Insect Pest Management in Organic Farming System

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Abstract

Due to the regulations of organic farming, few options remain for organic farmers to manage pests and diseases in their crops compared to conventional farming. However, major pests could still be managed through manipulation of the agroecosystem processes in advantage of the crops and disadvantage of pests. The limited number of active plant protection substances authorized for use in organic farming can provide support to natural and biological control agents in suppression of pests and diseases. This chapter highlights the principles and strategies of crop protection in organic farming, the cultural practices adopted, the active substances allowed for use to suppress pests, and the impacts on faunal and floral biodiversity. A case study of organic date palm cultivation is discussed.

Keywords

organic farming

holistic approach

biopesticides

pest management

Chapter and author info

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1. Introduction

Organic agriculture is a holistic production system that sustains the health of soils, ecosystems, and people. It relies on ecological processes, biodiversity, and cycles adapted to local conditions rather than the use of inputs with adverse effects. Organic agriculture combines tradition, innovation, and science to benefit the shared environment and promote fair relationships and a good quality of life for all involved [1]. Holistic means near-closed nutrient and energy cycle system considering the whole farm as one organism [2]. Organic agriculture relies on a number of farming practices based on ecological cycles and aims at minimizing the environmental impact of the food industry, preserving the long-term sustainability of soil and reducing to a minimum use of nonrenewable resources [3]. Organic agriculture is both a philosophy and a system of farming aiming to produce food that is nutritious and uncontaminated with substances that could harm human health [4]. Organic farming benefits to the ecosystem include conservation of soil fertility, carbon dioxide storage, fossil fuel reduction, preserving landscape, and preservation of biodiversity [3].

Pest management in organic farming is achieved by using appropriate cropping techniques, biological control, and natural pesticides (mainly extracted from plant or animal origins). Weed control, the main problem for organic growers, can be managed through cultural practices including mechanic cultivation, mulching, and flaming. Organic farming is characterized by higher diversity of arthropod fauna and conservation of natural enemies than conventional agriculture [3, 5].

According to the IFOAM [1], organic agriculture is guided by four principles: health (soil, plant, animal, and human), ecology (living ecological systems and cycles), fairness (environment and life opportunities), and care (protect the health and well-being of current and future generations as well as the environment). The US Congress passed the organic food product act in 1990, while the European Union (EU) set up the first regulations on organic farming in 1991, and in the same year, the Codex Alimentarius Commission officially recognized organic agriculture. Gomiero et al. [3] gave more details on history of organic farming, total global areas, organic standards, and impact on the environment. The chapter deals with pest management in organic farming system with an example of organic date production as case study.

2. Principles and strategies of crop protection in organic farming system

Pest management in organic farming is a holistic (whole-farm) approach that largely depends on the ecological processes and biodiversity in the agroecosystem. Accordingly, most IPM tactics, principles, and components match with organic farming systems [6]. The goal of this strategy is to prevent pests from reaching economically damaging levels without causing risk to the environment. Successful IPM programs in organic farming may have the following components: (1) monitoring crops for pests, (2) accurately identifying pests, (3) developing economic thresholds, (4) implementing integrated pest control tactics, and (5) record keeping and evaluation.

The factors that render crop habitat unsuitable for pests and diseases include limitation of resources, competition, parasitism, and predation [7]. These factors play an important role in maintaining equilibrium of the agroecosystem and suppression of harmful pests. Faunal and floral diversities play a substantial role in pest and disease management in organic farming system [8, 9]. The four principles of pest management in organic farming system, namely, prevention, avoidance, monitoring, and suppression, will be discussed in this chapter with special reference to date palm as case study.

3. Differences between organic and conventional farming with respect to plant protection

Few options of plant protection substances are available for certified organic growers compared to conventional ones. Thus, they should capitalize on the natural processes and management of the ecosystem to control harmful organisms. Organic farms had a more diverse arthropod fauna, on average, than conventional farms. The average for five 30-second vacuum samples per farm was approximately 40 arthropod species in conventional tomato compared to 66 species in organic tomato fields. Additionally, natural enemies (parasitoids plus predators) were more abundant on organic farms [10]. Arthropod biodiversity, as measured by species richness, was, on average, one-third greater on organic farms than on conventional farms [10].

Under organic farming systems, the fundamental components and natural processes of ecosystems, such as soil organism activities, nutrient cycling, and species distribution and competition, are used directly and indirectly as farm management tools to prevent pest populations from reaching economically damaging levels. Soil fertility and crop nutrients are managed through tillage and cultivation practices, crop rotations, and cover crops and supplemented with manure, composts, crop waste material, and other allowed substances.

Soil-borne and root pathogens are usually found in low levels in organic farming as compared to conventional farming [11]. Pathogens such as *Pythium* spp., *Sclerotium rolfsii*, *Phytophthora* spp., and some *Fusarium* can survive on organic matter of the soil, in the absence of their hosts for long periods, and are thus difficult to be controlled with crop rotation. Additionally, airborne pathogens cannot be controlled with cultural practice such as crop rotation [12]. Powdery mildew and rust diseases (airborne) and insect pests such as aphids and whiteflies (sucking insects) are less serious in organic farming than in conventional farming due to lower nitrogen concentrations in foliar tissues or phloem of plants in the former compared with the latter [11]. Almost all pesticides available for organic farming have short residual effects and work through direct contact mode of action as compared to the persistent systemic pesticides used in conventional farming. Table 1 gives the main differences between organic and conventional farming with respect to soil fertility, biodiversity, and other criteria.

