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Pests and diseases of selected fruit crops in southern part of Ethiopia

BACHELOR'S THESIS

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Declaration

I hereby declare that I have done this thesis entitled Pests and diseases of selected fruit crops in southern part of Ethiopia independently, all texts in this thesis are original, and all the sources have been quoted and acknowledged by means of complete references and according to Citation rules of the FTA.

In Prague 15.4.2022

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Lukáš Machek

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I am grateful to my family and friends who fully supported me through my studies and crucial points, such as finishing my thesis.

Abstract

Ethiopian fruit harvests are plagued by various insect pests and diseases, which have posed a significant problem in the development sector. In most cases, people do not know how to protect their crops against pathogens. Therefore this thesis presents an overview of the most common diseases and pests on selected fruit crops in southern Ethiopia: *Mangifera indica*, *Persea americana*, *Carica papaya*, *Annona muricata*, *Citrus sinensis*, *Citrus limon*, *Passiflora edulis*, *Musa × paradisiaca*, *Citrullus lanatus*, *Cucumis melo*. And also elucidation of appropriate prevention and control methods against the most common diseases and pests. Apart from the literature review, 51 farmers were interviewed in Arba Minch Zuria woreda. The survey showed that most respondents face serious problems with prests and diseases infestation. Only 4 % applied chemicals to combat pests and diseases; most rely on preventive measures, acceptable if done correctly, or traditional plant protection methods. Most farmers used traditional preventive methods such as weed control or disposal of post-harvest residues to fight pests and diseases. However, they are keen to learn new plant protection and prevention methods, preferably in an environmentally friendly way. Despite the fact that the majority of farmers claimed to be able to identify dangerous species, they lack the necessary tools, expertise, or both to protect their crops.

Interestingly, 92 % of the farmers did not think agriculture could be harmful to the environment. However, 82 % of the respondents thought that agricultural chemicals, such as pesticides, herbicides or insecticides, are harmful to the environment and human health. To improve the yields of fruit species in Arba Minch, farmers should be thoroughly informed about the most common pests and diseases in their area and trained in protecting their crops. Biological plant protection strategies should be emphasised to preserve the environment and protect human health.

Keywords: Eastern Africa, fruit trees, plant health, plant protection, prevention

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1. Introduction

Agriculture in Ethiopia covers about 67 % of total employment (The World Bank 2019) and accounts for 35 % of Ethiopia's gross domestic product (The World Bank 2020). Ethiopia's agro-ecological diversity means that temperate, subtropical, and tropical fruits may be grown in various locations in Ethiopia. For example, large areas of the country's southern and south-western regions receive enough rainfall to grow fruits suited to the local climate (Amer 2002). Despite this potential, the area mainly relies on smallholders. There are 3,6 million farmers engaged in fruit cultivation (Etissa et al. 2021). With a total area under fruit cultivation of approximately 104,500 ha and a yearly production of approximately 777,431 t (Central Statistical Agency 2018). One of the major problems threatening the Ethiopian financial and food security are pests and diseases regularly infestating the locally grown crops, representing a significant barrier to tropical fruit production as well. Arba Minch Zuria is known as one of the Ethiopian most productive areas in terms of fruit cultivation (Gamo Zone Office of Agriculture 2020). However, pests and diseases frequently lower local farmers' yields by weakening the plant or affecting post-harvest processing. Problems vary from cosmetic issues that make the harvested product less marketable to fatal issues that decimate local or regional output. Furthermore, Ethiopian fruit harvests are plagued by various insect pests and illnesses, which has posed a significant problem in the development sector (Earecho 2015). Therefore, this study aimed to present an overview of diseases and pests on chosen fruit crops in southern Ethiopia and define the relevant disease and pest prevention and management techniques.

2. Literature Review

2.1 Plant protection

Plant protection is a set of actions to prevent the spread of pests and diseases by indirect and direct methods. In indirect protection, the pest is not directly killed, but its population is controlled so that it falls below the threshold of tolerance. Indirect methods consist of agrotechnical methods such as disposal of post-harvest residues, weed control and tillage, selection of a suitable site and a suitable sowing method, and breeding methods (Hudec & Gutten 2007). Direct methods consist of the use of chemicals (sprays), biological control (use of a specific organism to reduce the population of the harmful organism), mechanical measures (fencing, non-woven films), and physical methods (thermotherapy) to kill pests on plants deliberately. Biotechnological approaches that employ natural responses to diverse natural compounds often found in nature to manage pests, allowing pests to interact with one another, develop, or breed, are relatively recent. Each of these strategies has benefits and drawbacks, and combining them typically yields the most significant benefits at the lowest cost (Kazda et al. 2010).

2.2 Selected fruit crop species

2.2.1 Persea americana

Persea americana, an avocado tree, a member of the Lauraceae family, is a subtropical tree that can grow up to 20 meters. The tree is grown for its fruits, classified as large berries with one large seed (Hurtado-Fernández et al. 2018). The fruits of *P. americana* are from 7 to 20 cm long and are pear-shaped, containing a crafty flesh, which is primarily green, and an exocarp whose colour differs from green to dark brown or black, depending on the variety. The trees are self-pollinating and reproduced mainly by grafting, so avocados maintain their quality and quantity of production (McCarthy & McCauley 2020). Mexico is nowadays the largest producer of avocado fruits worldwide (FAO 2019). Avocado trees are highly watered, demanding species. To grow one avocado, 320 litres of water is needed (Danwatch 2019).

Major *P. americana* diseases in Ethiopia are anthracnose, powdery mildew, scabs, and spots, whereas rust, dieback and soot are considered minor diseases. The most common pests on avocado trees are scale insects and flies (Earecho 2015).

