branco and Liz (2009)
	Beauveria bassiana	General insects	Azevedo Filho and Tivelli (2017)
	Metarhizium anisopliae	General insects	Azevedo Filho and Tivelli (2017)
Biological control (entomophages)	Predatory mites	Mites	Azevedo Filho and Tivelli (2017)
	Natural enemies (ladybugs, lacewings, and wasps)	General insects	MAPA (2016) Vianna Junior (2015)
Attractive plants	Sweet potato	Leafcutter ants	MAPA (2016)
	Sugarcane	Leafcutter ants	MAPA (2016)
	Black sesame	Leafcutter ants	Anacleto et al. (2017)
	Cassava	Leafcutter ants	MAPA (2016)
Repellent plants	Yellow alamanda	Aphids	MAPA (2016)
	Rosemary	Butterflies	MAPA (2016)
	Garlic	General insects	MAPA (2016)
	Rue	Caterpillars and aphids	MAPA (2016)
	Marigold	General insects	MAPA (2016)
	Chamomile	General insects	MAPA (2016)
	Paradise tree	Aphids and grasshoppers	MAPA (2016)
	Citronella	General insects	MAPA (2016)
	Cilantro	Caterpillars, mites, and aphids	MAPA (2016)
	Comfrey	General insects	MAPA (2016)
	Clove and geranium	General insects	MAPA (2016)

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Type of control	Strategies	Targets	References
	Mint	Ants, moths, and butterflies	Anacleto et al. (2017) MAPA (2016)
	Leucaena	Leafcutter ants	MAPA (2016)
	Castor bean	Mosquitoes	MAPA (2016)
	Basil	General insects	MAPA (2016)
	Mastruz	Aphids and insects	MAPA (2016)
	Sage	Moths	MAPA (2016)
	Tomate	Aphids	MAPA (2016)
	Nettle	Aphids	MAPA (2016)
Cultural control	Organic fertilization Green manure and mulching Species association Elimination of host plants and crop remains Maintenance of spontaneous vegetation (habitat for natural enemies) Companion plants Windbreaks Crop rotation	General insects	Azevedo Filho and Tivelli (2017) Vianna Junior (2015) Corrêa Junior and Scheffer (2013) Pitarello and Marba (2012) Anjos et al. (2009) Branco and Liz (2009) Resende and Madeira (2009)

Source: Prepared by the author (2023).
*MAPA = Ministry of Agriculture, Livestock and Supply: Agroecological Files.

The present survey allowed for the identification of the most recommended tools in studies for pest management, focusing on preventive strategies and population monitoring. This approach ensures that control measures are only implemented upon reaching the economic damage threshold, allowing for the maintenance of natural balance and the implementation of different strategies to minimize crop damage (VIANNA JUNIOR, 2015; LOPES et al., 2016; ZANUNCIO JUNIOR et al., 2018). In this way, the pest management and control methods listed in this review were grouped into eight classes, as described in Table 1, to facilitate data analysis and understanding (traps, alternative insecticides, animal-based insecticides, plant-based insecticides, biological control, attractive plants, repellent plants, and cultural control).

The use of traps for sampling and monitoring arthropod populations facilitates the assessment of infestation incidence and severity (LOPES et al., 2016). It also helps determine the right timing and method for pest management (MICHEREFF FILHO et al., 2013). This study reported recommendations for different types of baits and devices for insect trapping, which can be easily used in school gardens due to their low cost and the possibility of involving students in their construction (Table 1).

Alternative insecticides are an environmentally-friendly option for pest control. They are biodegradable, less persistent, can be produced on the farm, and do not leave hazardous residues in vegetables and fruits, thereby contributing to food safety and sustainability (LOPES et al., 2016). Examples of alternative insecticides include milk, lime, ash, detergent, soap, mineral oil, eggshell, charcoal powder, among others (ANACLETO et al., 2017; AZEVEDO FILHO; TIVELLI, 2017). Plant-based insecticides encompass a wide range of plant extracts obtained from species such as rosemary, garlic, rue, horsetail, marigold, among others (Table 1).