Organic farming (OF)	Conventional farming (CF)
Synthetic fertilizers and synthetic pesticides are not permitted	Synthetic fertilizers and synthetic pesticides are allowed
Genetically modified organisms (GMOs) are not allowed	GMOs can be used
Soils have higher water holding capacity than CF	Soils have less water holding capacity than OF
OF has larger floral and faunal biodiversity than CF (complex crop pattern)	CF has smaller biodiversity than OF (simple crop pattern)
The agricultural landscape is characterized by heterogeneity (multicultural system)	The agricultural landscape is characterized by homogeneity (monocultural system)
Minimizing the use of nonrenewable resources by recycling plant and animal waste into the soils (on-farm inputs)	Depends largely on nonrenewable resources (off-farm inputs)
OF is more sustainable than CF	CF is less sustainable compared to OF
Strictly regulated by international and national institutional bodies such as Codex Alimentarius and IFOAM	Not strictly regulated
Crop protection depends mainly on natural processes such as soil fertility, crop cycle, and biodiversity	Crop protection relies mainly on human intervention with synthetic chemicals

Organic farming (OF)	Conventional farming (CF)
(more preventive)	(more curative)

Table 1.
Fundamental differences between organic and conventional farming.

4. Crop protection practices in organic farming

Practices and tactics used in organic farming are based on the three management strategies, which include prevention, monitoring, and suppression. These practices will be intensively discussed in the following paragraphs:

4.1. Identification and monitoring of crop pests

Crop pests include insects, weed, plant pathogens, invertebrate, and vertebrate animals. Identification of insect pests and their natural enemies is an important step in any pest management program. Insect pests and natural enemies could be identified using keys and field guides or otherwise consulting an official identification bodies. Unlike insect pests, plant pathogens including fungi, bacteria, virus, and nematodes are difficult to identify in the field and may need laboratory diagnosis. However, signs of insect damage and symptoms of plant diseases may be easily distinguished in the field. Weeds could be easily identified using key and field guides.

Monitoring is the regular inspection or scouting of field crops for pests, including insects, pathogens, nematodes, and weeds, to determine their abundance and level of damage. It serves as an early warning system for the presence of pests and diseases providing information for decision-making regarding management action and evaluation of control methods. Insect pests can be monitored through visual observation, pheromone and light traps, sticky traps, water traps, yellow traps, sweep nets, beating trays, and pitfall traps. Scouting data are used to develop economic thresholds, a useful decision-making tool to start control action when a pest population reaches or exceeds the specified economic threshold.

4.2. Tactics used for pest prevention and suppression in organic farming

A successful integrated pest management (IPM) program in organic farming incorporates a variety of pest management tactics such as cultural, mechanical/physical, biological, and biopesticide (allowed for organic use) tactics individually or in combination. Each control tactic, discussed below, employs a different set of mechanisms for preventing and suppressing pest populations.

4.2.1. Cultural pest control

The goal of cultural control is to alter the environment, the condition of the host, or the behavior of the pest to prevent or suppress an infestation. It disrupts the normal relationship between the pest and the host and makes the pest less likely to survive, grow, or reproduce [13]. In agricultural crops, crop rotation, selection of crop plant varieties, timing of planting and harvesting, irrigation management, crop rotation, and use of trap crops help reduce populations of weeds, microorganisms, insects, mites, and other pests. These cultural practices are more preventive than curative and thus may require planning in advance [13, 14, 15]. The diversified habitat provides these parasites and predators with alternative food sources, shelter, and breeding sites [16]. Tillage can cause destruction of the insect or its overwintering chamber, removal of the protective cover, elimination of food plants, and disruption of the insect life cycle generally killing many of the insects through direct contact, starvation or exposure to predators, and weather [13]. The use of trap strip crops can control insect damage at the field edges and at the same time avail refuge and food for beneficial insects. Insect resistance is an important component of pest and disease management. Quality-based resistance can be induced in plants through management of nutrients and irrigation. Intercropping and biodiversity play an important role in pest management in organic farming [13].

4.2.2. Mechanical and physical pest control

One of the simplest methods of physical or mechanical pest control is handpicking insects or hand-pulling weeds. This method works best in those situations where the pests are visible and easily accessible [17]. Physical or mechanical disruption of pests also includes such methods as mowing, hoeing, flaming, soil solarization, tilling or cultivation, and washing [17]. Animals such as kangaroos cause damage by eating yellow dates; hence, fruit bunches are covered to protect them from such damage [18].

Devices that can be used to exclude insect pests from reaching crops in organic farming include, but not limited to, row covers, protective nets with varying mesh size according to the pest in question, and sticky paper collars that prevent crawling insects from climbing the trunks of trees. Water pressure sprays can be employed to dislodge insect pests such as aphids and mites from the plant surface. Insect vacuums, on the other hand, could be used to remove insects from plant surface and collect them into a collection box.