2.2.2 Mangifera indica

Mangifera indica, a mango tree, is a subtropical tree from the family Anacardiaceae. A single tree can grow up from 15 to 30 meters. *M. indica* originates in the region of Myanmar, Bangladesh, and north-eastern India (United States Department of Agriculture 2004). The tree is mainly grown for its fruits, commonly known as mangoes. When ripe, mangoes have yellow or orange-coloured flesh and are from 8 to 12 cm long. The exocarp is green in colour. The fruit of *M. indica* is single-seeded and contains one flat seed. The world's largest producer of mangoes is India (Barreto et al. 2008). Once the production lifespan is finished, *M. indica* wood can be used to make musical instruments and furniture (Puskar 2012). Significant diseases of mango trees in Ethiopia are anthracnose and powdery mildew. Minor diseases are soot, gummosis, and blight. Major pests of *M. indica* are white mango scale, fruit flies, and flies (Earecho 2015).

2.2.3 Carica papaya

Carica papaya, commonly known as papaya, is a tropical herb from the family Caricaeae that usually grows from 5 to 10 meters tall. The whole plant contains natural latex and can be found in every part of the *C. papaya* (Heywood et al. 2007). Interestingly, papaya plants can be male, female, or hermaphrodite, depending on the variety (Craene 2010). *C. papaya* is grown for its fruits classified as large berries, about 15-45 cm long. The inside of the fruit contains orange flesh and a lot of tiny black seeds (Heywood et al. 2007). The origin of *C. papaya* is in Mexico and the north of South America, but recently its biggest producer is India (FAO 2019). The plant grows very fast and can produce fruits in 3 years; however, it cannot withstand the cold climate. Thanks to the papaya ringspot virus, papaya became the first transgenic fruit species that had its genome sequenced (Borrell 2008). Major diseases of *C. papaya* in Ethiopia are anthracnose, powdery mildew, and spot. Minor diseases of *Carica papaya* is rust (Earecho 2015). Pests of *C. papaya* are leafhoppers, mealybugs, scale insects, fruit flies and stone weevils (Pantoja et al. 2002).

2.2.4 Annona muricata

Annona muricata is an evergreen tree from the Annonaceae family that can grow up to 9 meters. It is grown for its edible fruits, commonly called soursop or gishta, because of its acidulous taste when the fruit is ripe (Morton 1987). Gishta is dark green in colour and prickly, and the fruit can grow up to 30 cm long. The fruit is used in nectar, juice, or even candies preparation (Morton 1987). The origin of *A. muricata* is in Central America and India (PIER 2008). The tree handles poor soil conditions, but it cannot be cultivated in cold climates (Morton 1987). The biggest producers of *A. muricata* are Mexico, Peru, and Brazil (FAO 2019). In general, significant pests of gishta trees are mealybug, *Planococcus citri,* and borer. Major diseases are black rot, seedling blight, anthracnose, and diplodia rot, while the minor disease of *A. muricata* is the burn of string (Pinto et al. 2005).

2.2.5 Citrus sinensis

Citrus sinensis, an orange tree, is an evergreen tree that reaches 10 to 15 m in height from the family Rutaceae. It is a hybrid between *C. reticulata* and *C. maxima* and originates in China and India. The biggest producer of oranges is Brazil (Statista 2020). Its fruits are 6-10 cm in diameter and are called hesperidium, a modified berry (Koch & Avigne 1990). The outer coloured layer is called flavedo, and the inner white, spongy layer is called albedo. Pests identified as major are leaf miners, bud mites, fruit flies, false codling moths, thrips, red scales and aphids (Tola et al. 2014; Gebreslasie & Meresa 2018). Major diseases of *C. sinensis* are anthracnose, armillaria root rot, black root rot, blast, melanose, citrus canker and stubborn disease (Mitiku 2017; Gebreslasie & Meresa 2018; Ur Rehman et al. 2020).

2.2.6 Citrus limon

Citrus limon is a tree from the Rutaceae family with evergreen foliage and yellow edible fruits (Klimek-Szczykutowicz et al. 2020). The fruits of *C. limon*, like other citruses, are called hesperidium, which is a modified berry. The pericarp of hesperidia is divided into two morphologically different parts: the rind (exocarp and mesocarp) and the pulp (endocarp), which are hydrolytically divided (Koch & Avigne 1990; Cronje et al. 2011). Major diseases of *C. limon* are citrus greening, citrus canker, melanose, gummosis, sooty mold, and blue mold. The main pests of *C. limon* are woolly whitefly, mealybugs, scale insects, leafminer, fruit fly, aphids, red scale and root weevil (Gebreslasie & Meresa 2018).

2.2.7 Passiflora edulis

Passiflora edulis is a perennial vine from the Passifloraceae family, commonly called passion fruit. It is native to southern Brasil and Paraguay (Morton 1987b). The biggest producer of *P. edulis* is Brasil (Cerqueira-Silva et al. 2014). The most cultivated varieties are Purple and Yellow, which differ in the colour of the fruits. *P. edulis* grows well in hot and humid conditions typical for tropical regions (Joy & C.G. 2012). *P. edulis* primary pests are lepidopterous defoliators, flies, stem weevil, coreid bugs and mites (Joy & C.G. 2012). Secondary pests are aphids, caterpillars, mealybugs and last but not least, scales. *P. edulis* fungi associated diseases include anthracnose, collar rot, fusarium wilt, crown rot, root, scab, and brown spot. Virus associated diseases include woodiness, leaf mottle disease, mosaic disease and vein clearing. Bacterial diseases are bacterial spot and bacterial grease spot (Joy & Sherin 2012).

2.2.8 *Musa × paradisiaca*

Plantain or cooking banana is a hybrid between *Musa acuminata* and *Musa balbisiana* from the Musaceae family. It is usually a 2 to 9 meter-tall plant with starchy fruits generally used for cooking. These hybrid fruits are available year-round, making plantains great all-season staple food (Redhead & Division 1989). Especially in West and Central African countries, plantains play a crucial role in subsidising the local dietary needs. Its major diseases are anthracnose, black sigatoga, rhizome rot, bunchy top and Moko disease (Ministry of Agriculture, Forestry and Fisheries 2007). Major pests of *Musa × paradisiaca* are banana aphid, banana weevil and coconut scale (Earecho 2015).