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However, many active ingredients of plant origin, derived from the secondary metabolism of plants, are also notably used in the production of chemical insecticides. Thus, they should be judiciously used to prevent the development of resistance or toxicity to various organisms (VIANNA JUNIOR, 2015). Therefore, application of plant extracts should only be considered when other management strategies prove ineffective (VIANNA JUNIOR, 2015). Furthermore, animal-based insecticides with repellent action, derived from the pests themselves, are available (ANACLETO et al., 2017).

Biological control involves the use of entomopathogenic microorganisms that cause diseases in insects or natural entomophagous enemies that feed on insects (predation) or use the insect as a host for oviposition, leading to its death (parasitism) (MICHEREFF FILHO et al., 2013; SILVA et al., 2020). In balanced environments, natural enemies help maintain pest populations at tolerable levels, preventing a significant damage to crops. However, conventional agriculture, with its intensive use of agrochemicals and monoculture practices, reduces agrobiodiversity, thereby favoring pest proliferation (SILVA, 2013). Notable among the natural enemies is the application of entomopathogenic fungi and bacteria, along with mites, ladybugs, green lacewings, and wasps, as demonstrated in Table 1.

Some repellent plants produce metabolites that discourage insects and pest mites, preventing attacks on the crops of interest (ZANUNCIO JUNIOR et al., 2018). These plants include rosemary, garlic, citronella, basil, nettle, among others (Table 1). Secondary metabolites are not essential for the survival and are synthesized as mechanisms of plant defense against herbivory, attacks of pathogenic agents, and pests in general (ROCKENBACH et al., 2018; BORGES; AMORIM, 2020). However, other plants have bioactive compounds that attract pollinating insects and natural enemies. In this case, plants are generally used in refuge areas to prevent the entry of insects and mites into the crops (LOVATTO et al., 2012).

Cultural control encompasses the use of various agroecological strategies to minimize the occurrence of pest in the cultivation area, aiming to preserve the natural balance in ecosystems. According to the trophobiosis theory, plants under stressful environmental and nutritional conditions are more susceptible to pest attacks, as they tend to provide higher levels of readily assimilable amino acids. As a consequence, maintaining natural biodiversity helps inhibit the outbreak in pest populations (ZANUNCIO JUNIOR et al., 2018). The literature reports a series of measures, including organic fertilization, green manure, mulching, association between different plant species, elimination of host plants for pests, manual insect removal, crop residue elimination, irrigation management, spontaneous vegetation maintenance, healthy seedling use, companion plant cultivation, crop rotation, windbreaks, and fallow (Table 1).

Organic fertilization, using animal manure, biofertilizers, compost, or vermicompost-derived fertilizers, helps improve soil fertility in agroecological systems, allowing the replacement of chemical inputs by the alternative ones (ALMEIDA et al., 2019; MEINEN JUNIOR et al., 2020). In addition, the use of green manure, which involves intercropping of grasses or legumes, not only makes the soil richer in nutrients but also enables the maintenance of its natural biodiversity, serving as a habitat for natural enemies of pests (LOPES et al., 2016).

Intercropping of plants from different species inhibits the emergence and proliferation of pests, as insects and mites can be specialists, directing their attacks to specific

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crops at the expense of others (ZANUNCIO JUNIOR et al., 2018), making it difficult for them to access the preferred crop (ALMEIDA et al., 2019). While intercropping of antagonist plants can trigger negative and harmful allelopathic interactions, companion planting results in beneficial effects to the associated species (MARIANI; HENKES, 2015).

Moreover, agricultural practices focused on preserving natural vegetation, coupled with the implementation of windbreaks (Table 1), play a role in reducing water loss due to evapotranspiration in crops, mitigating plant tissue injuries, and preventing erosion caused by winds and rains. An additional advantage is the incorporation of mulch from these plants into the soil, thereby supporting the development of the natural biota (LOPES et al., 2016).