4.2.3. Biological pest control

Biological methods are the use of beneficial organisms that can be used in the field to reduce insect pest populations. Biological control is grouped into three categories: importation or classical biological control, which introduces pest's natural enemies to the locations where they do not occur naturally, augmentation involves the supplemental release of natural enemies, boosting the naturally occurring population, and conservation, which involves the conservation of existing natural enemies in the environment [19]. The role of beneficial species on pests is of relatively greater importance in organic agriculture than in conventional agriculture, because organic growers do not have recourse to highly potent insecticides (such as synthetic pyrethroids) with which to tackle major pest problems [13].

4.2.4. Biopesticide control

Biopesticides are characterized by having minimal or no risk to the environment, natural enemies, and nontarget organisms due to their mode of action, rapid degradation, and the small amounts applied to control pests. They are slow acting, have a relatively critical application times, and suppress rather than eliminate a pest population [20]. Biopesticides have limited field persistence and shorter shelf life and present no residue problems. Thus, they are approved for pest management in organic crops.

5. Plant protection products (PPPs) authorized in organic farming

The crop protection in organic farming is holistic, and, hence, it is extremely difficult to separate inputs as plant nutrients (fertilizers) and plant protectants (pesticides) [6]. Plant protection products authorized for use in organic farming differ among countries depending on the differences in crops, pests, and cropping systems, as well as regulations and standards adopted by these countries [21]. Organically approved pesticides fall into the following groups: biorational, inorganics, botanicals, microbial, oils, and soaps. The most widely used as insecticides are microorganisms, natural pyrethrins, rapeseed oil, and paraffin; the most widely used as fungicides are copper compounds, sulfur, and microorganisms. The rules of organic agriculture allow the use of unregistered products such as nettle slurry, which is used against aphids. It can be prepared on the farm or shared among farmers [21, 22].

The basic substance concept was introduced by the EU regulation 1107 in 2009. It was defined as substance not intendedly used for plant protection purposes; however, it can still be used in protection of plants either directly or as a diluent. According to this definition, substances used as foodstuff such as vinegar and sunflower oil can be used as plant protection [23]. The basic substances of plant and animal origin, which are used as foodstuff, can be legally used in crop protection in organic farming with the exception of being used as herbicides. These basic substances include chitosan hydrochloride, fructose, sucrose, *Salix* spp. cortex, and *Equisetum arvense* L. (field horsetail) which are used as elicitors of the plant self-defense mechanism. Sunflower oil, whey, and lecithins are used as fungicides, while vinegar is used as fungicide and bactericide, and *Urtica* sp. is used as insecticide, fungicide, and acaricide [21]. In organic farming, only active substances listed in the Commission Regulation (EC) No. 889/2008 (Table 2) can be used. New update is frequently being made by the EC to add or remove PPPs from the list.

Name of product	Purpose and specifications of use
Azadirachtin from the neem tree (*Azadirachta indica*)	
Beeswax	Used as protectant for treatment of cuts and wounds after pruning or in grafting
Plant oils	Used for control of small-bodied insects such as thrips, aphids, and whiteflies
Laminarin (from *Laminaria digitata*) or kelp or brown algae seaweed	A polysaccharide from the group of the glucans, used to protect plants against fungi and bacteria. Kelp should be grown according to the organic standards
Pheromones	Used only in traps and dispensers
Pyrethrins from the leaves of *Chrysanthemum cinerariaefolium*	Used as insecticide
Pyrethroids (only deltamethrin or lambdacyhalothrin)	Used only in traps with attractants or pheromones
Quassia from the plant *Quassia amara*	Only insecticide and repellent
Microorganisms, e.g., *Bacillus thuringiensis*, *Beauveria bassiana*, and *Metarhizium anisopliae*	Origin should not be GMOs
Spinosad from the soil bacterium *Saccharopolyspora spinosa*	Used as insecticide
Ethylene	Insecticidal fumigant against fruit flies
Paraffin oil	Used as insecticide

Name of product	Purpose and specifications of use
	against small-bodied insects
Fatty acids (soft soaps)	Insecticide against mite, thrips, and aphids
Lime sulfur (mixture of calcium hydroxide and sulfur)	Used as fungicide
Kieselgur (diatomaceous earth) from the hard-shelled diatom protist (chrysophytes)	Used as mechanical insecticide
Naturally occurring aluminum silicate (kaolin)	As insect repellent against a wide range of insects at a rate of 50 kg/ha
Calcium hydroxide	Used as fungicide
Sodium hypochlorite (bleach or as javel water). It is a disinfectant with numerous uses, and its effect is due to the chlorine	Used in seed treatment as viricide and bactericide
Sulfur	Used as broad-spectrum inorganic contact fungicide and acaricide
Copper compounds such as: copper hydroxide, copper oxychloride, copper oxide, tribasic copper sulfate, and Bordeaux mixture (copper sulfate and calcium hydroxide)	Used as fungicide and bactericide maximum of 6 kg copper per ha annually
Sheep fat (obtained from fatty sheep tissues by heat extraction and mixed with water to obtain an oily water emulsion)	A triglyceride consisting predominantly of glycerine esters of palmitic acid, stearic acid, and oleic acid. A repellent by smell against vertebrate pests such as deer and other game animals. It should

Name of product	Purpose and specifications of use
	not be applied to the edible parts of the crop
Quartz sand	Used as repellent against vertebrate pests

Table 2.