2.2.9 *Citrullus lanatus, Cucumis melo*

Watermelon and muskmelon are herbaceous vines from the Cucurbitaceae family, widely grown and utilised throughout Africa, where the species are native. The biggest producer is China (Paris 2015). Their fruits of melons are mainly used for juice preparation or as snacks. The Muskmelons exist in many varieties, which fall into four basic categories: charentais, honeydew, galia and cantaloupe. The most common diseases include downy mildew, powdery mildew, anthracnose, fusarium wilt and cucumber mosaic disease. red pumpkin beetle, fruit fly, whitefly and thrips are the most common pests of *C. lanatus* (Okrikata et al. 2021).

2.3 Diseases

This chapter contains descriptions and potential control measures of major diseases detected in the fruit mentioned above.

2.3.1 Anthracnose

A group of fungal diseases affects many plants in humid and warm areas. The primary pathogen of tropical and subtropical crops is *Colletotrichum gloeosporioides* (Uddin et al. 2018). It causes withering, wilting and tissue dying. The typical infection is in developing shoots and leaves. Symptoms include lesions of different colours and open spots in fruits, leaves, and stems of flowers. Other infections form cankers on branches and twigs. The disease can be avoided by using disease-free seeds, disease-resistant plant varieties, destroying diseased parts, or applying fungicides (Weir et al. 2012).

Figure 1. Example of anthracnose disease on the fruit of Citrus sinensis (Daoud et al. 2019)

2.3.2 Powdery mildew

Plant disease of fungal origin with worldwide occurrence. Causes a powdery growth on the surface of fruits, leaves, buds, and flowers. Many races of species such as *Erysiphe*, *Microsphaera*, *Phyllactinia*, Sphaerotheca, and *Uncinula* cause powdery mildew disease. White powdery appears due to large numbers of conidia borne in chains. The spores are wind-borne and do not need free water for germination and infection. Leaves turn yellow and then whiter, flowers are distorted, and fruit quality and yield are reduced. Adequate protection against powdery mildew is sulphur dust but should not be applied in hot weather. Other effective treatments are copper-based fungicides, baking soda solutions, and neem oil. The prevention against powdery mildew is by planting resistant crop varieties, removing diseased plant parts and sterilising contaminated gardening shears (Huang et al. 2000).

Figure 2. Example of powdery mildew on leaves on Mangifera indica (Greenlife Crop Protection Africa 2017)

2.3.3 Scab

Bacterial or fungal plant disease. Crustaceous lesions characterise it on tubers, leaves, stems and fruits. On affected plants, leaves may whiter and drop early. It can be prevented by not using wood ash, fresh manure and lime because that will improve the alkalinity of the soil and scabs spread rapidly in dry, alkaline soils. Other prevention methods include using resistant crop varieties, disease-free seeds and spraying plants with fungicides (Lerat et al. 2009).

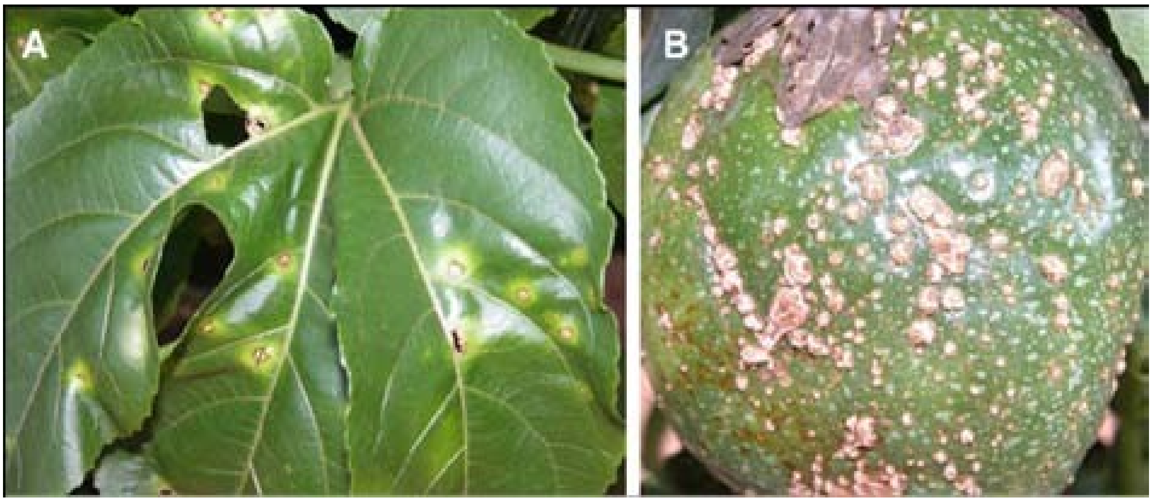

Figure 3. Example of scab on fruit and leaves of Passiflora edulis (Joy & Sherin 2012)

2.3.4 Black root rot

A fungus type disease is characterised by tissue lesions near the soil's surface. Plants may be stunted and grow slowly and poorly. Small dark brown to black bands may be seen in infected roots, and the roots can become badly rotten as the disease progresses. The fungus that causes this disease is called *Thelaviopsis basicola*, and it forms rectangular-shaped chlamydospores or rectangular-shaped endoconidia. The spreading can be set both in water and soil. The preventive measures which can be used are good sanitation practices and the usage of pathogen-free seeds (Koike et al. 2020a).

Figure 4. Example of black root rot of Citrullus lanatus (Egel 2018)

2.3.5 Leaf spot

A fungal, bacterial or viral disease, however, this disease may also be caused by abiotic elements such as environmental conditions, toxicities and herbicide injuries (Isleib 2012). The wind, which may carry nematode eggs, insects, numerous microscopic fungal spores, and bacterial cells, can distribute pathogens. Fungal, bacterial, and viral leaf spot infections can also be transferred by animal and insect vectors. When the following requirements are met: favourable environmental circumstances, a pathogenic agent, and a susceptible host, leaf spot disease arises (Lucas & Campbell 1992). Attaching to the plant surface, sprouting through spores, and penetrating the host tissue is how fungal leaf spot infections work. The colonisation of the host tissue is subsequently followed by the emergence of symptoms (Narayanasamy 2008). Variety selection, crop rotations, plant hygiene, and seed and foliage fungicide application have all been ways to prevent leaf spot disease (Government of Australia 2021).