Other strategies, such as manual insect removal, host plant management, and crop residue removal (Table 1) promote the control of arthropod population levels, as pests can persist in plant residues during periods between production cycles, infesting crops in subsequent harvests (ZANUNCIO JUNIOR et al., 2018; ALMEIDA et al., 2019). In addition, agricultural practices, including planting healthy and pest-free seedlings, crop rotation, and proper irrigation management (Table 1) have positive effects, being essential for agroecological pest management (SOUZA; RESENDE, 2014). Crop rotation improves soil fertility, reduces erosive processes, and controls pest populations by alternating different crops over time (ALMEIDA et al., 2019). On the other hand, irrigation management allows controlling water availability to inhibit pest proliferation (ZANUNCIO JUNIOR et al., 2018).

Vegetable gardens and other agricultural crops can suffer losses and damages not only from pests, but also from pathogenic agents. Biotic diseases result from continuous modifications or alterations in plant physiology that affect the growth and development of plants. They are caused by viruses, fungi, bacteria, protozoa, and nematodes, requiring distinct control strategies for each causal agent (BETTIOL; MORANDI, 2007; VIANNA JUNIOR, 2015). The occurrence of diseases requires the presence of a set of favorable aspects: a susceptible host, the presence of a pathogenic agent, and favorable environmental conditions. As a result, to promote disease control, it is necessary to prevent any of these factors from being conducive to the onset of the infectious process (BETTIOL; MORANDI, 2007).

Various strategies for controlling diseases in vegetables were compiled and classified into three categories: alternative control, biological control, and cultural control (Table 2). Alternative control primarily involves strategies, such as the application of mixtures and syrups, plant extracts, and other products such as hot water, baking soda, a mixture of milk and baking soda, a mixture of soap, kerosene, and copper sulfate, algae extract, fertilizers, and cow urine (ANACLETO et al., 2017; AZEVEDO FILHO; TIVELLI, 2017).

Table 2 – Agroecological strategies for controlling plant diseases according to the literature (2011-2021)

Type of control	Strategies	Products	Targets	References
Alternative control	Mixtures and syrups	Bordeaux mixture	Fungi and bacteria	Azevedo Filho and Tivelli (2017) MAPA (2016)*
		Copper sulfate solution	Fungi	MAPA (2016)
		Sulfocalcic solution	Fungi	Anacleto et al. (2017) Azevedo Filho and Tivelli (2017)
		Viçosa solution	Fungi and	Anacleto et al. (2017)

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Type of control	Strategies	Products	Targets	References
			bacteria	
	Plant extracts	Garlic or garlic + soap + mineral oil	Fungi and bacteria	MAPA (2016) Bettiol and Morandi (2007)
		Chamomile	Fungi and bacteria	Anacleto et al. (2017) MAPA (2016)
		Nasturtium	Nematodes	MAPA (2016)
		Horsetail	Fungi and bacteria	Anacleto et al. (2017) MAPA (2016)
		Onion or onion + garlic	Fungi and bacteria	MAPA (2016) Bettiol and Morandi (2007)
		Paradise tree	Fungi	Bettiol and Morandi (2007)
		Clove	Fungi	Anacleto et al. (2017)
		Marigold	Nematodes	MAPA (2016) Corrêa Junior and Scheffer (2013)
		Eucalyptus	Fungi	Bettiol and Morandi (2007)
		Tobacco	Fungi	Jorge et al. (2012) Bettiol and Morandi (2007)
		Papaya tree	Fungi	Bettiol and Morandi (2007)
		Bitter cassava	Nematodes	MAPA (2016)
		Cassava	Nematodes	MAPA (2016)
		Mint	Fungi	Bettiol and Morandi (2007)
		Neem	Fungi	Bettiol and Morandi (2007)
	Other products	Hot water	Fungi and bacteria	MAPA (2016)
		Baking soda	Fungi	MAPA (2016)
		Seaweed extract	Fungi and bacteria	Azevedo Filho and Tivelli (2017)
		Resistance-inducing fertilizers (phosphites, amino acids)	Fungi and bacteria	Azevedo Filho and Tivelli (2017)
		Milk or whey or milk + baking soda	Fungi	Anacleto et al. (2017) MAPA (2016)
		Cow urine	Fungi	Bettiol and Morandi (2007)
Biological control	Fungi	*Trichoderma*	Fungi	Azevedo Filho and Tivelli (2017) Bettiol and Morandi (2007)
Cultural control	Intercropping or crop diversification Balanced nutrition and organic fertilization Removal of crop residues Vector elimination Proper irrigation Healthy seedlings Crop rotation Use of mulch		Fungi and bacteria	Azevedo Filho and Tivelli (2017) Vianna Junior (2015) Corrêa Junior and Scheffer (2013) Jorge et al. (2012) Pitarello and Marba (2012) Lopes et al. (2009) Resende and Madeira (2009)