Plant protection products approved by the European Union (EU) for use in organic farming [24].

6. A case study of organic date palms

There are about 100 million date palms in the world mostly distributed in Asia and North Africa, producing 7.78 million ton of dates annually [25]. The international famous date palm cultivars include Medjool, Deglet Noor, Barhee, Halawy, Khalas, and Khadrawy. Organic dates are now produced in many countries around the world including Tunisia, Israel, Saudi Arabia, Egypt, Sudan, Iran, Algeria, and the USA. Date palm, whether grown conventionally or organically, has numerous pests and diseases including 132 species of arthropod (insects and mites), 52 vertebrate pests (birds, rodents, bats), and 28 non-arthropod pests (slugs and snails, parasitic nematode) [26, 27]. Additionally, more than 16 important fungal, phytoplasma, and unidentified diseases attack the date palm. The major ones include Bayoud, black scorch, *Diplodia*, Khamedj inflorescence rot, Belaat, graphiola leaf spot, Al-Wijam disease, brittle leaf disease, and Faroun disease [28]. These pests and diseases may cause substantial losses in date palm groves if left unmanaged. Therefore, a well-planned and supervised pest management program is important to maintain a sustainable date palm production in organic farming system. Some examples of injuries inflicted by pests on date palm and dates are shown in Figures 1 and 2.

Figure 1.

Symptoms of damage on the fruit bunch stalk (left) due to Oryctes elegans and on the trunk (right) due to Jebusaea hammerschmidti.

Figure 2.

Fatal damage caused by the larvae of the longhorn beetle Jebusaea hammerschmidti on the apical meristem (Goumara) of a date palm.

Date palm pests of economic important in organic farming could be prevented through an IPM program comprising the following components: selection of planning materials, pest monitoring, cultural management, and conservation of natural enemies of pests.

6.1. Selection of planning materials

To a healthy vigorous palm that yield good quality date fruits, one should start with good planting materials whether tissue culture seedlings, offshoots, or mature palms. Planting materials should be adapted to the area where to be grown, in addition of being healthy and free from pests and diseases. Such planting materials should be obtained from nurseries certified for organic date palm production, where strict quarantine measures and protocols are applied. Many serious pests and diseases of date palm including the invasive red palm weevil spread rapidly through movement of infested planting materials [29]. Dubas bug, scale insects, longhorn beetle, and rhinoceros beetle also invade new areas through transportation of infested offshoots and mature palms (Figure 3). Thus, application of preventive and protective controls through strict implementation of agricultural quarantine controls, as well as non-trading of any offshoots or infected palms, are essential for the establishment of new date palm plantation.

Figure 3.

Many important pests and diseases of date palm can be introduced into new areas through transporting unhealthy planting materials.

6.1.1. Characteristics of a good date palm offshoot

1. Make sure that the offshoot belongs to the cultivar that is intended to be grown. Selection should be made during harvesting time of the mother palm, because it is easy to identify the date palm cultivar from the characteristics of its fruit.
2. The offshoot should be 3–4 years old, with length of approximately 1–1.5 m and diameter of 25–35 cm with an average weight of 20–30 kg.
3. The offshoot should contain numerous undamaged roots.
4. The offshoot should be free of insect pests and diseases.
5. The offshoot should be mature and hence will have a better chance of survival after transplanting. Bearing fruits and having daughter offshoots indicate the maturity of the offshoot.
6. Care must be taken not to wound the offshoot during detachment from the mother palm, as the wounds would predispose the offshoot for bacterial and fungal diseases, as well as for opportunistic insect pests such as the dynastic beetles, termites, and red palm weevil.

6.2. Pest monitoring and mass trapping

Monitoring of major date palm pests is essential for decision-making such as determination of economic threshold that largely help in starting control actions and avoidance of routine preventive treatments. Pheromone trapping could be used to determine population cycles and prediction of pest outbreaks. Pheromones can also be employed in mating disruption, attack and kill, and male inhalation techniques to reduce pest populations [30]. The same devices of pheromone and light traps can also be used for mass trapping of adult insect pests, particularly gravid females that lead to drastic reduction in pest population (Figure 4) [31].

Figure 4.

Solar light trap (top left), pheromone-baited trap (top right), adult borers collected by the light trap (bottom right), and adult of red palm weevils mass trapped through pheromone trap (bottom right).

6.3. Cultural management

Services of date palm that are important in the management of pests and diseases include irrigation management, field sanitation, removal of weeds, organic fertilization, old frond pruning, frond base cutting, offshoots removal, pollination, fruit thinning, spines removal, fruit bagging, and harvesting. Each one of the abovementioned operations is carried out at specific time of the year with specific purpose; however, each operation can control palm pests and diseases in one way or another. Thus, adoption of date palm calendar for each locality will provide control of date palm pests and diseases.