Figure 5. Leaf spot on Carica papaya caused by fungi Asperisporium caricae (Ogata & Heu 2001)

2.3.6 Melanose

Diaporthe citri causes citrus melanose, a fungus disease that affects citrus trees worldwide. This illness causes fruit quality to deteriorate, lowering the selling and export value of the crop (Ur Rehman et al. 2020). Infections can be found on leaves that have not fully opened. After leaf infection, dark-coloured, elevated, corky pustules emerge. Yellowed leaf tissue or yellow halos may surround the pustules. The yellow colour may turn green in the future. Shoot apices that have been severely diseased may become deformed or dieback. Mature, fully inflated leaves are resistant to infection. Infection shows on fruits as darkly coloured, elevated pustules of varied sizes. The pustules may coalesce into a cracked appearance, known as mudcake melanose, or they may spread across the fruit surface with a splash or with flowing water (Gebreslasie & Meresa 2018), causing tear-stain symptoms. The pustules may be more significant when the disease affects extremely immature fruits (Nelson 2008). For the treatment of citrus melanose, proper pruning and copper-based fungicides are recommended. It is best to avoid planting sensitive plant types (Ur Rehman et al. 2020).

Figure 6. Example of melanose on the fruit of Citrus sinensis (Agrolink 2022)

2.3.7 Fusarium wilt

A fungal disease caused by *Fusarium oxysporum*. Yellowing, stunting, and death of seedlings, as well as yellowing and stunting of older plants, are all symptoms. Plants infected wilt quickly, their lower leaves turn yellow and dry, their xylem tissues turn brown, and the plant may die. The roots are not rotted in the early stages of the illness. Many plants, such as carnations and gladiolus, have one-sided symptoms at first. The seed itself usually is harmless when obtained from sick plants, but the seed coat is frequently contaminated by tiny bits of infected tissue and spores. This is how many of the most severe fusarium wilt illnesses spread. Heat treatments and chemical fumigation can help minimise the presence of pathogenic Fusarium in the soil. These treatments are more successful in annual plants than permanent plantings at controlling the fungus. In general, the best way to treat Fusarium wilt illnesses is to use resistant or tolerant cultivars rather than soil-applied fungicides (Koike et al. 2020b).

Figure 7. Example of fusarium wilt on leaves of Citrullus lanatus (University of Florida 2021)

2.3.8 Moko disease

The devastating bacterial wilt of bananas and plantains is known as Moko sickness. *Ralstonia* (*Pseudomonas*) *solanacearum* is the bacteria that causes the sickness. Humans and animals are unaffected by this bacteria. Moko may quickly spread an epidemic after a plant in the field becomes infected, especially if the bacteria seep from the flowers' male bud onto other plant parts and even into the soil. Moko has been blamed for yield losses of up to 75 %. The illness begins with the yellowing and withering of older leaves, eventually becoming necrotic and collapsing. Then, before decomposing, the younger leaves produce light green or white panels. Fruits may ripen or split when they end up forming. Moko illness is incurable, and it is burdensome and costly to treat. Protecting locations where the illness does not present is the primary way of control. The only efficient way to manage the infection is to destroy the diseased plant and any host plants, such as *Heliconia* species (Ministry of Agriculture, Forestry and Fisheries 2007).

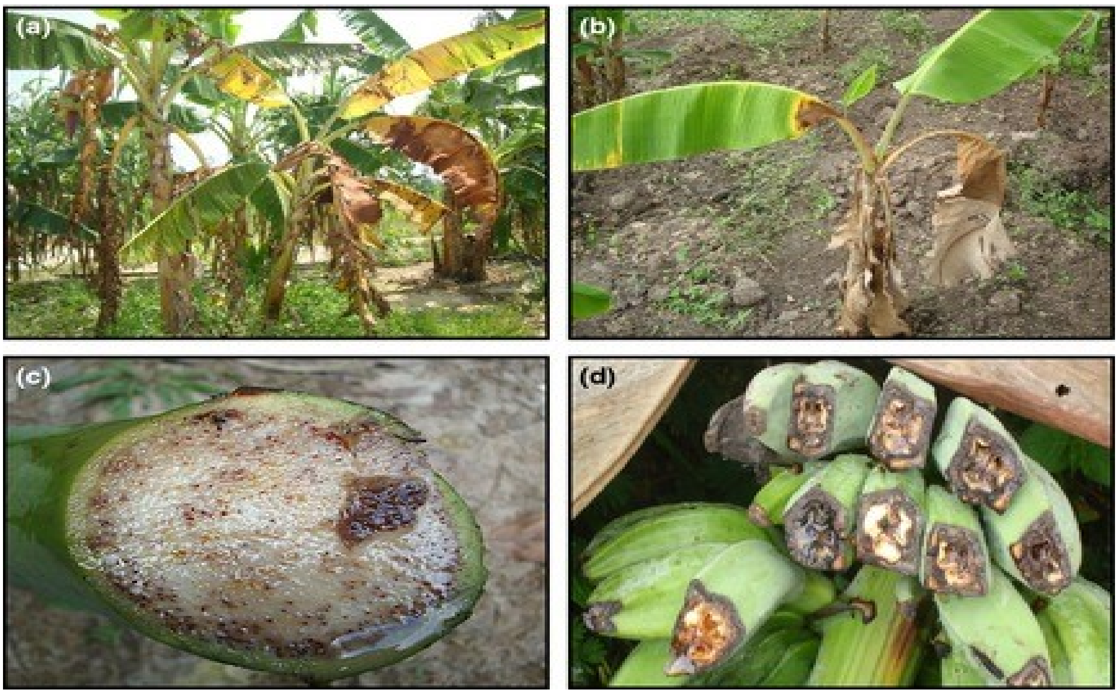

Figure 8. Example of Moko disease on leaves and fruits of Musa × paradisiaca (Zulperi et al. 2014)

2.4 Pests

This chapter contains descriptions and potential control measures of major pests detected on the fruit mentioned above.