Source: Prepared by the author (2023).
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The utilization of alternative products provides several benefits, such as ease of preparation and cost-effectiveness, as many of these materials can be readily sourced or

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cultivated within the school gardens. Furthermore, these products exhibit low toxicity for those applying them and have a reduced potential for contaminating the vegetables with chemical residues that may be detrimental to human health and the environment (MARIANI; HENKES, 2015).

On the other hand, biological control involves implementing measures that encourage the proliferation of beneficial natural microorganisms (natural biological control) or introducing new organisms to inhibit pathogens and enable sustainable agricultural cultivation (applied biological control) (PEREZ-ALVAREZ et al., 2019; SILVA et al., 2019). This study delves into the utilization of fungi as biocontrol agents for controlling fungal diseases in vegetables was investigated. These microorganisms suppress the growth of phytopathogens through competition for space and nutrients, synthesis of antifungal substances, production of lytic enzymes, and induction of resistance mechanisms in plants (CHEN et al., 2016; KEJELA et al., 2017).

Furthermore, cultural practices such as intercropping, crop diversification, balanced nutrition and organic fertilization, removal of crop residues, vector elimination, use of healthy seedlings, crop rotation, and the use of straw, also mentioned in pest control, were described as strategies for prophylaxis of diseases in vegetables, including stimulating natural biological control, through the preservation of native antagonistic microorganisms (SILVA et al., 2020).

4.2 Second phase

In the second stage of this study, different agroecological strategies adopted in Brazilian school gardens for pest and disease control were surveyed. The literature review from the past five years resulted in a list of 18 works, including scientific articles and abstracts. These studies showed the use of agroecological techniques, either individually or in combination, with a preventive focus mainly based on cultural management (Table 3).

Table 3 – Agroecological strategies adopted in Brazilian school gardens according to the literature (2016-2021)

Adopted strategies	References
Organic fertilization and green manure, cover crops, biofertilizers, biodiversity islands, maintenance of spontaneous plants, mulching, fallow, windbreaks, soil microbiota restoration, and crop rotation	Lopes et al. (2016)
Material reuse	Silva et al. (2016)
Organic fertilization	Bohm et al. (2017)
Organic fertilization and material reuse	Cardoso et al. (2017)
Organic fertilization and alternative pest and disease control	Pereira and Fernandes (2017)
Organic fertilization and use of PET bottles	Decarli and Fraga (2018)
Organic fertilization and use of PET bottles	Oliveira et al. (2018)
Organic fertilization and alternative pest and disease control	Sehn et al. (2018)
Alternative pest and disease control	Alves et al. (2019)
Organic fertilization, green manure, use of bioinsecticides for caterpillar control (alternative pest control)	Fialho et al. (2019)
Organic fertilization	Garberlini Neto and Silva (2019)
Organic fertilization, intercropping, and crop rotation	Ribeiro et al. (2019)
Organic fertilization and green manure, mulch, pest and disease control with plant extracts, insect traps, soil solarization, use of PET bottles, and other materials for	Botrel et al. (2020)