6.3.1. Organic fertilization and irrigation (soil condition)

Management of irrigation to avoid conditions that are congenial to the development of pests and diseases (e.g., red palm weevil) is an important soil conditioning practice in organic farming. Another important practice is maintaining soil health and nutrients to increase palm immunity against pests' attack, such as the longhorn beetle, which is known to inflict serious damage on weak unattended undernourished date palms. Healthy palms with balanced nutrients and irrigation withstand attack by this opportunistic insect pest. High humidity, which is conducive to the buildup of Dubas, is expected to prevail in densely planted orchards. High soil moisture (flood irrigation and basin irrigation) increases the infestation by the red palm weevil in date palm groves [32]. Care has to be taken when applying organic manure to newly transplanted date palm offshoots, because it may contain eggs and different stages of the rhinoceros beetles, which are considered serious pests of date palm. However, the organic manure can be disinfested from these grubs and other insect pests using physical methods or chemicals permitted in organic farming system. In this respect, the farm wastes including eradicated palms can be pulverized and used for production of compost (Figure 5). Organic fertilizers are added to date palm during the end of October–December. This is to promote date palm growth and increase its immunity against pests and diseases. About 5–50 kg of organic fertilizer is required per palm, depending on age.

Figure 5.

Shredding machine for pulverizing date palms severely infested by the red palm weevil, Rhynchophorus ferrugineus.

6.3.2. Palm spacing

Well-spaced date palms (8 × 8 m) have no problem of dub bug insect which represents a real problem in narrowly spaced plantations [33]. Densely spaced palms facilitate the spread of crawling mites and scale insects from one palm to another. Sallam et al. [32] reported high incidence of red palm weevil infestation in closely spaced date palms. He attributed the high infestation to the high in-grove humidity caused by densely planted farms.

6.3.3. Pruning of date palm

Pruning is the most important practice that contributes significantly in management of pests and diseases, and it includes the removal of old dry fronds (leaves), offshoots, aerial offshoots, fibers, and spines (Figure 6). Frond removal has two parts: cutting of fronds from the lower whorls of the canopy (Tagleem) and cutting the rachis base (petioles) 1–2 years after frond cutting (Takreeb) [34, 35]. The advantages of frond pruning are listed below:

1. Facilitates climbing of the date palm by the farmers.
2. Reduces fire hazards in date palm plantations, particularly during dry seasons.
3. Improves aeration around the palm trunk and thus reduces humidity and discourage hiding and oviposition by trunk borers.
4. Reduces transpiration rate of newly transplanted palms and hence increases the chance of palm survival.
5. Reduces hiding places for unwanted arthropods such as cockroaches, scorpions and non-arthropods such as snail, slugs, as well as vertebrate pests (birds and rats)
6. Facilitates handpicking of large-sized grubs and adults of trunk borers.