2.4.1 Scale insects

Many insect families (order *Hemiptera*) with a waxy shell that resembles scales or cottony cushions on their bodies. After settling on the plant where it would feed, the insect secretes the waxy coating. Depending on the family, this scale can be hard, smooth, or sculptured (Capinera 2008). The variety of host plants for each scale insect species is limited, and scale insects damage plant roots, bark, leaves, twigs, and fruits. Many scale species have a waxy layer protecting their adults against contact pesticides. On the other hand, Scales may typically be managed using horticultural oils that smother them, systemic insecticides that poison the sap of the host plants, or biological control agents like parasitic wasps and ladybirds. Scales can also be treated using insecticidal soap (BBC 2019).

Figure 9. Example of scale insects on the fruit of Carica papaya (University of Hawaii 2018)

2.4.2 White mango scale

Aulacaspis tubercularis is a tropical, cosmopolitan, polyphagous armoured scale that is one of the most important pests of mango crops worldwide because it causes conspicuous pink blemishes on the mango fruits, lowering their commercial value and making them unsuitable for export markets. If no management measures are performed, the bug can cause up to 90 % output losses in mango trees, posing a danger to long-term mango production (del Pino et al. 2020). *Aulacaspis tubercularis* eats mango leaves, branches, and fruit, wreaking havoc on the tree. *A. tubercularis* causes largely cosmetic (chlorosis) damage as a result of females and juvenile stages sucking sap (phloem) off leaves, branches, and fruits (Otieno 2021). Control of *A. tuberculosis* is now reliant on using a small number of insecticides, most of which have little efficiency and are harmful to beneficial insects (del Pino et al. 2020).

Figure 10. White Mango Scale on leaves of Mangifera indica (Maňourová 2021)

2.4.3 Mealybugs

Mealybugs belong to the *Pseudococcidae* insect family. The bodies of mealybugs are segmented and frequently wax-coated. Wax filaments may be found around the body borders of the elderly. The filaments towards the back of certain species are longer, which can be used to identify between species. Mealybugs eat in colonies in slightly sheltered regions such as between two touching fruits, in a plant's crown, in branch crotches, on stems near the earth, or between the stem and touching leaves. Roots are eaten by a few mealybug species (Cloyd 2011). Mealybugs are frequently introduced into gardens on new plants, tools, and pots. Insecticides struggle to control mealybugs. Fortunately, in external systems such as landscapes and gardens, most species have natural enemies that keep their numbers below harmful levels. To keep mealybug numbers under control, the usage of plants known to be less prone to issues, inspecting plants for mealybugs before bringing them into a property, and using biological management and cultural methods is key (Flint 2019). It was claimed that the parasitoid *Gyranusoidea tebygi*, which was introduced into West Africa, is effectively controlling the pest (Pena et al. 1997).

Figure 11. Example of mealybugs on fruits of Carica papaya (Pena & Johnson 2022)

2.4.4 Stone weevil

Sternochetus mangiferae is a monophagous pest and one of the most common mango pests found in almost every mango-growing country. Adults typically emerge after the fruits have fallen and dormant until the next fruiting season. Fruit, seeds, seedlings, and cuttings carrying larvae, pupae, or adults are used for long-distance dissemination. The most severe impact of this pest is the disruption of fruit export due to quarantine requirements. The injured fruits have visible hard, amber-coloured protective resin markings over the eggs on the fruit skin, which typically leads to the downgrading of the fruit (Peng & Christian 2007). Good orchard cleanliness, which includes destroying all fallen fruit, stones, and fruits with seed weevil damage during and soon after mango harvest, is efficient to lower adult populations. *S. mangiferae* adults are well controlled by the ant *Oecophylla smaragdina*. Control has been established utilising *Oecophylla* ants in conjunction with orchard cleaning (Kok 1979).

Figure 12. Example of stone weevil on Mangifera indica (Government of Western Australia 2016)

2.4.5 Leaf miner

A leaf miner is several insect species whose larval stage lives in and feeds on plant leaf tissue. Moths (*Lepidoptera*), sawflies (*Symphyta*), and flies make up the great bulk of leaf-mining insects (*Diptera*). This habit is also seen in several beetles. Leaf miners, like woodboring beetles, feed inside the tissues of the leaves, choosing to consume only the layers with the least amount of cellulose. This protects them from numerous predators and plant defences (Faeth et al. 1981). Because they are shielded inside the plant's leaves, pesticide sprays might be challenging to control. Some leaf miners can be controlled by spraying diseased plants with spinosad, an organic pesticide. The leaf miner must absorb spinosad since it does not kill on touch. In a given season, two or three applications may be necessary. However, if sprayed when bees or other helpful arthropods are present, this will have a negative ecological consequence (Tomé et al. 2015; Pasquet et al. 2016).

Figure 13. Example of leaf miner on leaves of Persea americana (Davis & Wagner 2011)

2.4.6 Aphids

Aphids are part of the Aphidoidea superfamily, which includes tiny sap-sucking insects. Aphids are among the most damaging insect pests to cultivated plants in temperate climates. They operate as carriers for plant viruses and disfigure attractive plants with honeydew deposits and the consequent growth of sooty moulds, in addition to weakening the plant by sucking sap (Piper 2007). They harm crops and diminish yields as direct feeders on plant sap, but they have a higher impact as plant virus vectors. These viruses are spread by aphids moving between various plant areas, neighbouring plants, and even further afield. In this regard, the probing activity of an aphid tasting a host is more harmful than long-term aphid feeding and reproduction by stay-put aphids. The mobility of aphids impacts the timing of viral outbreaks (Emden & Harrington 2017). Because aphids breed quickly, insecticide control is challenging, and even little areas ignored may allow the population to rebound quickly. Aphids may live on the undersides of leaves where spray misses them, and systemic pesticides may not penetrate flower petals successfully. Finally, some aphid species are resistant to carbamates, organophosphates, and pyrethroids, among other pesticide types (Pundt 2011). Yellow-pan or Moericke traps can be used to sample aphid populations. These are water-filled yellow pots that attract aphids. Aphids prefer green, and their affinity to yellow may be due to brightness rather than a natural colour preference (Evans & Medler 1966).