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Adopted strategies	References
bed construction	
Organic fertilization, research on natural methods for pest and disease control	Cancelier et al. (2020)
Green manure (vegetative ground cover)	Layoun and Zanon (2020)
Organic fertilization (composting and manure), bioconstruction, crop consortium, heirloom seeds, and use of bamboo as shade net	Macêdo et al. (2020)
Organic fertilization	Silva et al. (2020)
Organic fertilization, mulch, uprooting of infested plants, crop rotation, pest control, repellent plants, attractive baits, manual insect picking, and windbreaks	Venzke (2020)

Source: Prepared by the author (2023).

The tools for agroecological management of school gardens, focusing on the control of pest arthropods and diseases, were grouped based on similarities into categories. The most frequently reported categories were organic fertilization (83.3% of the studies), alternative control (38.9%), material reuse (33.3%), green manure (22.2%), mulching (16.7%), crop rotation (16.7%), intercropping, traps, and windbreaks (11.1% each). Other topics mentioned in only one article out of the eighteen evaluated accounted for 5.6% collectively: uprooting of plants, bioconstruction, biofertilizer, insect picking, biodiversity islands, spontaneous plants, fallow, soil biota restoration, heirloom seeds, and soil solarization. Although 38.9% of the studies mentioned the use of alternative strategies for controlling pathogens and pests, only a subset of these studies (57.1%) described how these techniques were applied and which organisms were targeted.

4.3 Third phase

Taking into consideration the agroecological strategies employed in school gardens, it can be observed that the vast majority of schools use organic fertilization to improve soil fertility, thereby promoting better plant development and, at the same time, encouraging the preservation of the natural biota, which results in lower incidence of pests and diseases (PRIMAVESI, 2008). Additionally, the use of strategies for alternative pest and disease control was observed in several studies, as well as the reuse of materials in the construction of the beds.

Based on the strategies adopted in the gardens (Table 3), the management of school gardens can be enriched with additional preventive-focused methodologies, aiming at the preservation of local ecosystems (MICHEREFF FILHO et al., 2013), and the use of traditional knowledge for their sustainable management (ZANUNCIO JUNIOR et al., 2018). Many of these insights can be rediscovered and used to improve the quality of the produced vegetables. In this sense, the adoption of intercropping of different plant species, the preservation of spontaneous species, and the use of plants repellent to pests and attractive to natural enemies can significantly contribute to environmental balance and agroecological management of crops. Such strategies have low implementation costs and allow minimizing the incidence of harmful organisms to vegetables, and can be employed during the ecological transition process (MICHEREFF FILHO et al., 2013).

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Other methodologies such as the use of windbreaks on the borders to prevent the entry of new pests and diseases, the manual elimination of adult insects and infested vegetative material, as well as the monitoring of crops with traps and baits can be adopted to monitor the incidence and severity of pests and diseases on site, in order to propose alternative control strategies (ZANUNCIO JUNIOR et al., 2018). Furthermore, the different approaches raised in this study can minimize losses in vegetable production, without causing contamination of the environment and food with synthetic chemicals. In this way, it is possible to promote natural biological control by stimulating the development and proliferation of beneficial microorganisms and natural enemies.

5 CONCLUSIONS

This study successfully identified alternative methodologies described in the literature for the control of pest arthropods and phytopathogenic microorganisms. The adoption of these agroecological strategies in the management of school gardens does not require significant financial resources and promotes the production of safe and healthy food, which can be used in school meals.

Although some schools already use agroecology-inspired knowledge in their gardens, there is a wealth of information available in the literature that can contribute to improving the productivity and quality of vegetables, without causing adverse impacts on the environment and simultaneously promoting the preservation of soil and local biodiversity. Therefore, this work, along with future studies, may contribute to the development of educational materials focused on the sustainable management of urban and school gardens.

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