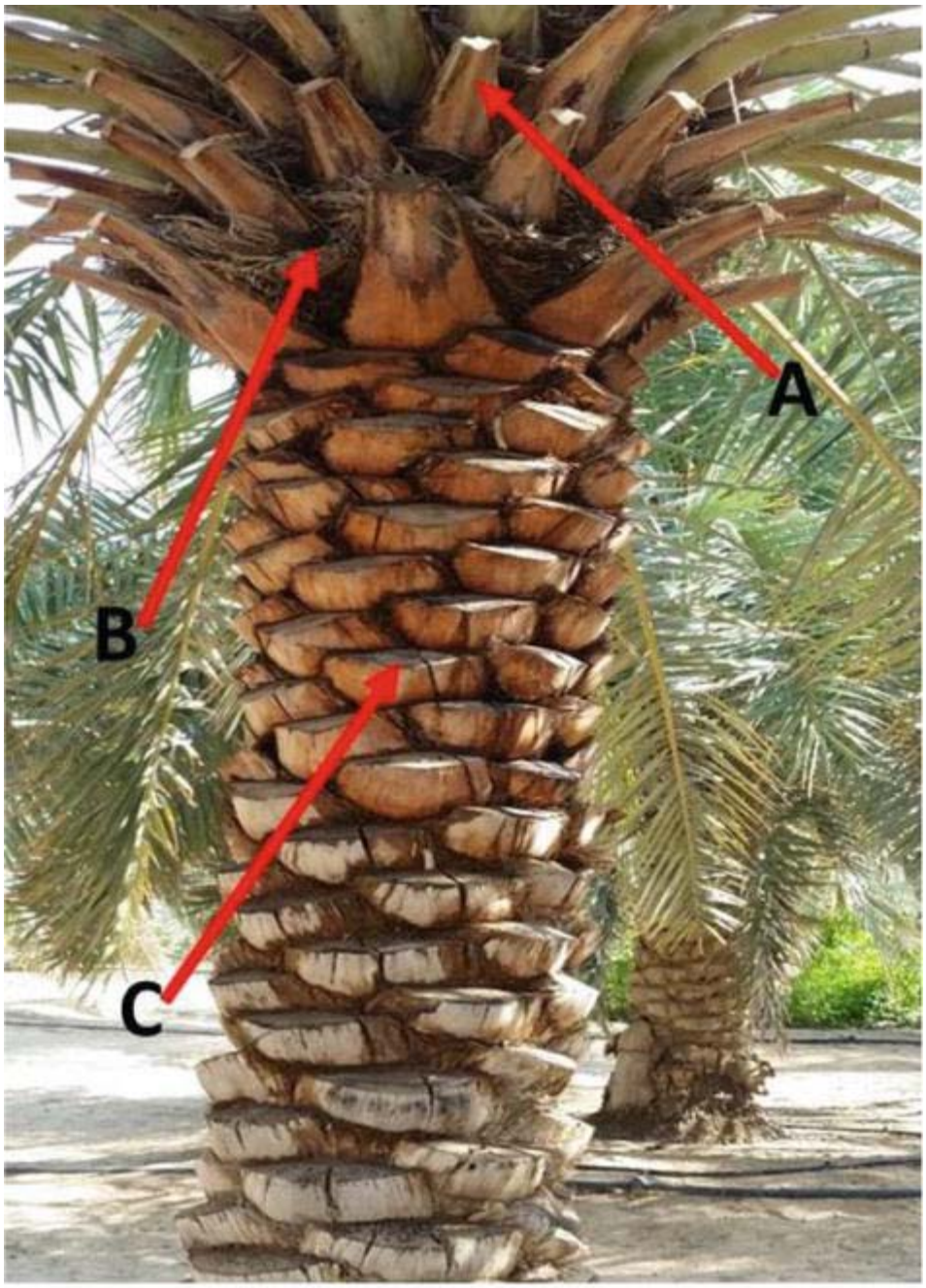

Figure 6.

Pruned palm trunk showing cut frond (A), fibers (B), and cut frond base or petiole pruning (C).

The following precautions are recommended to be taken during pruning process:

1. Prune only fronds after 3–7 years (old dry fronds) on only palms that are 7 years old or above.
2. Curry out pruning during December–January, when temperatures are low to avoid infestation by the red palm weevil where activity of the weevils is at the lowest level.
3. Treatment of wounds and pruned surfaces immediately with bee wax or any other substance allowed in organic farming to obscure the kairomones (odor emitted by the palm) which attract the red palm weevil and other palm pests.
4. Avoidance of palm overpruning as fronds protects the palm's heart from excessive heat as well as from cold during winter.
5. Cutting frond base should be inclined outward with downsloping 45° to avoid accumulation of rainwater in the area between the base of the frond and trunk.
6. Disinfection of pruning equipment such as saws, sheers, and sickles to avoid the spread of fungal diseases such as black scorch and *Fusarium* wilts.

It has been stated that tillage practices and leaf pruning had the greatest effect in reducing termite, long antennae, and horned beetles, respectively. On the other hand, sucker removal operations had the greatest effect in reducing the severity of injuries of horned and long antennae beetles in date palm trees [15]. In addition, larvae of long antennae beetles can complete overwintering in the petioles of damaged leaves. Therefore, pruning the dry, damaged, and old leaves can reduce the severity of injuries of borer pests. Termites attack the dry and damaged parts of date palm tree, so pruning the petiole is very effective in reducing nutrient availability, population growth, and severity of injury [15].

6.3.4. Pollination, fruit, and bunch thinning

For good quality date fruits, pollen grain should be obtained from certified bodies to be sure that they are free of pests and diseases such as the inflorescence beetle *Macrocoma* sp. and the fungal pathogen *Mauginiella scaettae* and *Thielaviopsis paradoxa*, which cause Khamedj inflorescence rot and black scorch diseases, respectively [36]. In this respect, the author stated that extracting pollen and mixing with talc/flour or with water for mechanical pollination proved to be cost-effective and more efficient in prevention of inflorescence pests and disease than traditional pollination methods.

Fruit thinning has two types: strand thinning either made by cutting the end of the strands or removal 30% of the strands from the center of the spathes [35]. It is carried out in February–March 2–3 days after female spathes opening and before pollination. Bunch thinning, on the other hand, involves the removal of the whole bunch and is usually done after pollination. It is carried out in a way that 6–8 bunches are left in each mature date palm. The number of bunches per palm should corresponds to the number of green functioning fronds, i.e., 9–12 green fronds per bunch to ensure high yield of date fruits with high quality [35]. The bunch thinning should be made even on all sides of the palm taking into account the distribution of bunch loads. This is essential to avoid curving of palm head as the case with the cultivar Barhi. Weak infested or infected bunches with undersized fruits and incomplete pollination should be removed first during thinning process. Latifian [37] reported that bunch pruning helped in decreasing the lesser moth, *Batrachedra amydraula* infestation.

6.3.5. Fruit bunch bagging, harvesting, and sorting

The use of insect-proof fruit bunch covers, made of woven monofilament polyethylene yarn (40 mesh), excludes all insect pests including beetles, ants, flies, rats, and birds (Figure 7). These bags are more expensive than the loose net bags. Bunch covering and bunch-remained pruning had suitable effects in decreasing the date spider mite, *Oligonychus afrasiaticus*, raisin moth *Cadra figulilella*, and the lesser date moth, *Batrachedra amydraula* infestation [38, 39]. Early harvesting of cultivars such as Barhee, Deglet Noor, and Medjool provides satisfactory control against ripening dates including date moth, raisin moth, carob moth, greater date moth, and sap beetles [40, 41]. Fruit bagging and early harvesting provide effective control against fruit depredation by frugivorous birds [42]. Culling of infected/infested date fruit during harvesting and field drying is considered as an important step in the management of pests and diseases during transit and storage [36].