Figure 14. Example of aphids on Citrus sinensis (Government of Western Australia 2020)

2.4.7 Fruit flies

As the significant pest of *Mangifera indica* and other studied crops, fruit flies (Diptera: Tephritidae) are causing damage to fruit both in the adult and larvae stages. Fruit fly larvae, in general, induce premature fruit drop and fruit pulp destruction. When the fruit rots, it is no longer acceptable for harvesting or human consumption (Earecho 2015). In the *Mangifera indica* case, the most contaminated cultivars by fruit flies are those that mature early. In contrast, the least affected cultivars are those that mature in the middle of the season. Infestation incidence and intensity are not statistically different between late and early season cultivars, but they are distinct from mid-season cultivars (Isabirye et al. 2016). The best method to prevent crops from fruit flies is insecticides (Stonehouse et al. 1998).

Figure 15. Fruit fly on the fruit of Mangifera indica (Barzman et al. 2015)

3. Aims of the Thesis

This bachelor thesis aims to provide an overview of major diseases and pests on selected fruit crops in southern Ethiopia and to elucidate appropriate methods of prevention and control of these diseases and pests. Furthermore, to analyse the approach of local farmers towards the protection of these fruit species in Arba Minch Zuria woreda.

4. Methods

The methodology consists of a literature review and an analysis of survey results carried out in autumn 2021 in the district of Arba Minch Zuria, Gamo Gofa, SNNPR (Southern Nations, Nationalities and Peoples Region), Ethiopia.

4.1 Literature Review

The majority of the information was obtained from scientific articles published in databases such as Web of Science, Scopus, Science Direct, Google Scholar and Researchgate. Following this, various scientific books were reviewed, supplemented by FAO, The World Bank, and Statista statistics. All of these sources are included in the 'References' section of this thesis.

4.2 Study site characteristics

The farmer survey was done in four different kebeles: Kolla Shara, Chano Doriga, Chano Chaliba and Chano Mile.

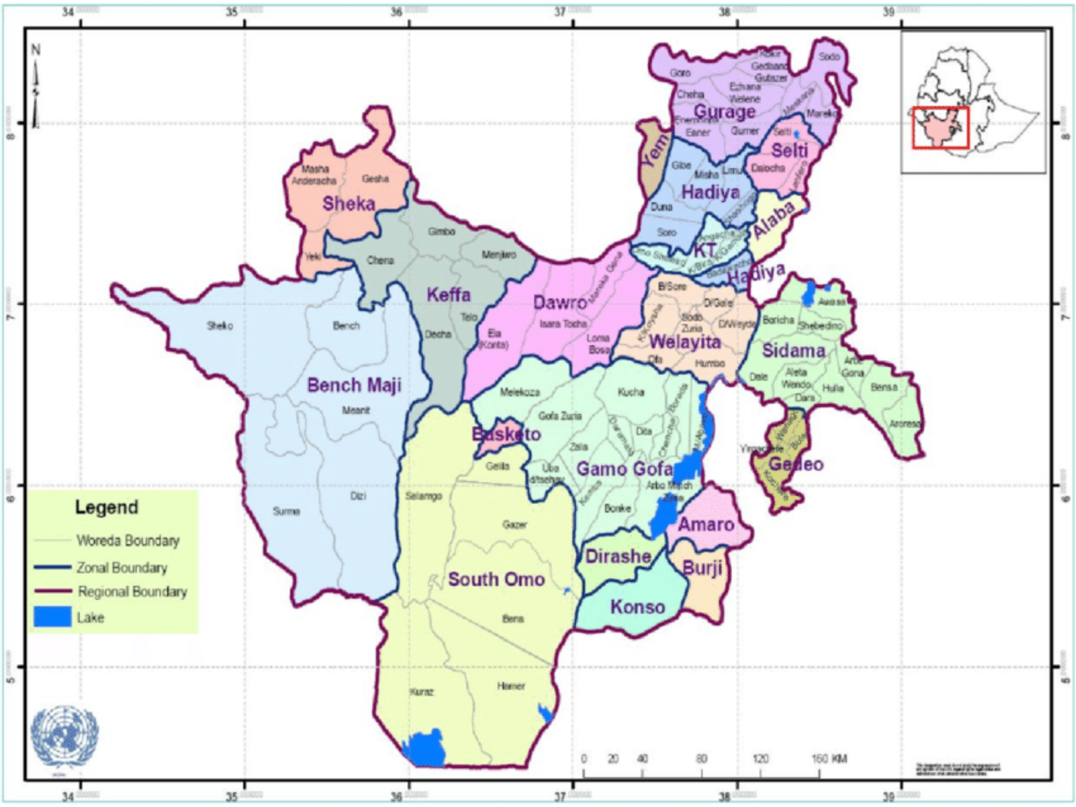

Figure 16. Map of SNNPR, Ethiopia with districts (Gurmu et al. 2017)

Figure 17. Map of selected kebeles within Arba Minch Zuria woreda (Google Earth 2022)

4.3 Data collection and evaluation

The field data were gathered in the four kebeles mentioned above using a semi-structured questionnaire available in the Appendix. A semi-structured interview is a verbal exchange in which one person, the interviewer, seeks to obtain information from another person, the interviewee, by asking questions (Yengoh & Brogaard 2014).

In total, 51 farmers were interviewed in kebeles mentioned above. 12 from Kolla Shara + 13 from Chano Doriga + 13 from Chano Chaliba, and 13 from Chano Mile. The data collection was supervised by Firew Tadesse, local coordinator of Mendel University project "Implementation of fruit value chain for improved nutrition and efficient production in Arba Minch Zuria, Gamo Gofa, SNNPR, Ethiopia", led by Ing. Petr Němec, Ph.D. This thesis became the basis for further research and practical implementation in this project.

5. Results

The survey took place in four municipalities (kebeles) in the SNNPR region: Kolla Shara, Chano Doriga, Chano Chaliba and Chano Mile. In total, 51 farmers were interviewed, represented by 45 men and 6 women. The average age of participants was 44 years. 78 % of the farmers cultivated their crops in less than 1 hectare. Most of the respondents did the farming activities alone or within a family (92 %); only 8 % of participants stated to be a part of a co-operative. The most cultivated fruit species among the respondents were mango (*Mangifera indica*), avocado (*Persea americana*), papaya (*Carica papaya*) and lemon (*Citrus limon*). Mango was grown by 98 % of the farmers, followed by avocado (55 %), lemon (47 %), papaya (24 %), gishta (6 %), and orange (2 %). Note that many farmers grew more than just one crop.

Most farmers regularly deal with diseases and pests on their fruit species; only 4 % respondents have not yet encountered any. 84 % of the participants claimed to identify particular pests and diseases, 80 % had the knowledge from a friend or an expert. The rest had their information both from an elder, friend or expert, family members or radio, as seen in Table 1.

25 % of respondents claimed that leaves and fruits at the same time are the most affected part of the crop by pests and diseases. Whereas 25 % responded that all parts are affected the same in their case, 16 % told the interviewer that just leaves of their crops are affected by diseases or pests. When talking about flowers, 18 % of farmers pointed out that they have issues with this part, but it was every time with a collocation with fruits and leaves (6 %) or just with leaves (12 %). In the case of stems, only 16 % of respondents stated that this is the most affected part of their crops. However, we subtracted 2 % from this result in the case of fruit and stem infection occurring together on the same plant, and the same with 8 % when the disease or pest occurred both on leaves and stem simultaneously. Moreover, we subtracted another 4 % when the infection occurred on fruits, leaves and stems together. What should be said is that in the question "Which part of the fruit is most affected?", every farmer from Kolla Shara kebele responded that all parts of the plant are affected the same, while in other kebeles, the answers mainly differ by each farmer.

73 % of the farmers used traditional methods of dealing with pathogens, whereas 4 % relied on pesticides, only 6 % did not apply any solution, traditional method or chemical

application. 18 % out of all respondents applied both traditional methods and chemicals. 85 % of farmers applied preventive plant protection measures, 29 % of them in weed control, 18 % in the disposal of post-harvest residues, 2 % selection of a suitable cultivation site, and 8 % used breeding methods. Some farmers used a combination of these preventive methods: disposal of post-harvest residues and selection of sustainable cultivation site (2 %), breeding methods together with weed control (4 %), disposal of post-harvest residues and weed control (4 %). Other farmers used weed control together with a selection of sustainable cultivation site (12 %), breeding methods combined with disposal of post-harvest residues (4 %), and 2 % of the farmers used a combination of breeding methods and selection of sustainable cultivation site.

92 % of respondents thought that agriculture is not harmful to the environment. Except for four farmers in Chano Mile kebele, every farmer thought agriculture was not harmful to the environment. Of the 8 % who thought agriculture is harmful to the environment, 75 % said it is because of chemical usage, and the 25 % thought it is because of the distribution of pests and exotic plants.

The use of chemical sprays for plant protection was confirmed by 31 % of respondents, 20 % of all respondents thought it is hard to get chemicals on their market, 25 % responded that chemicals are expensive, and 2 % lack the knowledge to identify the type of chemicals. 45 % said that it is not hard for them to get chemicals and equipment, the rest responded they it is both hard to obtain and expensive (6 %), and 2 % responded that they lack the knowledge to identify the type of chemicals and they are too expensive. 82 % of all responded farmers thought that chemicals used in agriculture are harmful to human health and the environment. The majority of respondents (84 %) said that they would like to have the possibility to use environmentally friendly products for crop protection. 98 % of the farmers used fertilisers when they grew their crops. 14 % of these respondents used only artificial fertilisers, 46 % used only organic fertilisation, such as manure, and 40 % used a combination of both artificial and organic fertilisers.

Table 1. Results of the survey

	<1 ha	**>1ha**				
Field size	40	11				
	Alone, family	Co-operative				
Farm running	47	4				
	Avocado	Mango	Papaya	Orange	Lemon	Gishta
Species	28	50	12	1	24	3
	YES	NO				
Plant or disease encounter	49	2				
	YES	NO				
Ability to identify pest or disease	43	8				
	Elders and friend or expert	Family members	Radio	Friend or expert	Nobody	
Aquisition of knowledge	1	1	1	41	7	
	Fruit and leaves	Leaves	Stem	Fruit and stem	Leaves and flowers	All parts
Affected part of plant	13	8	1	1	6	13
	Leaves and stem	Fruit, leaves, flowers	Fruits, leaves, stem			
	4	3	2			

Table 1. continued

	Traditional methods	Chemical application	Do nothing	Do both		
Solution application	37	2	3	9		
	YES	NO				
Preventive measures	43	8				
Preventive measures identification	Breeding methods	Disposal of post-harvest residues	Weed control	Selection of a sustainable site	Breeding methods, disposal of post-harvest residues	
	4	9	15	1	2	
	Disposal of post-harvest residues, selection of a sustainable site	Breeding methods, weed control	Disposal of post-harvest residues, weed control	Weed control, selection of sustainable site	Breeding methods, selection of a sustainable site	
	1	2	2	6	1	
	YES	NO				
Is agriculture harmful to the environment	4	47				
If yes, how?	By using chemicals	Spread of pests and exotic plants				
	3	1				

Table 1. continued

	YES	NO				
Specific spray usage	16	35				
Difficulties in gaining pest and disease management tools	Hard to obtain chemicals	Expensive to buy chemicals	Lack of knowledge to identify the type of chemicals	Not hard to obtain tools and equipments	Hard to obtain, expensive	Expensive, lack of knowledge
	10	13	1	23	3	1
	YES	NO				
Chemicals harmful to human health and the environment	42	9				
	YES	NO				
If yes, knowledge about products safer for the environment	34	8				
	YES	NO				
Possibility of environmentally friendly product usage	43	8				
	YES	NO				
Fertiliser usage	50	1				
	Artificial	Organic	Both			
Type of fertiliser	7	23	20			

Figure 18. Survey filling with farmers from four different kebeles (Anna Maňourová 2021)

6. Discussion

The diversity of selected fruit crops' diseases and pests in Arba Minch Zuria, Gamo Gafa, SNNPR, Ethiopia is mainly caused by a broad spectrum of grown species in a relatively small area. It goes hand in hand with the fact that most farmers grow their crops on fields that are less than one hectare in size.