Figure 7.

The white-eared bulbul Pycnonotus leucotis (top), damage on dates due to bulbul (bottom left), and bunch covering to control birds (bottom right).

6.3.6. Phytosanitation in date palm groves

Both field and palm sanitation can have a profound effect in reducing the population of pests and diseases of date palm. The removal of fallen date fruits on the basin of the palm and in the leaf axil of unpruned palms helps provide control for the nitidulid beetles, lesser date moth, and other insect pests [40]. The fallen fruits provide suitable breeding site for these insect pests as well as for rats and birds. Thus, all dried litter around palms should be carefully removed. In organic farms, grazing animals such as goats, horses, and donkeys may be used to clean weeds, fallen fruits, and other farm wastes [40]. Neglected date palm farms represent suitable breeding sites for serious date palm pests including the red palm weevils, longhorn beetle, and rhinoceros beetle [29, 35]; thus, infested old neglected palms should be eradicated.

6.4. Conservation and enhancement of natural enemies of pests

The date palm agroecosystem comprises diverse groups of natural enemies including insect predators, parasitoids, spiders, predatory mites, birds, entomopathogenic nematodes, and microorganisms. In this respect, El-Shafie et al. [26] listed 90 species of predators and parasitoids from 9 orders and 23 families. Out of the listed species, the most important are the general predator *Chrysoperla carnea* and the braconid wasp *Bracon* spp. that is highly associated with the date moth *Cadra cautella*. Predatory mites from the family Phytoseiidae such as *Phytoseiulus persimilis* and *Neoseiulus* sp. and *Trichogramma* parasitoids are common. Al-Khatri [43] reported more than 70% parasitism of Dubas bug in Oman by the specialist egg parasitoid, *Pseudoligosita babylonica*. He also mentioned other species of Dubas natural enemies including the hymenopterous *Bocchus hyalinus*, *Aprostocetus* sp., and *Aphanogmus* sp. as well as the coccinellid *Cheliomenes sexmaculata*.

Several measures taken in date palm plantation can enhance survival and biodiversity of natural enemies. For example, the exclusion of synthetic pesticides by rules of organic farming is the cornerstone in conservation of natural enemies of pests. Intercropping of date palm with annual plants may avail new habitats for predators of pest such as the lacewing. Soils with high population of diversified beneficial organisms such as ground beetles (carabids) and earwigs, which are commonly to be encountered in the date palm agroecosystem (El-Shafie, unpublished data), are expected to maintain low levels of harmful pests. On the other hand, cultural control techniques create a balance between pests and their natural enemies, and they are more effective in the prevention of outbreaks of date palm borer pests [15]. The growing of hedgerows, strip crops, and windbreaks provides suitable habitats and source of pollen and nectar for beneficial organisms [3, 16]. Provision of nesting boxes for owls in date palm groves has a noticeable reduction in the population of field rats [27]. In addition to the abovementioned measures to conserve natural enemies, repeated release of purchased predators and parasitoids can maintain their numbers, which cause substantial reduction in pest populations. In this context, Ali and Hama [33] reported that the release of *Trichogramma* sp. twice a year at a rate of 300–500 individuals/palm contributed significantly in the integrated management of the lesser date moth, *C. cautella*.

6.5. Synopsis

The major date palm pests and diseases prevailing in organic date palm plantation, which cause economic damage, are listed in Table 3, with possible measures to control them.

Pest	Time of appearance	Possible control measures
Red palm weevil, *Rhynchophorus ferrugineus*	All the year round with adult peaks in March–May and October–November	Pheromone trapping of adults, removal and destruction of infested palm, strict quarantine measures to prevent entry of the weevil in date grooves, application of azadirachtin, the *Beauveria bassiana*, and other biological control agents
Termites (*Microcerotermes diversus*, *Odontotermes smeathmani*)	All the year round	Keeping palm healthy palms, removal of dry fronds and litters from around palm basin, application of azadirachtin as curative measures
Green pit scale insect (*Palmaspis phoenicis*) and white scale (*Parlatoria blanchardi*)	All the year round	Pruning and removal of infested fronds, adequate fertilization and irrigation, application of mineral oils (96%) at a rate of 10/1000 liters of water, application of azadirachtin
Weeds	All the year round	Mechanical weeding, grazing by farm animals, use of covers to smother weeds
Rodents	All the year round	Use of mechanical traps, provision of nesting sites for predatory birds, such as owls, that can effectively control rodents in date palm grooves
Inflorescence weevil (*Derelomus* sp.), inflorescence beetle	With beginning of inflorescence	Use of uninfested pollen, dusting with microfine sulfur at a rate of 50 g/ palm