As the literature review provided an overview of diseases and pests on selected fruit crops in southern Ethiopia and elucidated appropriate methods of prevention and control of these diseases and pests, colocations were found between selected fruit crops and their significant diseases and pests.

Although the diseases and pests of each fruit crop differ, some are standing in two or more places simultaneously. Melanose is a significant disease for citrus fruits, in our case, *Citrus limon* and *Citrus sinensis* (Gebreslasie & Meresa 2018). Also, anthracnose plays its role as it is the most represented disease in this study and this group of fungal diseases by *Colletotrichum gloeosporioides* causing withering, wilting and tissue dying occurs remarkably on the selected species (Pinto et al. 2005; Joy & Sherin 2012; Earecho 2015; Mitiku 2017; Gebreslasie & Meresa 2018; Ur Rehman et al. 2020; Okrikata et al. 2021).

There is one insect pest that also occurs multiple times on selected crops. On fruit flies, have been shown that they do not much select the fruit species they are going to feed with. Fruit fly ia a major pathogen of *Mangifera indica*, *Carica papaya* or *Citrus sinensis* (Pantoja et al. 2002; Tola et al. 2014; Earecho 2015; Gebreslasie & Meresa 2018).

In the practical part, the survey showed that the introduction of biological control is essential to make cultivated crops more secure. Such as for mealybugs when it is found to be safe and not to damage the environment in other ways, for example, damaging populations of other insects (Pena et al. 1997). For example, another insect genus that feeds on pests could be even harder to control, thanks to the fact that it could be possibly dangerous for the environment because this could lead to overpopulation of the helpful insect and throw the farmers into another problem (Kazda et al. 2010). Respondents were willing to learn new ways to fight pests and diseases and, in addition, reduce the number of chemicals which can harm the environment. The usage of organic pesticides or natural oils might be considered as a biological plant protection method (BBC 2019). However, it should be taken into account that it depends on the season and that bees or other beneficial insects would not be harmed by pesticides, even organic ones (Tomé et al. 2015; Pasquet et al. 2016). The survey showed that it is hard for 55 % of the farmers to obtain ecologically friendly chemicals for the biological control of pests.

Surprisingly, it was found that despite the fact that 92 % of the responders did not think that agriculture is or can be harmful to the environment, 82 % of both sides also think that the chemicals used in agriculture could harm the environment and human health. This raises the question if all of this 92 % of farmers did never use artificial chemicals on their crops or they were not enough educated to decide differently.

7. Conclusion

Pests and diseases are one of the most severe threats to smallholder farmers in Arba Minch Zuria, generating both financial and food insecurity. Various pests and illnesses have a detrimental impact on the output of grown fruit species on a regular basis. Despite the fact that the majority of our respondents claimed to be able to identify harmful species, farmers frequently lack enough means, expertise, or both to preserve their crops. Only 4 % applied chemicals to combat pests and diseases; most rely on preventive measures, acceptable if done correctly, or traditional plant protection methods. This strategy, however, may not be the most successful. Fortunately, 84 % of respondents expressed a desire for ecologically friendly plant protection solutions if they were accessible. As described in the overview, all the major pests and diseases of the selected fruit crops seem to be susceptible to one or two ecological methods of plant protection. Therefore, biological plant protection strategies should be prioritised and farmers encouraged and trained to apply them in practice.

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Appendices

List of appendices

Appendix 1. Plant protection survey

1. How old are you?

2. What is your gender?

    a. Male
    b. Female
    c. Other

3. Can you estimate how big the farm you manage is?
    a. < 1ha
    b. > 1ha, please specify
    c. If you use other units, please specify how big is your farm in your units

4. You run your farm:
    a. Alone, with family
    b. Within a co-operative

5. Which of these species do you grow? (circle the appropriate ones)
    a. Avocado (*Persea americana*)
    b. Mango (*Mangifera indica*)
    c. Papaya (*Carica papaya*)
    d. Orange (*Citrus* × *sinensis*)
    e. Lemon (*Citrus limon*)
    f. Lime (*Citrus aurantifolia*)
    g. Gishta (*Annona muricata*)
    h. Passion fruit (*Passiflora edulis*)
    i. Watermelon (*Citrullus lanatus*)
    j. Muskmelon (*Cucumis melo*)

6. Have you ever encountered a plant disease or pest that threatened these plants?
    a. YES
    b. NO

7. Are you able to identify the species of the disease or pest?
    a. YES
    b. NO

8. If yes, where did you get the knowledge?
    a. elders
    b. family members
    c. using the internet
    d. radio
    e. book resources
    f. help of a friend/expert

9. What part of the plant is the most affected?
    a. fruit
    b. leaves
    c. stem
    d. flowers
    e. all of them
    f. other parts – specify

10. What would you do if your plants were infested? What solution/method will you apply?
    a. use traditional methods - specify
    b. apply chemicals - specify
    c. do nothing

11. Do you take any preventive measures against the emergence of plant diseases or pest infestations?
    a. YES
    b. NO

12. If yes, please indicate what preventive measures have you taken or are you taking against the effects of diseases or pests on your crops.
    a. breeding methods
    b. disposal of post-harvest residues
    c. weed control
    d. selection of a sustainable site

13. Do you think that agriculture is harmful to the environment?
    a. YES
    b. NO

14. If yes, how, what practises?

15. Do you use any specific sprays for plant protection? If yes, please specify which ones.
    a. YES
    b. NO

16. How hard is it to get pest and disease management tools in your country (prices, availability on the market)? For example, chemical sprays, etc.

17. Do you think chemicals are harmful to human health and the environment?
    a. YES
    b. NO

18. If yes, do you know that there are safer products that do not pollute and destroy water and soil?
    a. YES
    b. NO

19. Do you/Would you use environmentally friendly products to protect your plants from diseases and pests?
    a. YES
    b. NO

20. Do you use any fertilisers?
    a. YES
    b. NO

21. If yes, which types of fertilisers do you use?
    a. artificial
    b. organic – e.g. manure