Pest	Time of appearance	Possible control measures
(*Macrocoma* sp.)	February–March	
Bayoud disease, *Fusarium* wilt caused by *F. oxysporum* f. sp. *albedinis*	All the year round	Cultivation of resistant date palms, removal and incineration of infested palms, avoidance of the spread of the disease pathogen through irrigation, use of organic fertilizer rich in chitin to enhance the development of actinomycetes which antagonize the pathogen
Inflorescence rot (Khamedj disease) caused by *Mauginiella scaettae*	February–March	Avoid the use of infected pollen, treatment of the palm with Bordeaux mixture (0.3–0.5%) after harvest and before inflorescence of the next year as preventive measures Treatment (dusting) with microfine sulfur at a rate of 50 g/palm
Black scorch disease caused by *Thielaviopsis paradoxa*	All the year round	Avoid making wound on the palm, sanitation measures such as removal and destruction of badly infected palms, application of Bordeaux mixture, and use of microfine sulfur (80%) at a rate of 2.5 g/1000 liters of water after harvest
Diplodia disease (basal leaf rot) caused by the fungus *Diplodia phoenicum*	All the year round	Use of healthy uninfected offshoots, avoidance of making wounds in palms, disinfection of pruning equipment, application of copper sulfate or copper carbonate
Lesser date moth (Humeira) (*Batrachedra amydraula* Meyer)	February–March	Field sanitation including removal of fallen fruits, use of pheromone or light traps, use of *Bacillus thuringiensis*, biological control using egg parasitoid *Trichogramma* and

Pest	Time of appearance	Possible control measures
		the larval parasitoid *Bracon* sp.
The old world dust mite (*Oligonychus afrasiaticus*)	April–July	Removal of weeds around palms, which may act as alternative host for the mite, use of windbreak to reduce dust storms, spraying, bunches with a strong stream of water to dislodge mites and destroy webbing; use of predatory mites and coccinellids, dusting bunches with sulfur
The longhorn beetle (*Jebusaea hammerschmidti*), the bunch borers (*Oryctes agamemnon arabicus*, *Oryctes elegans*), and the frond borer (*Phonopate frontalis*)	April–July Larvae of the longhorn beetle are found inside the palm all year round	Pruning of old dry fronds, avoid using uncured farm manure as organic fertilizer, handpicking of larvae during frond base cutting, light trapping of adult beetles, maintaining healthy palms, application of the fungi *Beauveria bassiana*, *Metarhizium anisopliae*, and the entomopathogenic nematode *Rhabditis blumi*
Date palm Dubas bug (*Ommatissus lybicus*)	March–April September–October	Pruning of infested lower fronds to remove Dubas eggs, spraying with azadirachtin (2–3 ml/per liter of water), application of agricultural soaps, biological control with fungi such as *Beauveria* and the egg parasitoid *Oligosita* sp.
Fruit rots	June–July	Bunch covering and avoidance of fruit injuries by insects and birds
Birds	July–October	Covering of bunches during Khalal stage with bird-proof nets
Pests of stored dates	September–November	Bunch bagging to exclude pests that start infestation in the field, sanitation and

Pest	Time of appearance	Possible control measures
		disinfestation storehouses before use, freezing dates at −18°C

Table 3.

Calendar of major pests and diseases in organically grown date palms and their management in the Gulf region.

7. Impact of pest management in organic farming on the environment

As mentioned earlier in this chapter, pest management in organic farming depends mainly on crop husbandry and biological control. The prohibition of synthetic fertilizers and pesticides leads to conservation of natural enemies including predators and parasitoids. The absence of harmful pesticides also increases diversity of pollinators of crops and minimizes pesticide residues in food products [13, 16, 19]. The community of microorganisms flourishes well in organically managed farms leading to increased organic matter decomposition, soil fertility, and sustainability of the ecosystem. Organic farming enhances the biodiversity of the ecosystem through multicropping and growing of hedges and refuges for beneficial insects as well as wildlife [3]. Preserving biodiversity contributes much in reducing the initial invasion and subsequent establishment of organic farms by pests and diseases [3, 8, 9, 44].

8. Conclusions

Crop protection in organic farming is more preventive than curative. Thus, husbandry practices such as crop rotation, fertilization, cultivation, use of resistant varieties, and preservation of natural enemies play an essential role in pest management. Plant protection products (PPPs) permitted in organic farming should only be used when cultural and biological controls fail to suppress pest populations below economic damage levels. Floral and faunal diversities represent the cornerstone in the strategy of managing pests and diseases under organic production system. Crop protection program in organic farming needs to be documented to allow inspectors to file their reports, which are essential for the certification process. The documents needed are a well-written plan, copies of scouting records and protocols used in monitoring of different pests, and provision of pest management guidelines, according to the organic standards, if available. For optimizing pest management tactics in organic farming, future research priorities and recommendations would include:

1. Long-term ecological studies on ecosystem biodiversity to elucidate its potential role in pest management
2. Testing more plant protection products including plant extracts and microbial preparations for use in pest population suppression
3. Exploitation of inherited resistance in different crops against plant herbivores
4. Strengthening participatory research approach with organic farmers and encouraging citizen science to optimize existing practices and develop new techniques